Stephanie Clark
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The Sensory Evaluation of Dairy Products

Third Edition

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Preface

Cheeses undergoing sensory assessment at an American Cheese Society Judging & Competition. (S Clark image)

The Sensory Evaluation of Dairy Products is intended for all persons who seek a book entirely devoted to the sensory evaluation of dairy products and modern applications of the science. Three early editions of this book were published in 1934, 1948 and 1965, under the title *Judging Dairy Products*. Subsequently, the first edition *The Sensory Evaluation of Dairy Products* was published in 1988. The second edition, published in 2009, has served as the primary reference on the topic for the last decade. We are pleased to present this newest edition, which includes not only significant updates/revisions of the previous chapters, but entirely new chapters related to Mold-Ripened Cheeses (17), Goat and Sheep milk cheeses (18) and Washed-Rind Cheeses (19).

Three different methods are available for tracing causes of sensory defects in dairy foods: (1) chemical procedures, (2) microbiological tests and (3) sensory evaluation. The simplest, most rapid and direct approach is sensory evaluation. With its focus on sensory evaluation, this book should serve well as (1) a reference text for all persons interested in the history, art and science behind the sensory evaluation of dairy products; (2) a guide to assist in tracing the origins of identifiable sensory defects in dairy products with hints or strategies for their correction; (3) a practical guide to the preparation of samples for sensory evaluation and (4) as a training tool for personnel in the evaluation of dairy products.

A food technologist trained and experienced in flavor evaluation of dairy products has an "edge" over someone who is competent only in performing chemical and/or microbiological methods of product analysis. Correct diagnosis of the type and cause(s) of sensory defects is a prerequisite to application of remedial measures in production, processing and distribution stages. For dairy processors, the most important requirement of a comprehensive quality assurance program is careful and

Technical (left) and aesthetic (right) judges evaluate a variety of cheeses at a recent American Cheese Society Judging & Competition. (S. Clark image) competent flavor evaluation of all dairy ingredients – in addition to the standard microbial and chemical component testing. Based upon sensory judgments, occasionally some milk, cream or other dairy ingredients may merit rejection. An important premise of the dairy industry is *dairy product quality can be only as good as the raw materials from which they are made.*

In this book, the authors have attempted to present a reasonably complete overview of the sensory evaluation of most of the major commercial dairy products in the United States and Canada. Furthermore, the authors have deemphasized the terms "judging," "scoring" and "organoleptic analysis" in favor of the more contemporary terms "flavor" or "sensory evaluation." The latter terminology is more reflective of the marked progress made in relating objective flavor perception to the areas of sensory panel methodology, statistics, human behavior, psychology and the psychophysics of human sensory perception. In addition to traditional practices, this book devotes several chapters to modern sensory evaluation methodology, since this science has profoundly advanced since the first edition of this book.

The early chapters of this edition review the history, physiology and psychology of human sensory perception, with emphasis on dairy products evaluation. Chapter 4 includes an overview of some of the different state, regional and national dairy products competitions held annually in the United States. Chapters 5 through 10 focus on dairy products evaluated in the annual Collegiate Dairy Products Evaluation Competition, including descriptions of various sensory defects, their causes and remedial steps to minimize or eliminate their occurrence in fluid milk, butter, cottage cheese, yogurt, Cheddar cheese and ice cream. Chapters 11 through 19 cover the sensory evaluation of several dairy products not included in the collegiate contest, but that are most assuredly evaluated in plants and judged at other various dairy product competitions. Additionally, each of these chapters is intended to serve as a guide to dairy foods manufacturers who seek to optimize the quality of their products.

Chapter 20 is devoted to modern sensory evaluation practices, including an overview of modern affective and analytical sensory tests, as well as the application of objective sensory languages (such as the Cheddar cheese lexicon) to scientific and market research.

An appendix section guides coaches or instructors through chemical tests, and preparation of samples for evaluation by Collegiate Dairy Products Evaluation teams.

In preparing this edition of *The Sensory Evaluation of Dairy Products*, the authors from industry and academia have applied their philosophy and instructional techniques to convey their expertise at describing sensory quality and shortcomings of dairy foods. This edition of the book brings together a historical perspective of the sensory evaluation of dairy products, the stages of advancement of this field of applied science, personnel development, improvements in sensory assessment techniques and methodologies, as well as the role of statistical validation and other modern and progressive approaches. Simultaneously, many of the chapter contributors to this edition have relied on the sound discussion and guidance of earlier authors of the four earlier editions of *Judging Dairy Products* and *The Sensory Evaluation of Dairy Products*. The current chapter authors retained many of the pertinent details and clearly stated descriptions of the so-called "ideal products" and the scope of various sensory defects pertaining to flavor, body and texture, color and appearance, as so adequately delineated by the forerunner sets of authors. Hence, the chapters dealing with given dairy product categories (e.g. Fluid Milk and Cream; Butter; Cheese; etc.) are in many cases extensively reliant on the discussions and perspective from earlier authors of the first four variations of this book. The current authors have inserted focus and discussion on updating the science of sensory assessment of the respective dairy products in line with ingredient changes, technological progress and the availability and application of modern sensory techniques.

The reader should recognize that a clear distinction exists between the concepts of "quality," "flavor profile," "preference" and "acceptability." The primary aim of this book is to describe the subject of sensory quality, which is not directly associated with flavor profiles and not always directly associated with consumer acceptability. Product quality and consumer acceptability of products vary throughout the United States, Canada and the world. For instance, cottage cheese curds that may be evaluated as "firm/rubbery" are familiar and desirable to consumers on the US West coast, while relatively "weak/soft" curds are more commonly preferred by consumers on the East coast. Additionally, it is generally presumed that vanilla ice cream consumers on the US East coast prefer higher intensities of the "vanilla note" than customers from the West and/ or Mid-West. Consumer acceptability of a particular product of one coastal region may differ from preferences in the Mid-West or on the opposite coast. Goat cheese consumers in the United States prefer mild flavors,

Quality in the eyes of official judges does not necessarily guarantee success in the marketplace. (S. Clark image) while a more robust typical "goaty" aroma and flavor is expected in Europe. Ideally, definitions of attributes and defects should not deviate from one coast to another, though preferences for styles and intensities may vary. As previously emphasized, quality and the presence of specific sensory attributes – designated either historically or by industry professionals as product defects – are not necessarily related to consumer acceptance.

Many dairy products are defined in the US Code of Federal Regulations (CFR). If product quality is perceived as the absence of sensory defects, the consequences of compositional changes of a given dairy food (as introduced or changed by CFR specifications) need not be reflected in quality changes. However, certain product characteristics may change as the result of formula alterations. For instance, reduction of the milkfat content of ice cream from 12% to 10% certainly could affect the given product's sensory and hedonic characteristics without affecting quality. In defining various dairy products, reference has been made to the CFR throughout the book. The reader is cautioned that since changes in the CFR may occur at any time, only the latest edition of this official document should be consulted for purposes of legal compliance (see Electronic Code of Federal Regulations: https://www.ecfr.gov/cgi-bin/ECFR?page=browse).

Technological progress has eliminated some sensory defects of dairy products reviewed in previous editions of this text but has also introduced some sensory attributes of dairy products not reviewed in previous editions. Some flavor descriptors or terms have continued in use over the years more by habit than due to logic. In this edition, an effort has been made to bridge the traditional terminology with more advanced knowledge of the defects. By necessity, this transition process must be gradual, to preserve our ability to accurately communicate the sensory properties of dairy products.

The editors gratefully acknowledge the technical and creditable contributions by our chapter authors, past and present. Without their outstanding efforts and dedication to the field of the sensory evaluation of dairy foods through the decades, this book would not be complete.

Although two of the authors of earlier editions of this book have passed away, we honor the pioneering work and original contributions of Dr. John A. Nelson (1890–1971; Montana State University) and Dr. G. Malcolm Trout (1896–1990; Michigan State University). We also recognize the 1988 volume, *The Sensory Evaluation of Dairy Products*, by Floyd W. Bodyfelt (1937–present; Emeritus Professor, Oregon State University), Dr. Joseph Tobias (1920–2011; University of Illinois) and Dr. Trout, which well-served many needs of dairy sensory scientists for two decades. Dr. Bodyfelt and Michael Costello (Washington State University) are appreciated for their contributions to the 2009 edition. We also acknowledge the untimely death of Pat Polowsky (1992–2021), who was the primary author one of our newest chapters. May volume 3 of The Sensory Evaluation of Dairy Products serve you well as you contribute to the field of dairy sensory science.

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Chapter 1
History of Sensory Analysis

MaryAnne Drake and Stephanie Clark

Humans have used their senses to evaluate food for several thousands of years. Given that so many phytotoxins and bacterial metabolites are bitter, sour, or rancid, mankind has probably used sensory evaluation since before *Homo sapiens* were human. Individuals can often tell by sight, smell, taste, and, to a lesser extent, touch, whether or not given food or beverage items are good or bad (e.g., safe or toxic). As civilization developed and the trading and selling of goods became commonplace, the first seeds of food sensory testing as we know it were planted. Potential food or beverage buyers tested or evaluated a small portion or a sample of products that hopefully represented the whole or the entire given lot of product. The product price was then established based on the relative quality of the product. This process of standardized product quality grading, the precursor of modern sensory analysis, subsequently emerged.

Several historical events in sensory science and the sensory analysis of dairy foods have occurred since that time, and some of these key developmental events are summarized in Table 1.1. In the early 1900s, the use of professional tasters and consultants began in different food and beverage industries (Meilgaard et al., 2016). US Federal grading standards for butter were initially established in 1913 (Table 1.1), the first National Collegiate Dairy Products Evaluation Contest was conducted in 1916 (Bodyfelt et al., 1988, 2008; Trout & Weigold, 1981), and the original dairy products evaluation textbook (Nelson & Trout, 1934, 1948, 1951, 1964) was

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Table 1.1 Selected events in sensory science and sensory analysis of dairy foods

Date	Item
1666	Newton introduced the color spectrum
1905	*Color Notation* manual published (Munsell color method)
1913	Grading established by the USDA for butter; Cheddar cheese subsequently
1916	First collegiate dairy products judging contest held (butter evaluation only)
1917	Milk and Cheddar cheese added to collegiate dairy products judging contest
1926	Vanilla ice cream added to the collegiate dairy products judging contest
1929	Improvements to Munsell color method by the Optical Society of America (OPA)
1930s	Swedish Natural Color system proposed by Tryggve Johansson
1934	First edition of *Judging Dairy Products* (Nelson and Trout) published; with subsequent editions published in 1948, 1951, and 1965
1940s	Development of the Triangle test
1947	Committee for Uniform Color Scales formed (by the Optical Society of America)
1944	The Food Acceptance Research Branch established by the U.S. Army Quartermaster Subsistence Research and Development Laboratory in Chicago, IL
1949	Development of the Hedonic scale by the US Army Quartermaster Laboratory
1957	First book published on the basics of sensory analysis by Tilgner (Polish)
1957	Flavor profile method (descriptive analysis) introduced by Arthur D. Little Company
1960	The OSA system of color evaluation adopted by the Optical Society of America
1962	Second sensory analysis book published by Masuyama and Miura (Japan)
1962	Cottage cheese added to the collegiate dairy products judging contest
1965	Third book on sensory analysis published by Amerine, Pangborn, and Roessler
1967	The AH-B theory for detection and measurement of sweet taste proposed
1968	American Society for Testing and Materials (ASTM) – First manual published
1970s	Creation of the Spectrum™ Descriptive Analysis Method, by Civille and colleagues at General Mills, based on experiences with the flavor profile and texture profile methods
1973	Institute of Food Technology (IFT) – Sensory Evaluation Division formed
1977	International Standards Organization (ISO 3591) Sensory analysis protocol – standardized apparatus – a wine tasting glass design
1977	Strawberry Swiss-style yogurt added to Collegiate Dairy Products Evaluation contest
1978	ISO 5492 Sensory analysis – apparatus – tasting glass for liquid product
1979	ISO 3972 Sensory analysis – determination of sensitivity of taste
1977	ISO 5492 Sensory analysis – vocabulary – Part I
1978	ISO 5492 Sensory analysis – vocabulary – Part II
1979	ISO 5492 Sensory analysis – vocabulary – Part III
1981	ISO 5492 Sensory analysis – vocabulary – Part I
1982	ISO 5492 Sensory analysis – vocabulary – Part V
1983	ISO 5495 Sensory analysis – methodology – paired comparison test
1986	Sensory Spectrum company incorporated: Spectrum™ Descriptive Analysis Method
1988	First edition of *The Sensory Evaluation of Dairy Products* (Bodyfelt et al.) published
1998	First edition of *Sensory Evaluation of Food* (Lawless and Heymann) published

(continued)

Table 1.1 (continued)

Date	Item
2002	*Umani* taste sensation officially accepted (based on the earlier work of Paris chef, Escoffier, and the subsequent studies of Japanese chemist, K. Ikeda. He credited glutamic acid as the source of the newest "taste" sensation, meaning "delicious" in Japanese (Krulwich, 2007))
2009	Second edition of *The Sensory Evaluation of Dairy Products* (Clark, Costello, Drake, and Bodyfelt) published
2010	Second edition of *Sensory Evaluation of Food* (Lawless and Heymann) published
2016	Fifth edition of Sensory Evaluation Techniques by Meilgaard, Civille, and Carr
2023	Third edition of *The Sensory Evaluation of Dairy Products* (Clark, Drake, and Kaylegian) Published

published in 1934. In the 1940s, the triangle difference test was developed in Scandinavia (Bengtsson & Helm, 1946; Helm & Trolle, 1946).

Sensory analysis became a focus of attention to the US Army Quartermaster Food and Container Institute in the 1940s and through the mid-1950s. Its focus was research in food acceptance for the armed forces, rather than simple provision of adequate nutrition (Peryam et al., 1954). In the 1960s and 1970s, the US government failed to conduct sensory evaluations on foods developed for malnourished people in several countries – the foods at issue were often rejected (Stone & Sidel, 2004). The food industry was quick to adopt sensory evaluation, quite possibly as a result of both the government's successes and most notable failures (Stone & Sidel, 2004). It was realized that sensory evaluation could contribute pertinent, valuable information related to marketing consequences and simultaneously provide direct actionable information. Organizing sensory evaluation tests through a basic structure, using well-defined (1) criteria (e.g., formal test requests, selection of an appropriate test method for an objective) and (2) selection of subjects, based on sensory skill or target market, sufficed to establish the soundness of this new science. Thus, this emerging field of sensory science substantially increased the likelihood of sensory evaluation services becoming accepted as an integral part of the research and development (R & D) process. Adoption of this new field of sensory analysis ultimately led to long-term success within those companies that adopted this critical step in their respective R & D programs and eventually marketing gains for pacesetting food products and beverages.

University-based sensory evaluation research first became visible in the late 1940s and early 1950s (Stone & Sidel, 2004). The University of California, Davis, University of Massachusetts, Oregon State University, and Rutgers University were among the first US colleges to offer courses in sensory evaluation, commencing in the 1950s.

One of the first tools developed for the instrumental evaluation of dairy product quality was the glass pH electrode, which became available in 1930 (Deisingh et al., 2004). This was one of the earliest forms of sensors available for the food industry. Other types of sensors followed, in the 1960s through the 1980s, which led ultimately to the development of electronic noses and electronic tongues (Deisingh et al., 2004). One of the earliest recent reports of the application of an electronic nose to detect complex vapors in the parts per billion range appeared in 1995 (Hodgins & Simmonds, 1995; Ampuero & Bosset, 2003; Harper, 2001). The development of electronic tongues is still in early stages (Deisingh et al., 2004), but at least one laboratory has reported application of the electronic tongue for milk evaluation (Winquist et al., 1997).

Chromatographic techniques have been used in the dairy industry for decades. For instance, early analysis of the fruity esters produced by psychrotrophic organisms in milk was conducted with gas chromatography combined with pre-columns, cold traps, and headspace samplings (Reddy et al., 1968; Hosono et al., 1974; Pierami & Stevenson, 1976). Patton, at Pennsylvania State University (Patton, 1954; Patton et al., 1956), and Day, at Oregon State University (OSU) (Day, 1967; Schultz et al., 1964; Lindsay, 1967), were some of the first food scientists (flavor chemists) to adapt chromatographic techniques, which were subsequently paired with mass spectrometry for a more thorough and detailed analysis of the flavor of a wide range of dairy products (i.e., fluid milks (Patton et al., 1956; Badings, 1984), concentrated and UHT milks (Arnold et al., 1968; Scanlan et al., 1968, Jeon et al., 1978), sour cream and buttermilk (Lindsay, 1967; Law, 1981), butter and cultured butter (Stark & Forss, 1966), Cheddar (Marth, 1963; Morris et al., 1966; Day, 1967), Swiss (Langler et al., 1966), and blue cheeses (Anderson & Day, 1966; Singh, 1968). Morgan's research at the University of Connecticut and subsequently at OSU (Morgan, 1976) combined his research experiences in dairy microbiology with flavor chemistry and explored the derivation of "malty," "fruity," and other developed off-flavors in milk and various other dairy products (Morgan, 1970a, b, 1976). The research area of flavor chemistry (identification of volatile and nonvolatile components responsible for specific sensory-perceived flavors) continues to this day. Identification of specific sources of desirable and undesirable flavors remains an area of key interest and application for the industry, but there remains no machine or instrument that can duplicate or fully replicate the human perception of flavor. Sensory analysis remains the foundation.

Sensory science as we know it has evolved into a set of quantitative procedures that enhance the efficiency and accuracy of food product development, quality control, market research, and marketing. Descriptive sensory analysis, an analytical sensory tool, involves training panelists to recognize and scale intensities of specific product attributes and allows powerful objective communication (Lawless and Heymann, 2010; Meilgaard et al., 2016).

Sensory evaluation, alone or in combination with other analytical procedures, is useful for quality control in the dairy industry. All told, predictability and quality of dairy products have improved in the past century as a direct result of formalized dairy product evaluation programs. With the combined goals and needs for progress in the sciences and technical advancements in instrumentation, there soon arrived an exponential expansion of rapid and precise, interlinked analytical tools to be closely linked with the more precise and confident sensory evaluation protocols for food

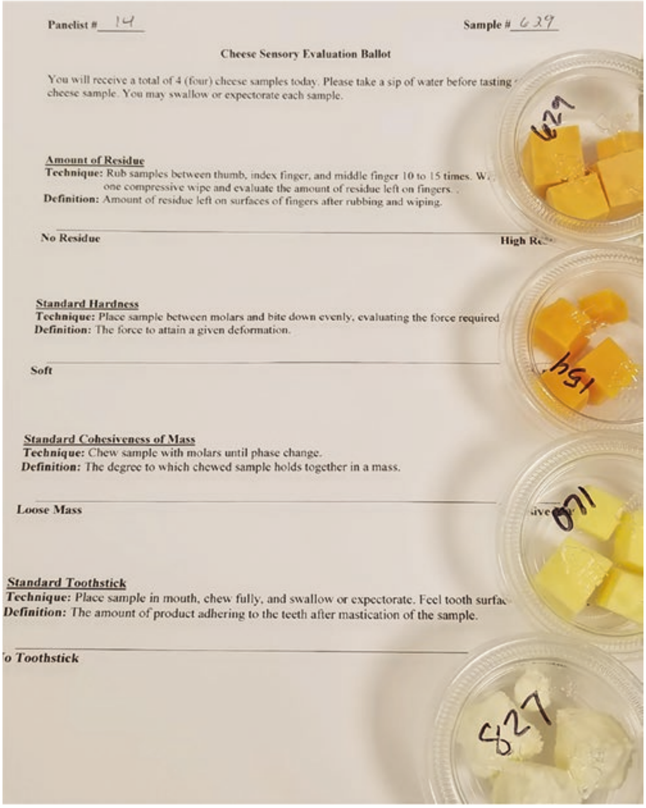

Fig. 1.1 Example of a cheese sensory evaluation ballot with identified attributes, definitions and an anchored scale. (S. Clark image)

products. Human sensory evaluation will always be a most critical component for advancing the industry's assurance of higher-quality dairy products for consumers.

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Chapter 2
Psychological Considerations in Sensory Analysis

Jeannine Delwiche

To many, the term "psychology" conjures the image of a distraught patient lying on a couch, telling her most intimate thoughts to a bearded man smoking a cigar and scribbling notes somewhere behind her. "What on earth do interpreted dreams, unhappy childhoods, and envy for certain aspects of male anatomy have to do with the sensory evaluation of dairy products?" you may ask. The answer is, "Not much." When we talk about psychological considerations in sensory analysis, we are not calling upon the ghost of Sigmund Freud, but instead referring back to some of his predecessors and contemporaries up north in Germany: Ernst Weber, Gustav Fechner, and Wilhelm Wundt. These men were all pioneers in the area of experimental psychology, a branch of psychology that does not rely upon interviews and introspection but rather upon the experimental method. Experimental psychology, in essence, does not trust the individual to be able to accurately tell the researcher what features are most important in determining a response. Instead, through careful design and controls, experimental psychology forces the individual to demonstrate what aspects are most important and to more or less "prove it."

The subdiscipline of experimental psychology known as psychophysics is of greatest relevance to sensory analysis. Fechner, while working in Weber's lab, gave rise to psychophysics with the publication of *Elemente der Psychophysik* (1860). Psychophysics is the area of natural science that deals with sensory physiology and which strives to explain the relationship between sensory stimuli and human responses. A major focus of psychophysics is to discover the relationship between a stimulus (C) and the resulting sensation (R). In its simplest form, this expression may be expressed as a mathematical function (f), $R = f(C)$. Inspired by Fechner's treatise, Wilhelm Wundt is credited with establishing the first laboratory for psychological research. The tools upon which the psychophysicist relied, and often still relies, were measured thresholds and direct scaling, tools that are often used today

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in sensory analysis. A complete discussion of psychophysics was provided by Amerine et al. (1965). Much of the early work in psychophysics was devoted to discovering how well a person could detect a stimulus. This was sought through the determination of threshold values, which is the minimal quantity of a substance or compound that can be detected, or the boundary at which the subject crosses from "not detecting" to "detecting."

When conducting psychophysics, the researcher begins with an experimental stimulus that can be measured objectively, and such stimuli can range from pure tones of known energy to salt solutions of known concentration. The investigator presents the stimulus in a neutral and repeatable fashion to the subject and then records the subject's assessment of that stimulus. After multiple presentations and assessments of the test stimuli, often by more than a single subject, the respective responses are analyzed statistically to determine the ways in which the subjects perceive the test stimuli. Similarly, the sensory analyst starts with known products, such as yogurts made at different production sites; presents the products in a neutral and repeatable fashion to the panelist; and then records the panelist's assessment of the products. After multiple presentations and assessments of the products, typically from more than one panelist, the responses are analyzed statistically to determine the product characteristics.

In psychophysics, the goal is to understand how individuals perceive the physical world, whereas in sensory evaluation, the goal is to understand the perceptual characteristics of the products. Nonetheless, the tools used in both psychophysics and sensory evaluation are the same and are subject to similar constraints when it comes to best practices.

2.1 Tools of the Trade

The basic tools used by sensory analysts and psychophysicists are (1) thresholds, (2) difference tests, and (3) ratings. One of the simplest tools utilized by both psychophysicists and sensory analysts are threshold measurements, several types of which have been identified to define more precisely the relationships between the magnitude of a given response and the perceived sensations (Amerine et al., 1965; Meilgaard et al., 2016). There are four types of thresholds (detection, recognition, difference, and terminal) that can be measured, but only two (detection and difference) can be measured with sufficient objectivity to be reliable measures. The easiest threshold to conceptualize is the *detection*, or absolute, *threshold*. It is the smallest amount of a particular stimulus that can elicit a sensation; stimuli of the same type with less intensity do not give rise to sensations. When dealing with taste and smell, the physical intensity is measured by concentration. Thus, the threshold for a particular taste or smell is the lowest concentration of a compound that a panelist can distinguish from water (or other solvent). At and above this concentration, the panelist will indicate that a compound is present, while below this concentration the panelist will indicate there is no compound present. Hence, detection thresholds are one way of establishing the relative potencies of different compounds, although caution must be used when making this comparison.

Actual differences in perception across individuals constitute a part of the variability in sensory data that sensory analysts learn to accept and psychophysicists learn to measure. In a study that examined the sensory threshold of off-flavors caused by either proteolysis or lipolysis of milk, 63% of the panelists detected an off-flavor at or below 0.35 mEq of free fatty acids (FFA)/kg milk (Santos et al., 2003). At a FFA concentration of 0.25 mEq FFA/kg milk, only 34% of the panelists could detect the off-flavor (also called rancid off-flavor). As illustrated by this example, the differences in individual thresholds may create a dilemma for milk marketing and quality assurance of fluid milk processors. With a wide range of individual consumer sensory thresholds for rancid off-flavor, where should the acceptance FFA-value be established? Threshold values also vary with testing or serving conditions (Amerine et al., 1965). For these reasons, threshold values are difficult to compare and must be interpreted with caution.

The *recognition threshold* is the level of a stimulus at which the specific stimulus can be recognized and identified. Typically, this level is higher than the detection threshold for the same stimulus. For example, if one was determining the threshold for diacetyl, the concentration at which it was detected would be lower than the concentration at which the aroma would be identified as "buttery." As mentioned above, this sensory measure cannot be made with complete objectivity. The reason has to do with the inability to control for response bias, a topic discussed below.

The *difference threshold* is the extent of change in a stimulus necessary to produce a noticeable difference. The amount of change needed is often referred to as the just-noticeable difference or "*jnd*." The difference threshold is quite similar to the detection threshold, but instead of looking for the lowest intensity that can elicit a sensation, one is determining the lowest increase in stimulation from some baseline intensity that can elicit a change in sensation. For example, given a baseline concentration of propionic acid, the jnd is the amount of propionic acid that must be added to the baseline concentration before it can be distinguished from the sample containing only the baseline concentration.

A complicating issue with the difference threshold is that the amount of stimulus that must be added to the baseline to be noticeably different increases as the intensity level of the baseline is raised. As an example, consider a room illuminated by candle light with only 10 candles. Let us speculate that the difference threshold is a single candle and that adding one candle's illumination to the room will increase the illumination by a just-noticeable amount. If we then raise the number of the candles in the room to 100, adding a single candle will no longer raise the illumination level by a noticeable amount. In fact, the just-noticeable difference (jnd) will now be 10 candles. This phenomenon is described by *Weber's law*, which states that the difference threshold divided by the baseline intensity remains constant. Difference thresholds change with stimulus intensity in a predictable way or stated mathematically

$$\text{Weber's law}: \Delta C / C = k;$$

where C is the absolute intensity of the stimulus, k is a constant (usually between 0 and 1), and ΔC is the change in intensity of the stimulus that is necessary for 1 jnd.

Thus, using our candle illumination example above, we can see that 1/10 = 10/100 = 10%. Another way of stating this is that the size of a jnd is a constant proportion of the original stimulus value.

Another practical interpretation of Weber's law indicates that the amount of an added flavor that is just detectable depends on the amount of that flavor that is already present. Knowing k allows the determination of how much added flavor compound is needed for a difference to be noted. Whereas Weber's research suggested the relationship between physical and perceived intensity was linear, Fechner's findings (1860) suggested the relationship between stimulus and response was logarithmic:

$$\text{Fechner's law}: R = k \log C$$

where R is the magnitude of the sensation, k is a constant, and C is the magnitude of the stimulus.

Later work by Stevens (1957) determined that the perceived magnitude of a response grows as a power function of the stimulus intensity:

$$\text{Stevens' power law}: R = kC^n$$

where R is the response, k is a constant, C is the absolute intensity of the stimulus, and n is the exponent of the power function (a measure of the rate of growth of the perceived intensity, as a function of stimulus intensity).

When n is larger than 1, the perceived sensation grows faster than the stimulus, as is the case for electric shock (3.5) or perception of weight (heaviness) (1.45). When n is smaller than 1, as is the case for many odors, the sensation grows more slowly in relation to the stimulus. A more comprehensive list of power functions is available in Meilgaard et al. (2016). However, just as with thresholds, exponents derived from power laws vary depending upon the subjects making the assessments as well as the methods used to determine them, often making direct comparisons of published values difficult.

The fourth type of threshold that can be measured is the *terminal threshold*, which is the magnitude of a stimulus above which there is no increase in the perceived intensity of the appropriate quality for that stimulus. Often, if the stimulus is increased in intensity beyond this level, pain occurs instead. For example, a solution of sodium chloride can become so concentrated that when it is sipped, it not only elicits the sensation of saltiness but also sensations of burning and/or stinging. The terminal threshold would be the highest concentration of sodium chloride above which there is no increased saltiness, only increased burning and stinging. As is the case with the recognition threshold, this measurement is prone to response bias and thus cannot be established with complete objectivity. There are a variety of procedures that can be used to determine thresholds, the details of which are beyond the scope of this chapter. What is important to note is that all modern assessments of thresholds, including those recommended by ASTM International, avoid single-stimulus judgments and otherwise control for response bias.

As mentioned above, response bias interferes with the ability to make objective measurements. When a person is asked to make a single-stimulus judgment, such as whether or not an aqueous solution contains a compound or if it is simply water, there are two distinct features that influence their decision: sensitivity and response bias. When measuring a threshold, the researcher is interested only in the sensitivity of the panelist. However, the response of the individual is also influenced by that individual's *response bias* or that individual's willingness to say, "Yes, I detect something other than water." An individual's response bias can be influenced by a variety of circumstances that are independent from the samples and his or her sensitivity, including emotional state, associated consequences of stating there is a stimulus (will the subject receive payment if she is correct? A shock if he is incorrect?), the percent of time a test stimulus (such as a low concentration of sodium chloride) is presented instead of a control stimulus (such as water), distractions within the test environment, etc. As the interests of both psychophysicists and sensory analysts are inclined toward measures of sensitivity, intended to assess sensory systems or product differences, modern sensory procedures are designed to eliminate response bias. To this end, a forced-choice difference test (discussed below) is typically incorporated into the determination of thresholds. In other words, rather than relying upon a panelist to state that he/she can detect a compound in solution, the panelist is asked to *demonstrate* his/her ability to detect it by selecting the sample that contains the compound from a set that contains both blanks and the compound in solution. In each sample set, the concentration of the compound is increased until the panelist can reliably select the sample with the concentration over samples that do not contain any compound (the blanks). In other words, instead of relying on the panelist to introspect upon whether or not a compound is present, the subject is asked to *prove* he/she can detect it.

As mentioned above, response bias cannot be eliminated from the measurement of recognition and terminal thresholds, which makes them far less reliable measures than detection and difference thresholds. When measuring a detection threshold, the panelist is challenged to select which unknown in a set of blanks and test stimuli contains the compound. When measuring a difference threshold, the panelist is asked to select which unknown in a set of baseline concentrations and test concentration contains *more* of the compound. Both of these tasks are *forced-choice difference tests*. Regardless of whether or not the panelist would be inclined to call all the samples the same or all the samples different from one another, he/she is forced to select a single sample, eliminating the individual's response bias from the task. It is not possible to set up such a force-choice situation for the measurement of either a recognition threshold or a terminal threshold. Recognition relies upon the individual's willingness to say that he/she recognizes the stimulus, which is his/her response bias. It is unfair to present a set of blanks and test stimuli and then ask the panelist to indicate which he/she recognizes – in actuality he/she may recognize none of them. Furthermore, it is unfair to ask a panelist to ignore pain when tasting extremely high concentrations of compounds in the course of measuring a terminal threshold.

2.2 Neutrality Is Key

Regardless of the sensory tool used (difference test, ratings, or thresholds), neutrality of sample presentation is key. This is because when measuring subtle differences between test stimuli, the panelist will draw upon all available cues in making his/her assessments. Sensory evaluation tradition suggests that samples be labeled with neutral, randomly generated three-digit numbers. Numbers with inherent meaning should be avoided (i.e., 666, 911, local area code, etc.). While it is not entirely necessary to use such labels, they are among the safest choices. Labels should not imply order or sequences, nor should they suggest quality; thus, labels such as A, B, C or 1, 2, 3 are particularly problematic. Two-digit numbers are often associated with sports figures and are generally less desirable for labeling samples. All labels should be generated in the same fashion, either on sticker labels or written directly on cups. All labels should be printed with the same font and style, or all written in the same handwriting, and all should be of the same color.

Other aspects of sample presentation should also be neutral. All samples need to be served at the same volume and same temperature. All samples should be served in identical neutral containers. Crushed cups and dented lids should not be used. When presented to the panelists, all samples should be presented with labels facing forward. Careful presentation is necessary to ensure that assessments are based only upon the characteristics of the samples themselves rather than upon extraneous cues.

2.3 Perception Is More Than a Sum of Its Parts

When asking panelists to assess dairy products, it is important to remember that the perceptual experience that occurs when a sample is placed in the mouth is a gestalt – a unified whole that cannot be derived from the summation of its component sensations. Not only are sensations of taste and smell elicited, but a variety of other sensory systems are also activated including sight, temperature, and texture. These sensations interact with one another and create the gestalt experience of flavor. Furthermore, it is simply not possible for a panelist to ignore a particular sensation while assessing others, even if the panelist attempts to comply with such instructions. A trained panelist may learn to separate the different aspects of the unified experience, but these sensations interact in the creation of the whole and the alteration of the components occurs before the panelist has the chance to disentangle them.

For example, taste and smell interact. Increasing the concentration of odor compounds typically increases ratings of taste intensity, and increasing the concentration of taste compounds generally increases ratings of smell intensity (Bonnans & Noble, 1993; Frank et al., 1989; Murphy & Cain, 1980; Murphy et al., 1977; Philipsen et al., 1995). Differential effects due to taste and odor qualities further complicate the issue. For example, the addition of sucrose to fruit juices not only increases sweetness and fruit odor but also decreases bitterness, sourness, and unripe odor (von Sydow et al., 1974). Color also interacts with taste and smell, wherein ratings of taste, smell, and flavor generally increase as color intensifies (DuBose et al., 1980; Johnson et al., 1982, 1983; Johnson & Clydesdale, 1982; Norton & Johnson, 1987; Teerling, 1992; Harrar et al., 2011; Harrar & Spence, 2013). Additionally, appropriately colored foods and beverages are identified correctly more often than uncolored and/or inappropriately colored items (DuBose et al., 1980; Hall, 1958; Moir, 1936; Philipsen et al., 1995; Stillman, 1993; Teerling, 1992; Spence et al., 2015). This is likely due to individuals associating certain flavors with specific colors, and when the colors are altered, identification becomes more difficult.

Texture impacts the perception of dairy products both directly and indirectly. How thick or thin, smooth or lumpy, crumbly or springy, etc., all impact assessments of the product. However, texture characteristics also control the concentration of taste and smell compounds released as well as the rate at which they are released (Overbosch et al., 1991). Increasing a product's thickness slows the diffusion of components to the sensory receptors, while decreasing the thickness will increase the rate of diffusion. This means that two items with identical amounts of taste and smell compounds, but different body/texture will differ in perceived taste and smell intensities. Additionally, the thicker-textured item will take longer to reach its peak taste and odor intensities and peak intensities will typically be lower than those of the thinner product. Recent work has also demonstrated that surface texture or tactile properties can influence taste and flavor (van Rompay & Groothedde, 2019).

Similarly, temperature impacts the perceived taste and smell (Delwiche, 2004). As a product is warmed, there is an increase in volatile components being released from it, and correspondingly odor intensity becomes stronger. Temperature itself can elicit taste sensations (Cruz & Green, 2000); thus, changing a product's temperature will alter its taste intensities. In addition, increasing product temperature can also decrease product thickness, resulting in the concomitant increases of taste and smell intensities as described above.

Appearance, aroma, flavor, body, and texture interactions are real, complex, and beyond conscious awareness and control. For these reasons, it is simply not possible for panelists to ignore specific perceptual features when making their assessments. If the researcher is interested in flavor differences but the products differ in texture, the researcher must realize that the flavor assessments will be impacted by the texture differences unless those differences are somehow eliminated. Nor is it possible for a panelist to ignore a temperature difference between samples if they are served at different temperatures. In fact, if a difference test is being conducted, sample temperature may be one of the ways that panelists differentiate the products.

2.4 Sensory Analysis: A True Science

From the discussion just presented, it should be clear that sensory analysis, like psychophysics, is a natural science. Like all natural sciences, measurements of sensory characteristics of foods or beverages can and should be taken carefully. When done properly, sensory information can provide great insight into the world. When measures are undertaken poorly, they do more to mislead than to inform. Careful controls must be implemented and followed when conducting sensory analysis, including (1) neutrality in the presentation of samples, (2) elimination of response bias, and (3) use of methods that require panelists to demonstrate their ability rather than relying upon self-reports. Failure to adhere to any of these controls diminishes the value of the resulting sensory data. By contrast, determining appropriate controls and ensuring they are in place will result in reliable and useful information about foods and beverages which no instrument can measure – their perceptual characteristics.

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Chapter 3
Physiology of Sensory Perception

Maria Laura Montero and Carolyn F. Ross

3.1 Introduction

Consumption and appreciation, the study of their physiology and the human reaction to stimuli, are fundamental to sensory evaluation. Sensory evaluation of food includes the critical examination and interpretation of important sensory attributes of a given product. Components of sensory evaluation of dairy products involves, but is not limited to, the perception of the color and symmetry of a wheel of cheese, the odor characteristics of cottage cheese after it has been stored at room temperature for several days, the relative degree of creaminess of whole milk, and the tanginess of a spoonful of yogurt.

During consumption of food, humans utilize their five primary senses to perceive different sensory signals. The five primary senses are: sight, hearing, touch, taste, and smell (Purves et al., 2018). The most primitive of these senses, taste, smell, and touch respond to chemical stimuli (Brown & Deffenbacher, 1979). Other human senses include temperature sensation (heat and cold), pain, visceral hunger, thirst, fatigue, and balance (Purves et al., 2018).

This chapter commences with a general discussion of sensory attributes and perception. A more detailed discussion of physiology involved in sensory perception follows, beginning with vision and concluding with chemesthesis (chemical mouthfeel).

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3.2 Perception of Sensory Attributes

Our perception of the environment, including food, happens through specialized sense organs or sensory receptors. The eyes are used for determining appearance and color, the nose for aromas, the tongue for taste, skin for touch, and the ear for any possible sound effects. Stimuli are defined as factors from the environment that elicit sensory impressions or perception (Dudel, 1981). Each sense organ responds to a particular range of stimuli and transmits information to the brain via the central nervous system (Dudel, 1981).

Response to a stimulus is best described as a chain (Schiffman, 1996):

$$\text{Stimulus} \rightarrow \text{Sensation} \rightarrow \text{Perception} \rightarrow \text{Response}$$

In this scheme, a stimulus generates a response via nerve signal(s) to the brain. Sensations involve the ability to transduce, encode, and perceive information generated by the stimuli (Purves et al., 2018). Specific sites in the brain are stimulated by the initial sensory input, and the brain interprets the incoming information into a perception. This perception is then translated into a response by the individual.

Up to a certain point, this response is proportional to the stimulus intensity. The nerve response suffices as a function of the frequency of the electrical discharge from the nerve, the higher the frequency, the stronger the sensation. However, all human sensory receptors vary in their sensitivity to stimuli (Amerine et al., 1965; Schmidt, 1981).

This chapter focuses on objective response to sensory perception, the type of response that arises from a physical or chemical reaction within individuals and a physiological response of the central nervous system (CNS).

3.3 Sensory Perception

The sensory perception of a person to food is a complex process. A number of overlapping sensory attributes bombard individuals as they first approach a food. Generally, they first notice the appearance of the food since appearance can be perceived quickly and noninvasively. Observation is typically followed by orthonasal perception. Individuals sniff to perceive the odor or aroma of the food (Landis et al., 2005). As the food is eaten, retronasal perception, “the perception of odors emanating from the oral cavity during eating and drinking,” (Landis et al., 2005) continues, as well as perception of the texture, taste, and possibly sound of the food. All of these attributes determine how individuals perceive the quality of the food, and this perception influences their liking of the food. Each of these attributes will be briefly discussed below.

Food or beverage appearance is a critical feature – it is often the first perceived attribute and serves as a primary deciding factor of the product quality. Therefore, appearance influences purchase decisions (Lawless & Heymann, 2010; McDougall, 1983).

Appearance is composed of a number of characteristics of the food, including but not limited to color, size and shape, visual surface texture, glossiness, clarity/turbidity, and carbonation level.

These attributes can be described in terms of spectrum terminology, which shows the degree or the extent to which these attributes are experienced:

Description – the actual color name or hue
Intensity – the strength of the color from light to dark
Brightness – the purity of the color, ranging from dull to pure, bright color
Evenness – the distribution of the color, ranging from uneven/blotchy to even (Meilgaard et al., 2007).

The final evaluation of the appearance of the food is determined by a combination of all the above-listed factors.

Odor or aroma is attributable to the detection of the volatile compounds that are released from the food. A distinction may be made among the terms, odor (when the volatiles are sniffed through the nose), aroma (odor of a given food product), and fragrance (odor of a perfume or cosmetic) (Meilgaard et al., 1999). The sense of smell is considered to be markedly more refined than the sense of taste, since an individual requires a relatively high concentration of tastant (a compound that is associated with a specific taste) in order to perceive a specific taste. The odor threshold values of some aroma compounds in water (20 °C) could be as low as 0.0045 mg/L (hexanal), 0.02 mg/L (vanillin), or 100 mg/L(ethanol) (Belitz et al., 2009). Meanwhile, the threshold concentration for some of the basic tastes are higher, for example, for citric acid is about 2 mM; for salt (NaCl), 10 mM; and for sucrose, 20 mM (Purves et al., 2018).

As a person masticates a food, the sensors in the mouth detect food texture and consistency. Texture is a complex term, defined by the structure of the food product. Food texture is a collective term of sensory experiences that originate from visual, audio, and tactile stimuli (Chen & Rosenthal, 2015). Components of texture include mechanical properties (including but not limited to hardness, cohesiveness, adhesiveness, springiness, denseness, and chewiness), geometrical properties (smooth, gritty, grainy, chalky, and lumpy), moisture and fat properties (juicy, oily or greasy), and air content or structure openness.

The noise produced by the food product is also related to texture, either during the rupture or the mastication of the food. In sensory evaluation of foods, measurements of noise include pitch, loudness, and the persistence of sounds. The sensation of food texture plays a key role in influencing consumers' liking of and preference for a food (Chen & Rosenthal, 2015).

The term flavor has many definitions, but within this chapter, this term will be defined as the "impressions perceived via the chemical senses from a product in the mouth" (Caul, 1957). Flavor includes the aromatic compounds released from the food in the mouth, the taste sensations (sweet, sour, salty, bitter, and umami) released from the soluble substance in the mouth, and the chemical feel factors in the mouth (astringency, cooling, metallic, spicy heat). Flavor is the sum of all of these sensory impressions or sensations that are perceived when a food or beverage is in the mouth.

The five human senses are thoroughly covered in other textbooks (Amerine et al., 1965; Lawless & Heymann, 2010; Piggott, 1984; Purves et al., 2018). Thus, the following discussion provides an overview of the senses and their importance in sensory evaluation, particularly in the sensory evaluation of dairy products.

Senses may be separated based on the type of stimuli to which they respond. Sight, hearing, touch, and temperature are considered to be physical senses in that they respond to physical stimuli. By contrast, the sensations of smell, taste, and pain are considered to be chemical senses in that the respective receptor sites all respond to chemical stimuli.

3.4 Vision

3.4.1 Vision: A Definition

The mechanism of vision has been the most persistently investigated. The terms vision and appearance are separated by their definitions. Vision may be defined as the psychological response to the objective stimulus generated by the physical nature of the object viewed (MacDougall, 1984). Appearance is the recognition and assessment of the properties (surface structure, opacity, color) associated with the object seen. Aside from color, foods and beverages have a large variety of characteristics associated with appearance. These characteristics include physical form and optical properties (gloss, transparency, haziness, and turbidity) (Lawless & Heymann, 2010).

3.4.2 How Vision Works

The first steps in the process of seeing involve the transmission and refraction of light by the optics of the eye. The photoreceptors transduce the light energy into electrical signals. These signals are then refined by synaptic interactions within the neural circuits of the retina. The retina contains neurons that are sensitive to light and transmit visual signals to central targets (Purves et al., 2018).

Response to a stimulus is best described as a chain of events:

$$\text{Light} \rightarrow \text{Cornea} \rightarrow \text{Pupil} \rightarrow \text{Lens} \rightarrow \text{Retina}\left(\text{the fovea}\right)$$

Vision is perceived through the eye (Fig. 3.1). It begins with light entering the eye and ends with the formation of an image on the retina. As light enters the system through the cornea, it moves through the aqueous humor and the pupil, which are

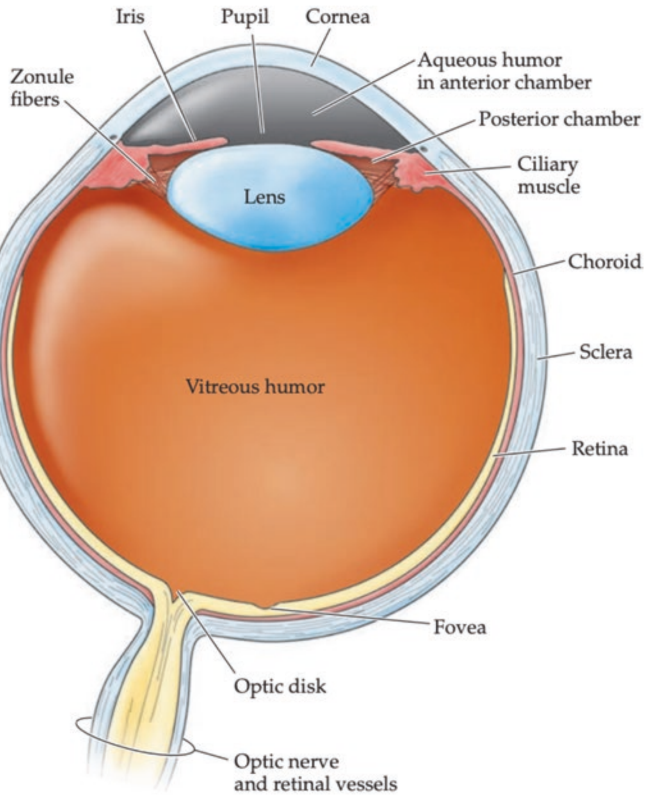

Fig. 3.1 Anatomy of the human eye. (From Purves et al., 2018)

both behind the cornea. The light is refracted by the crystalline lens. It then goes through the vitreous humor to the retina (Vera-Diaz & Doble, 2012). The retina, the innermost layer of the eye, contains neurons that are light sensitive. Five basic classes of neurons can be found in the retina: photoreceptors, bipolar cells, ganglion cells, horizontal cells, and amacrine cells (Purves et al., 2018). During perception, light is either reflected from or passed through an object; then, it enters the eye and is focused onto the fovea, a depression in the retina.

In the fovea, light is transformed into electrochemical impulses, which then travel toward the brain (Vera-Diaz & Doble, 2012). The fovea, approximately 1.5 mm in diameter, is the region where vision is most acute (Purves et al., 2018). Two types of photoreceptor cells, located on the fovea, rods,and cones, convert photons into electrochemical signals, which can stimulate biological processes (Vera-Diaz & Doble, 2012). The human retina contains approximately 90–120 million rods and 5 million cones; however, this number changes with ageing and certain retinal diseases (Vera-Diaz & Doble, 2012). The rods and cones contain photosensitive pigments that bleach upon exposure to light.

Rods are activated at the lowest levels of illumination/light or scotopic vision (Purves et al., 2018). These photoreceptors are extremely sensitive and can be triggered by a very small number of photons. Therefore, at very low light levels, the visual signal comes only from the rods (Purves et al., 2018; Vera-Diaz & Doble, 2012).

Cones are responsible for detecting color. They are the major determinant of perception under conditions such as normal indoor lighting or sunlight (photopic vision) (Purves et al., 2018). The distribution of the rods and cones across the surface of the retina also has relevant consequences for vision (Purves et al., 2018). The density of the rods sharply declines in the fovea, while the cones are exclusively and most densely packed in the center of the fovea (Purves et al., 2018).

3.4.3 Perception of Color and Appearance

The perception of color is a two-stage process that involves a physical and a psychological stage. From a physical standpoint, color is the perception that results from the detection of light as it has interacted with an object (Lawless & Heymann, 2010). The perceived color is affected by three factors: (1) the physical and chemical composition of the object, (2) the spectral composition of the light source illuminating the object, and (3) the spectral sensitivity of the given viewer's eye (Lawless & Heymann, 2010). The color of an object can vary in three dimensions: hue (color), lightness (brightness), and saturation (chroma or the purity of the color) (Lawless & Heymann, 2010).

During the physical evaluation of color, individual differences reflected in the spectral sensitivity of the viewer's eye are another critical factor to consider. Normal human color vision is fundamentally trichromatic (Purves et al., 2018). Cones contain three color-sensitive pigments that respond to blue, green, and red light (Lawless & Heymann, 2010). Color blindness results if the individual presents difficulty in distinguishing colors that are easily perceived by individuals with normal trichromatic vision (Purves et al., 2018). The most common type is red/green color blindness. Color blindness affects about 8% of male population in the United States and 0.44% females (Lawless & Heymann, 2010; Purves et al., 2018). Therefore, panelists should be screened for color blindness if sensory evaluation of dairy products involves color evaluation.

The psychological step of the evaluation of appearance/color is accomplished by translating either reflection or transmittance to trichromatic values and then to an appropriate color space.

3.4.4 Sensory Testing of Color and Appearance

During sensory evaluation, when food products are tested simultaneously, colored filters are often used to mask color differences. However, these efforts are often unsuccessful. Appearance evaluation may be influenced by the use of these filters since these filters mask differences in hue (color) but not always brightness and chroma. Thus, it has been reported that panelists often give consistent responses about a product's color even when filters are used (Meilgaard et al., 1999). Therefore, sensory data derived from evaluations that required color filters should be interpreted with caution.

3.4.5 Vision in the Sensory Evaluation of Dairy Products

The appearance of dairy products can indicate either the presence of good qualities, or quality defects within the products (Alvarez, 2016; Bodyfelt et al., 1988). In general, factors that may be evaluated by sight include: the product color, the style of the product, the condition of the package, the attractiveness of product finish and workmanship, and overall appearance characteristics. Using the aforementioned cues, an evaluator is able to provide an initial or cursory assessment of the product, which may be confirmed by subsequent sensory evaluation endeavors (Bodyfelt et al., 1988).

Cheese In Swiss cheese, some typical appearance defects include blindness; this defect is characterized by little to no eye formation; frog mouth, in this case, the eyes have an elongated shape; and nesty/streuble, this defect is characterized by the presence of small eyes clustered together in a localized area (Alvarez, 2016).

Butter Some common color and appearance defects in butter are color specks, and surface color faded, or high. Color specks are characterized by the presence of small spots in the butter body. The specks can present different colorations, such as black, green, red, yellow, or white (Alvarez, 2016). Surface color faded or high means the butter is either lacking an appropriate level of yellow or excessively yellow (Alvarez, 2016).

Yogurt Yogurt can also present sensory defects associated with appearance and color. Some examples are atypical color, color leaching, shrunken, free whey, and lumpy (Alvarez, 2016). Atypical color is much lighter, darker, or different than the specified flavor. Color leaching is when fruit color leaches into the yogurt body. Shrunken and free whey can be noticed by the presence of a yellow liquid between the yogurt and the container wall, where the yogurt pulled in. Meanwhile, a lumpy body appears rough or similar to Greek yogurt curd after stirring (Alvarez, 2016) (see Chap. 8, for a full description of possible defects in yogurt).

3.5 Hearing

3.5.1 Hearing: A Definition

The sound emitted when certain foods are bitten and chewed is considered a reflection of their auditory texture. Although hearing or sound is frequently excluded from sensory evaluation, the contribution of this sense to the evaluation of food quality and consumer liking should not be minimized.

Sound is the auditory perception of pressure waves formed by the vibration of air molecules; sound is an auditory perception (Purves et al., 2018). Sound is perceived through the vibrations conducted through the air. The external ear gathers sound energy and focuses it on the eardrum, or tympanic membrane (Fig. 3.2; Purves et al., 2018). The sound energy causes the eardrum to vibrate. The sound-induced vibrations are then transmitted through the small bones in the middle ear to the inner ear to create hydraulic motion in the fluid of the cochlea. The cochlea is a spiral canal covered in hair cells. In the inner ear, the frequency, amplitude, and phase of the incoming signal is carried by sensory hair cells. It is then encoded by the electrical activity of the auditory nerve fibers (Purves et al., 2018). These hair cells send neural impulses to the brain.

3.5.2 How Hearing Works

Figure 3.2 shows the structure of the human ear.

3.5.3 Auditory Texture

Auditory texture in foods is directly related with *crispness,* crunchiness, and crackliness (Lawless & Heymann, 2010). Crispness and crunchiness are noise-producing mechanisms of food used to describe the auditory texture of wet and dry foods, respectively. Crisp wet foods include fresh fruits and vegetables (Lawless & Heymann, 2010). Crunchiness and crispness differ in their frequencies. Crunchiness is more related to a larger proportion of low-pitched sounds (frequencies less than 1.9 kHz), while crispness is related to a larger proportion of high-pitched sounds (frequencies higher than 1.9 kHz) (Seymour & Hamann, 1988; Vickers, 1985). *Crisp* foods also break in a single stage, while crunchy foods break in several successive stages of applied pressure (Szczesniak, 1991). The intensity and pitch of crispness and crunchiness can be measured in terms of decibels.

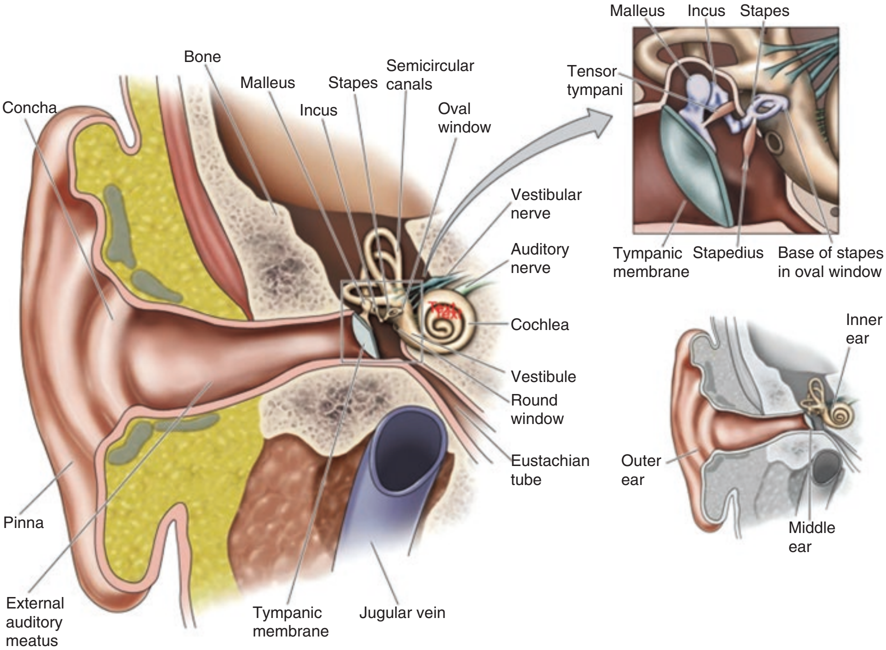

Fig. 3.2 The organization of the human ear. (From Purves et al., 2018)

3.5.4 Hearing in the Sensory Evaluation of Dairy Products

Attributes of noise (sound) can also be used during the sensory evaluation of dairy products.

Cheese In Swiss cheese, quality can be evaluated by gently tapping the outside of the cheese with the fingers or a sampling device like a cheese trier, which projects the relative size and/or distribution of *eyes* within the block of cheese.

Butter In butter, the relative amount of free moisture can also be estimated by the character of the *slushing* sound made when the sample piece is reinserted into the trier hole from which it was drawn (Bodyfelt et al., 1988).

3.6 Olfaction

3.6.1 Olfaction: A Definition

The olfactory system coordinates a response to stimuli called odorants. Odorants are volatile (vaporous), airborne, chemical stimuli. The olfactory system processes information from these stimuli about their identity, concentration, and quality (Purves et al., 2018).

3.6.2 *How Olfaction Works*

Figure 3.3 shows how olfaction works. Fig. 3.3a provides an overview of the anatomy of the system, while Fig. 3.3b provides a close-up of part of that anatomy. Figure 3.4 shows the pathway by which olfaction happens.

Olfactory receptor neurons (ORNs) are bipolar neurons. Olfactory receptors (ORs) are G-coupled proteins found on the cilia of the ORNs (Schiffman, 2007). G proteins are specialized proteins that have the ability to bind the nucleotides guanosine triphosphate (GTP) and guanosine diphosphate (GDP). G-protein-coupled receptors (GPCRs) are a large family of cell surface receptors that respond to a wide variety of external stimuli (Nature Education, 2014). ORs are part of the same families of proteins involved in vision and gustation (Mainland et al., 2014). The olfactory cilia are short, microscopic hairlike structures that detect and transduce odorants into an electrical signal (Reiserta & Reingruber, 2019).

The cilia of the ORNs provide a greater surface area for the OR to interact with odorants. The OR extend nerve fibers into a smaller number of glomerular structures in the olfactory bulb. The glomeruli are dense areas of branching and provide synaptic contact of the OR with the ORNs in the olfactory pathway (Lawless, 1991).

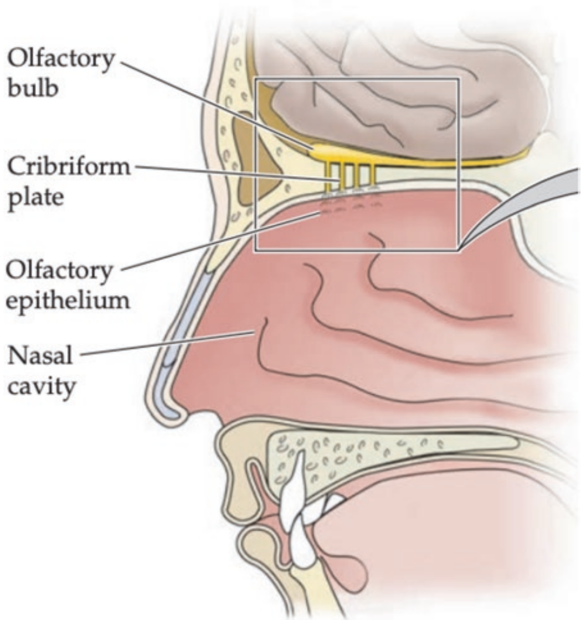

Fig. 3.3 Elements of the human olfactory epithelium. **Part A:** Peripheral and central components of the olfactory pathway. **Part B:** Close-up of region boxed in Part A. Relationship between the olfactory epithelium (which contains the ORNs) and the olfactory bulb (the central target of ORNs). (From Purves et al., 2018)

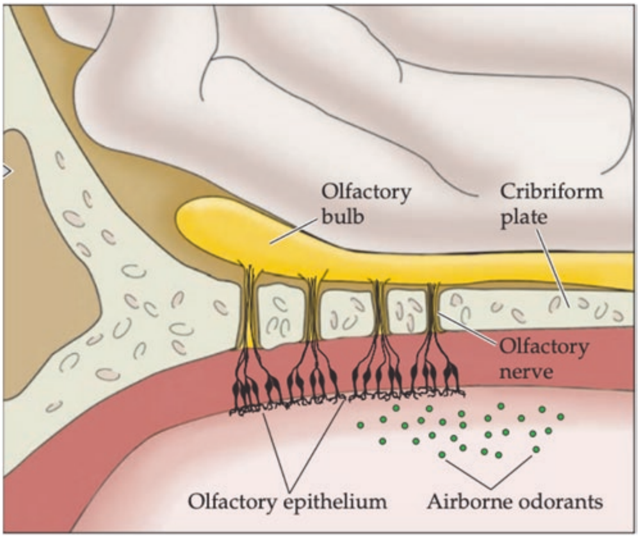

Fig. 3.3 (continued)

The anatomy of the nose allows only a small fraction of inspired air to reach the olfactory epithelium via the nasal turbinates (Fig. 3.3a). Under normal breathing conditions, about 5% of inhaled air reaches the olfactory receptors. However, during sniffing, the amount of air that reaches the receptors increases to about 20% (DeVries & Stuvier, 1961).

ORs are activated by odorant molecules carried into the nose during inhalation and dissolved in the mucus lining the nasal cavity (Fig. 3.4). Odorants are sensed by the olfactory receptor neurons (ORN), which are found in the olfactory epithelium (Fig. 3.3a) that line the interior of the nasal cavity (Fig. 3.3a, b). ORNs are activated when odorants bind to the ORs. OR activation initiates a biochemical transduction cascade that depolarizes the neuron(s) via the opening of ion channels located in the ciliary membrane (Reiserta & Reingruber, 2019). Specifically, the G proteins initiate a cascade of intracellular signaling events, which are propagated along the olfactory sensory axon to the brain. When a signaling molecule binds to a GPCR, it provokes activation in the G proteins, which triggers the production of any number of secondary messengers (Nature Education, 2014).

During odor perception, when a person sniffs a food product such as cheese, the mix of volatile compounds in the cheese flows over the ORs in the olfactory region of the nose. However, only those receptors specifically responsive to the compounds in the cheese will be activated. An important phenomenon in odor perception is adaptation or the tendency to become unresponsive to stimuli that are stable in space and time (Lawless & Heymann, 2010). By sniffing for 1–2 s, the optimal odorant contact is achieved (Laing, 1983). However, after 2 s, the receptors have adapted to the new stimulus, and 5–20 s are required for them to de-adapt before a new odor can produce a sensation.

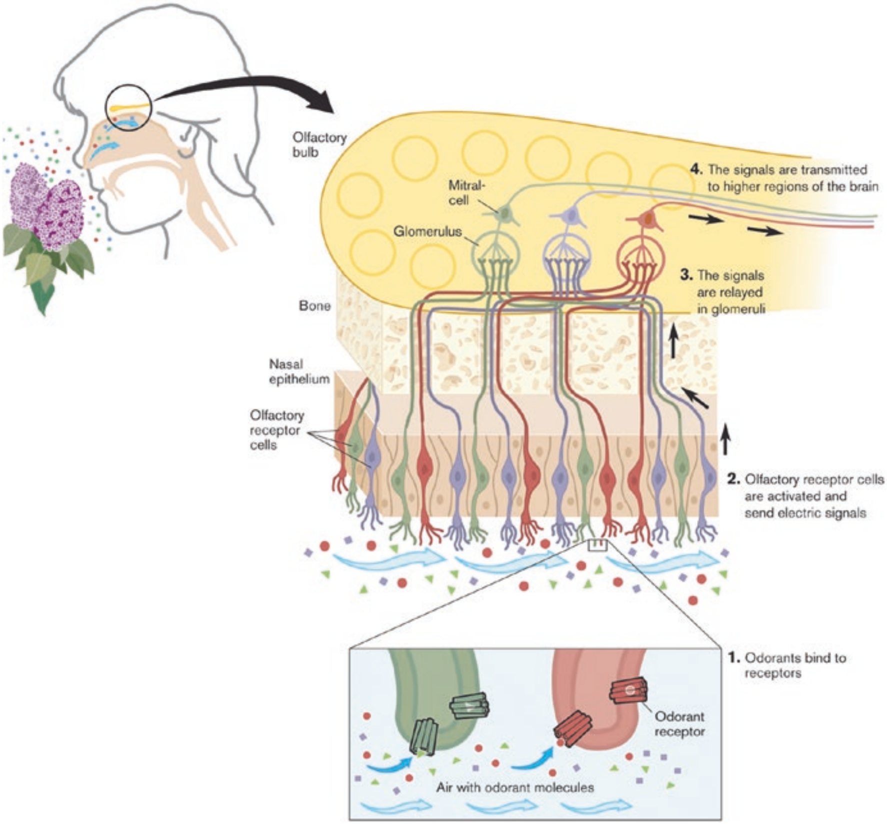

Fig. 3.4 Steps involved in the pathway for odorants detection. (From Press release. NobelPrize.org. Nobel Media AB 2020. Wed. 11 Nov 2020. https://www.nobelprize.org/prizes/medicine/2004/press-release/)

In sensory panels, adaptation may manifest in the increase of sensory thresholds or the frequency of zero intensity ratings for certain attributes. Adaptation also reinforces why sensory testing should be conducted in an odor-free environment and not be rushed.

3.6.3 Olfaction Science

3.6.3.1 History

Numerous theories of odor recognition and perception have been developed over the years (Amoore et al., 1967; Jones & Reed, 1989; Wright, 1954). Chemical, physiological, and anatomical studies have suggested that odor perception is caused by the chemical or physical attributes of response to odorants in the olfactory receptor in the olfactory epithelium. Those responses create patterns that are interpreted by the brain as odorant quality.

In the early 1990s, evidence showed that olfactory transduction used a G-protein-coupled pathway. Through molecular genetic techniques, Buck and Axel (1991) identified a family of approximately 1000 genes that encoded for the same number of different G-protein-coupled receptors in the olfactory epithelium of rats. The authors also described the expression patterns of odorant receptor genes in the olfactory epithelium. They showed that the axons of neurons that express the same odorant receptor converged in the olfactory bulb on the same glomeruli.

Axel and Buck illustrated that a single odorant is detected by multiple receptors and that different odorants are recognized by different combinations of receptors (Malnic et al., 1999). Overall, the combination of Axel and Buck's work showed that humans have a few hundred types of ORs, each of which can detect only a limited number of odors. Their work also showed that only one kind of receptor appears on each of the approximately 5 million odor-sensing nerve cells in the nose. In 2004, Buck and Axel were awarded the Nobel Prize in Physiology or Medicine for their discoveries on the central role of OR proteins in the encoding of olfactory information and the ORs gene family (Purves et al., 2018). The sense of smell long remained the most enigmatic of our senses. The basic principles for the recognition and remembrance of over 10,000 different odors were not well understood, but the research from Axel and Buck helped to expand the understanding of the olfactory system (Buck & Axel, 1991).

3.6.3.2 Human Thresholds

Mammals possess an olfactory system of incredible discriminating power (Amoore, 1970). Humans can differentiate among approximately 1 trillion odors (Bushdid et al., 2014). However, the ability of an individual to be able to detect a specific odorant as part of the aromatic profile of a food does not only depend on the concentration of the odorant in the food product but also on the odor threshold of that odorant (Czerny et al., 2011).

Threshold values for odorants are highly variable within and across individuals. A threshold can be defined generally as a stimulus intensity or the minimum concentration of a compound that produces a response in 50% of the individuals in a test panel (Bi & Ennis, 1998; Lawless, 1991). The sensitivity of the ORs varies with both the compound and the individual and may vary over a range of 10^{12} molecules/mL of air or more (Meilgaard, 1975). Odor thresholds have been reported to range from 1.3×10^{19} molecules/mL of air (ethane) down to 6×10^{7} (allyl mercaptan) molecules/mL of air (Harper, 1972).

The human nose remains the most sensitive tool for detecting odorants, surpassing the sensitivity of instrumental means. With analytical techniques such as gas chromatography, 10^{9} molecules/mL air may be detectable. Because the human nose is 10- to 100-fold more sensitive than this analytical technique, sensory evaluation by human noses is critical in the analysis of odorants.

The condition known as anosmia describes a person's inability to detect odor compounds or complete loss of smell (Purves et al., 2018), while hyposmia describes a partial loss of smell (Hannum et al., 2020). Specific anosmia is the inability to detect some families of similar aromatic compounds. A specific anosmia is defined as the condition in which the individual has an odor threshold greater than two standard deviations above the population mean concentration (Amoore et al., 1968). Common anosmias include trimethylamine, a fish spoilage taint, (Amoore & Forrester, 1976), and diacetyl, a compound associated with butter aroma (Lawless et al., 1994). Anosmias, while rare, do exist; therefore, potential panelists should be screened for sensory acuity prior to participation in a sensory panel.

As of Spring 2021, over 176 million people worldwide have been infected by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes coronavirus disease 2019 or COVID-19 (Johns Hopkins Coronavirus Resource Center, COVID-19 Dashboard). In response to this pandemic, multiple studies have tried to identify the causes and symptoms of the disease. Acquired anosmia and hyposmia have been recently reported as symptoms of COVID-19; however, studies of olfactory dysfunction show a prevalence that ranges from 5% to 98% (Hannum et al., 2020). A fundamental question for olfaction science is whether SARS-CoV-2 affects olfaction directly, by infecting olfactory sensory neurons or their targets in the olfactory bulb, or indirectly, by the perturbation of supporting cells. In a study conducted by Brann et al. (2020), findings suggested that SARS-CoV-2 infection of non-neuronal cell types leads to anosmia and related disturbances in the perception of odorants in individuals with COVID-19.

Sensory scientists need to be aware of the impact that this virus may have on the short- and long-term perception of odorants by individuals that presented with acquired anosmia as part of COVID-19 symptomatology. This anosmia may compromise their acuity to conduct sensory evaluation, mainly when aroma testing is crucial.

3.6.3.3 The Smell and Flavor Connection

Flavor detection involves the combination of olfactory and gustatory stimuli (Spence, 2015). Therefore, the sensory evaluations of most food-related flavors are dependent on olfactory perception. In order to perceive the odor of a specific chemical compound, the compound must be sufficiently heavy, lipophilic, and volatile (Keller & Vosshall, 2016). The volatility of a compound depends upon its molecular weight and molecular bonding properties. For odors to be perceived via the olfactory system, the upper limit of their molecular weight (MW) needs to be within the range of 300 daltons or lower (Moncrieff, 1967). The molecular geometry of odorants, and, more specifically, the composition and structures of the functional groups within the molecule play a key role in the perception of odorants (Keller & Vosshall, 2016). Keller and Vosshall (2016) used a sensory panel of 55 healthy people to test their olfactory perception of 480 molecules. These molecules were structurally and perceptually different and were presented at two concentrations. The authors found

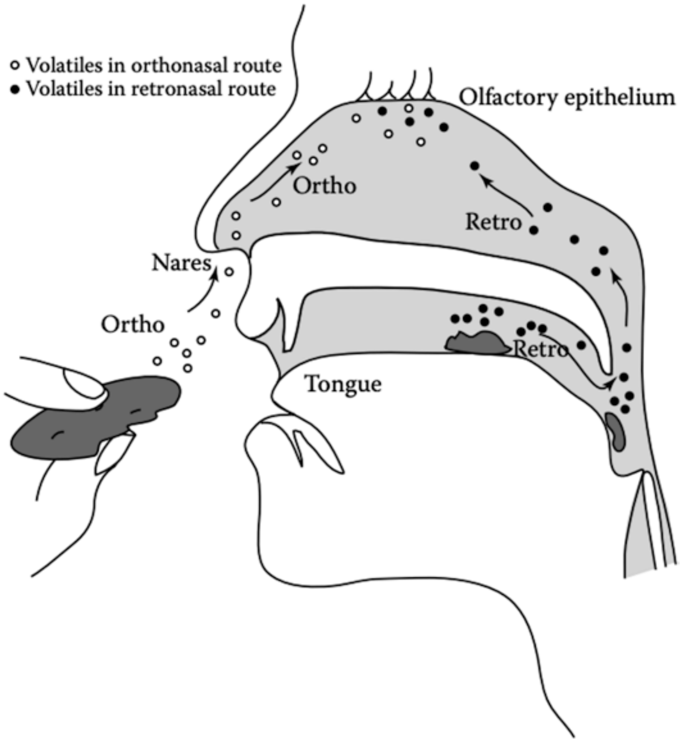

Fig. 3.5 Perception of volatile compounds in the orthonasal and retronasal route. (From Kringelbach, M.L., & Berridge, K.C. (Eds.). (2009) Oxford handbook: Pleasures of the brain)

a negative correlation between molecular weight and how intensely the participants perceived the tested compounds.

The greater part of what is known as food flavor is mediated by smell (Lawless 1991). Orthonasal olfaction detects odors that are perceived through the nostrils. Retronasal olfaction perceives those odors detected *in mouth* as the stimulus is transported up from the back of the throat and into the region of the ORs (Fig. 3.5).

3.6.4 Sensory Testing Issues

While the number of odor families that people can recognize is large, labeling given odors is not an easy task. Often individuals can recognize a smell but cannot make the verbal connection to identify the odor. This difficulty in verbal connection is one reason why many clinical tests of smell use a multiple-choice format to separate difficulties in smelling from problems in labeling (Doty, 1991). The sense of smell is also limited by the number of components present in a complex odor mixture.

Humans tend to perceive odors as whole patterns rather than individual components. This perception pattern makes odor profiling difficult (Engen, 1982).

Over the years, many odor classification schemes have been proposed. Historically, the challenges with odor classification lists have been the use and application of broad, associative, and subjective descriptors (Moncreiff, 1967). In 1970, Amoore developed a classification system of specific anosmias that point to a possible lack of a specific odor receptor type for a group of compounds. In Amoore's system, he proposed eight classes: ethereal, camphoraceous, musky, floral, minty, pungent, putrid, and sweaty.

Nowadays, specific food and beverage products and related industries have their own systems for aroma and flavor terminology. For example, the Wine Aroma Wheel was developed to arrange commonly used wine aroma characteristics (Noble et al., 1987). In this wheel, general terms are located on the innermost part of the wheel, and these terms become more specific as the user moves toward the outside of the wheel. Similarly, a cheese aroma wheel was developed for the evaluation of hard and semihard cheeses (Berodier et al., 1997).

One way of reducing variability when conducting sensory evaluation of dairy products is panel training. In this type of training, panelists are presented with the sensory language (or lexicon). Then, with the guidance of the panel leader, the panelists discuss these attributes as they relate or not to the products being tested (Drake, 2007). Lexicons of sensory attributes have been developed for multiple dairy products such as Cheddar cheese, dried dairy ingredients, chocolate milk, and butter (Drake, 2007).

Despite these efforts, no currently available arbitrary scheme reflects biologically significant categories of odorants. However, one of the most consistent aspects of olfactory perception schemes is the classification of odors as either pleasant and attractive or.

unpleasant and repulsive (Purves et al., 2018).

3.6.5 Olfaction and the Sensory Evaluation of Dairy Products

Olfaction, or smelling, plays a critical role in the sensory evaluation of dairy products. Important details about product quality can be determined with olfaction. A large component of flavor is the specific odor property of the food; hence, this attribute is critical in providing a thorough assessment of any dairy product (Bodyfelt et al., 1988).

Cheese In Cheddar cheese, a strong smell similar to the fragrance of alcohol in yeast bread or an odd fruity/pineapple odor is associated with the aromatic defect described as fermented/fruity (Alvarez, 2016). Another common defect is sulfide, which results in an unpleasant rotten egg smell when extreme (Alvarez, 2016).

Butter In butter, an uncommon *yeasty* aroma and flavor is described as a scent in butter, similar to yeast leavened bread dough, fragrant fruity, or vinegary aroma (Alvarez, 2016). Another defect that may be present in stored butter is tallowy. This defect provokes an aroma and flavor similar to oxidized tallow (Alvarez, 2016).

Yogurt *Cooked* aroma is an odor defect that may occur in yogurt made from scorched milk. It is characterized by nutty, cooked egg white, and scorched milk aromas (Alvarez, 2016).

3.7 Taste and Gustation

3.7.1 Taste and Gustation: A Definition

The sense of taste provides critical information about the origin and quality of food; therefore, in humans, it leads to specific eating responses (consumption or rejection) (Besnard et al., 2016). Taste is defined as the chemical sense responsible for the detection of nonvolatile compounds in food (Keast & Costanzo, 2015). Taste involves the detection of stimuli dissolved in water, oil, or saliva by the receptors in the taste buds. Five basic taste modalities are commonly recognized: sweet, sour, salty, bitter, and umami (a savory, meaty, broth-like, the taste of monosodium glutamate) (Besnard et al., 2016; Yamaguchi & Ninomiya, 2000).

Specific receptors have been identified for these five basic tastes. Other sensations, such as metallic and fat, have also been proposed to join the group of primary modalities (Besnard et al., 2016; Keast & Costanzo, 2015; Stevens et al., 2006). Regarding alimentary tastes, Hartley et al. (2019) stated that it is pertinent to critically evaluate whether new tastes, including umami, are suitably positioned with the four classic basic tastes (sweet, sour, salty, and bitter). The authors proposed the use of a subclass named alimentary for tastes not meeting basic criteria.

However, these basic tastes sufficiently describe most taste experiences, and adequate taste standards are reported in the literature (Lawless & Heymann, 2010).

3.7.2 How Gustation Works

Figure 3.6 illustrates the taste system. The important major components are papillae, taste buds, and taste cells.

Papillae are mainly located on the surface of the tongue (the epithelium) and only rarely in the mucosa of the palate and areas of the throat (Besnard et al., 2016). Papillae are multicellular protuberances surrounded by local folds, which form a furrow-like structure that concentrates tastants (Purves et al., 2018). Taste buds are distributed along the sides of the papillae as well as along the sides of the furrow (Purves et al., 2018).

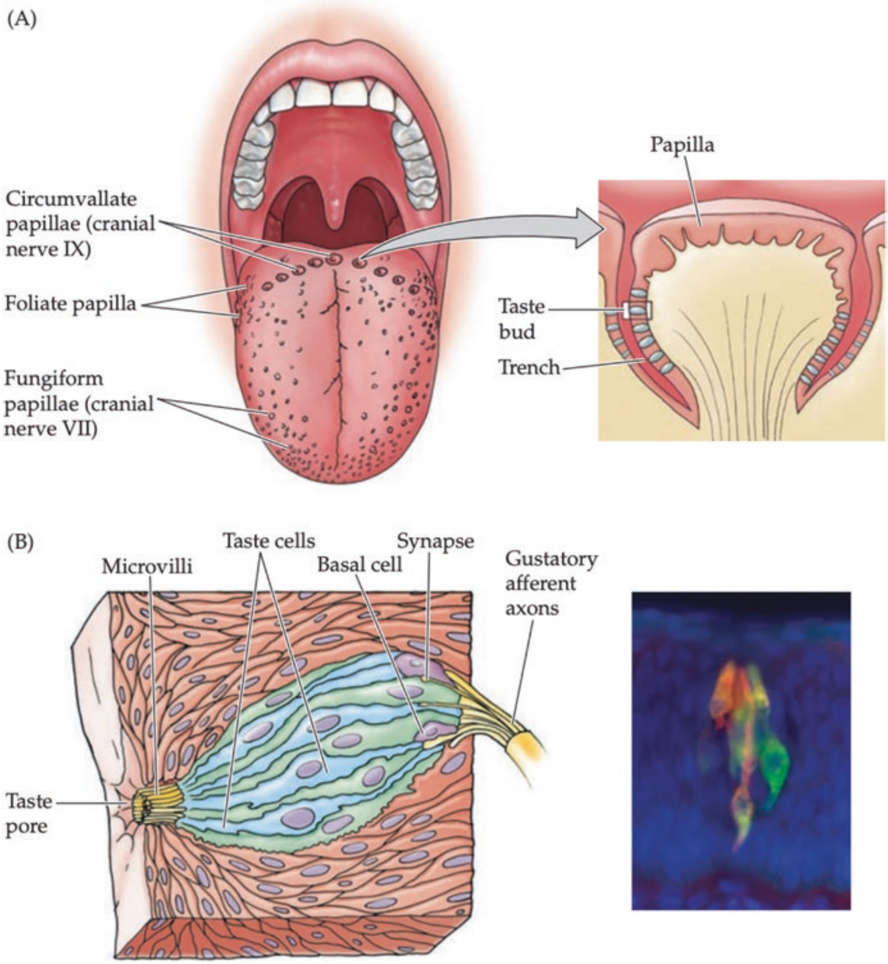

Fig. 3.6 The human tongue (**a**), a distribution of taste papillae on the surface of the tongue. The closeup indicates the location of individual taste buds on a circumvallate papilla. (**b**) Diagram and light micrograph of a taste bud showing various types of taste cells and the associated gustatory nerves. The taste cells make synapses on the gustatory afferent axons. (From Purves et al., 2018)

The distribution of taste buds is generally associated with certain papillae. On the epithelium, taste buds are found in three specialized papillae: circumvallates, foliates, and fungiforms (Besnard et al., 2016). Circumvallate papillae form a V-shape on the back of the tongue. They are large and easily visible. Circumvallate papillae contain most of the taste buds, approximately 48–50% (Besnard et al., 2016; Witt & Reutter, 2015). The backside of the tongue also contains foliate papillae. This type of papillae contains about 28% of the taste buds (Purves et al., 2018; Witt & Reutter, 2015). The fungiform papillae are large and mushroom-like in appearance. These papillae are found only on the front two-thirds of the surface of the tongue. They are most numerous and most dense at the tip of the tongue, where they can occur at 30/ cm^2 (Purves et al., 2018). These papillae contain about 24–25% of the total number of taste buds (Witt & Reutter, 2015).

Taste buds are located in the papillae of the tongue, the epithelium of the palate, oropharynx, larynx, and the upper esophagus (Witt & Reutter, 2015). Taste buds are specialized onion-shaped structures composed of 50–100 taste cells (Besnard et al., 2016) and are stimulated by sensory nerve endings. Taste cells are located in the cell membranes of taste buds and are renewed on average every 6–8 days (Purves et al., 2018). Taste cells use multiple signaling pathways to detect chemicals in food. Each taste bud is a heterogeneous assemblage of three different cell types (Besnard et al., 2016). The different types of taste cells include type I cells, the most frequently found, which serve as support cells. Type I cells have glial-like properties. Like the glia cells in the central nervous system, these cells help to clear neurotransmitters and redistribute ions (Witt & Reutter, 2015). They are thought to participate in sodium detection (Besnard et al., 2016). Type II cells have G-protein-coupled receptors. These cells detect bitter, sweet, and umami taste stimuli. Type III cells detect sour and salty stimuli (Dutta et al., 2020; Witt & Reutter, 2015).

Saliva is another important part of the gustation system that plays a key role in the orosensory perception or stimulation in mouth of food components (Besnard et al., 2016, Møller, 2014). Saliva is a complex solution of water, amino acids, proteins, sugars, organic acids, and salts that cover the gustatory sensors. Specific functions of saliva include preparation of the food for swallowing by altering its consistency, solvent action, cleansing action, and moistening and lubrication action (Best & Taylor, 1943; Carpenter, 2012).

The composition of saliva serves to modulate taste response. The amount of saliva secreted varies with the gland that is secreting the saliva. Saliva secreted by the sublingual glands is thick and mucous-like, while saliva secreted from the submaxillary (located in the floor of the mouth) is either thin and watery or thick and viscous, depending upon the stimulus. Saliva secreted by the parotid gland (located in the cheeks) is thin and watery; this is the saliva that is released in copious amounts during mastication.

Manipulation of the sample in the mouth suffices to stimulate the flow of saliva; hence, it is important to maneuver the sample around the mouth. Individuals show variation in the way they manipulate food in the mouth. Some people eat rapidly with just one or two chewing actions, while others chew food thoroughly before swallowing, thus affecting flavor release (Taylor, 2002).

Taste perception begins on the tongue and involves the detection of stimuli dissolved in water, oil, or saliva. Tastants are detected over the full surface of the tongue in the taste papillae. Chemical stimuli on the tongue first stimulate receptors in the fungiform papillae and then in the foliate and circumvallate papillae (Purves et al., 2018).

For flavor perception, the food must be masticated, solubilized, and diluted in saliva in order for a taste reaction to occur. In flavor perception of food products, both volatile and nonvolatile flavor compounds are released. The release of those compounds is influenced by the food product structure and chemical and physical properties.

Compared with olfaction, the contact between a solution and the taste epithelium is more consistent. There is no risk of the contact being too brief, but there is risk of oversaturation. Taste perception begins when chemical components of food interact with receptor proteins, which are found on the taste receptor cells. These taste receptor cells determine the identity, concentration, and qualities of chemical stimuli, such as *pleasant, unpleasan*t, or *potentially harmful* (Purves et al., 2018).

Taste perception occurs when the taste receptor cell within the taste buds makes contact with the outside fluid environment of the mouth through a pore at the top of the cell. The taste molecules are thought to bind to the hairlike cilia near the opening of the pore (Fig. 3.6b). In the pore, the taste receptor cells within the taste bud make contact with the primary taste nerves over a gap connection. In response, neurotransmitter molecules are released into the gap to stimulate the primary taste nerves and send the taste sensation signal on to the brain.

In addition to concentration of taste stimulus, other conditions in the mouth affect taste perception. These include temperature, viscosity, rate, duration, presence of other compounds in the food or beverage, and saliva flow and composition. Both stress and time of day affect these parameters.

3.7.3 Thresholds

Taste perception differs among individuals, and these differences appear to play a role in food choices. The simplest and best understood taste variation in humans is the ability to taste phenylthiocarbamide (PTC). Discovered serendipitously by Fox in 1931, PTC may be perceived by some individuals as intensely bitter (tasters) but remains relatively tasteless to a large fraction of the population (nontasters). Many studies have explored the genetic differences among individuals who are tasters versus nontasters (Drayna et al., 2003; Kaprio et al., 1987).

The ability to taste the bitter compound 6-n-propylthiouracil (PROP) is also genetically determined. PROP tasters have been divided into tasters, nontasters, and supertasters, those individuals with a heightened sensitivity to the bitterness of PROP (Bartoshuk et al., 1993b). PROP sensitivity has been correlated with increased densities of both fungiform papillae and taste buds, with supertasters having the highest density followed by tasters and then nontasters (Duffy et al., 1994). Several studies have explored the hypothesis that PROP sensitivity may heighten sensitivity to other taste compounds. For example, the perceived saltiness of NaCl, the burn of capsaicin, and the intensity of ethyl alcohol were all perceived as stronger by those individuals sensitive to PROP (Bartoshuk et al., 1998; Bartoshuk et al., 1993a). PROP sensitivity has been linked with a greater frequency of food aversions (Drewnowski et al., 1998).

Taste sensitivity has also been found to change with age. Using a variety of threshold tests, the majority of research studies show a decrease in sensitivity with increasing age (Murphy, 1986; Rolls & Drewnowski, 1996). More recently, detection thresholds of NaCl, KCl, sucrose, aspartame, acetic acid, citric acid, caffeine, quinine-HCl, and monosodium glutamate were determined in 21 young people (19–33 years) and 21 elderly people (60–75 years) (Mojet et al., 2001). As in previous studies, a significant effect in threshold was found for age but not for gender ($p < 0.05$). However, the interaction of age and gender was shown to be important. Older men were less sensitive than young men and women to acetic acid, sucrose, citric acid, NaCl, and KCl.

3.7.4 Taste Perception in Dairy Products

3.7.4.1 The Role of Saliva

Understanding how saliva is affected by different conditions and how this may impact sensory evaluation and dairy judging are important aspects to consider. Some components of the matrix (such as sugar and salt) can also influence the saliva-air partition of volatile compounds by changing the physicochemical conditions of the saliva phase.

Saliva secretion occurs when dairy products are taken into the mouth for tasting, with the amount and composition of the saliva varying with the type of dairy product consumed. Ingestion of dairy products such as milk stimulates a mucousy, viscous saliva. Ingestion of a semidry solid, such as cheese, results in the secretion of a thick, viscous, lubricating submaxillary saliva, and large quantities of diluting saliva from the parotid (Bodyfelt et al., 1988). Many dairy products are not in a readily perceived state when they enter the mouth.

3.7.4.2 The Problem of Aftertaste

The persistence of milk aftertaste is an attribute of milk that impacts some individuals' enjoyment. Aftertaste is a combination of tastes, flavors, textures, and feelings. In a survey conducted in 2001 by Dairy Management Incorporated, results indicated that the reason that the highest percentage of females did not consume milk was "too much aftertaste." In a subsequent study of milk likers and non-likers, Porubcan and Vickers (2005) found that salivary flow did not differ between the two groups. However, milk dislikers did have a higher salivary flow after consuming milk compared to saliva flow rate after consuming water. This increase in saliva production was attributed to the body's attempt to rid the mouth of milk aftertaste. In PROP analysis, results showed a significant interaction between taster status (nontaster, taster, and supertaster) and the liking rating of mouthfeel after swallowing. The authors concluded that women who disliked the aftertaste of milk may be more likely to be tasters and supertasters.

3.7.5 Taste and Gustation in the Sensory Evaluation of Dairy Products

Alvarez (2016) described a series of defects associated with taste and gustation in multiple dairy products.

Cheese Bitter, high acid, and high salt are common taste-related defects in cottage cheese. High diacetyl, fermented/fruity, and cooked are examples of flavor defects in cottage cheese.

Butter The presence of specific tastes and flavors in butter are associated with defects, including acid or bitter taste, cheesy, or rancid flavor (Alvarez, 2016).

Ice Cream Some commonly detected defects in ice cream flavor are cooked, oxidized, high sweetness, and unnatural flavor (e.g., high or low flavoring).

Yogurt Acetaldehyde (green apple-like flavor), cooked, and yeasty flavor are some examples of potential defects in yogurt (Alvarez, 2016).

3.8 Touch

3.8.1 Touch: A Definition

The somatosensory system is the most diverse of the sensory systems. It mediates a wide range of sensations, including touch, pressure, vibration, limb position, heat, cold, itch, and pain. All these sensations are transduced by receptors within the skin, muscles, or joints and conveyed to a variety of targets in the CNS (Purves et al., 2018).

The somatosensory system can be divided into subsystems. One subsystem, the tactile subsystem, transmits information from mechanoreceptors found in the skin (cutaneous) and mediates the sensations of fine touch, pressure, and vibration. The proprioceptive subsystem has specialized receptors associated with muscles, tendons, and joints. This subsystem is responsible for proprioception, or humans' ability to sense the position of the limbs (arms and legs) and other body parts in space. Receptors in a third somatosensory subsystem provide information about painful stimuli and thermal changes. This system also provides information about nondiscriminative (or sensual) touch (Purves et al., 2018). This chapter focuses on the tactile subsystem.

3.8.2 *How Touch Works/Perception*

In general, the skin senses are able to code three types of stimuli: mechanical, thermal, and pain related. Kinesthesis, or the deep pressure sense, is the result of stimuli pressing upon or displacing connective tissue without injury (Amerine et al., 1965). Kinesthesis is felt through nerve fibers in muscles, tendons, and joints. Kinesthetic perceptions correspond to the mechanical movement of muscles (heaviness, hardness, stickiness); these perceptions result from stress exerted by muscles and the sensation of the resulting strain. The relative level of the texture of a given food is judged partially through the perception of the forces that are needed to physically break down the structure of the food.

Somesthesis is the tactile sense or skin-feel caused by displacement of hairs or deformation of the skin without injury. Tactile sensations may be transmitted from a variety of sites as shown in (Fig. 3.7). The epidermis, dermis, and subcutaneous layers are responsible for somesthetic sensations of touch, pressure, heat, cold, itching, and tickling.

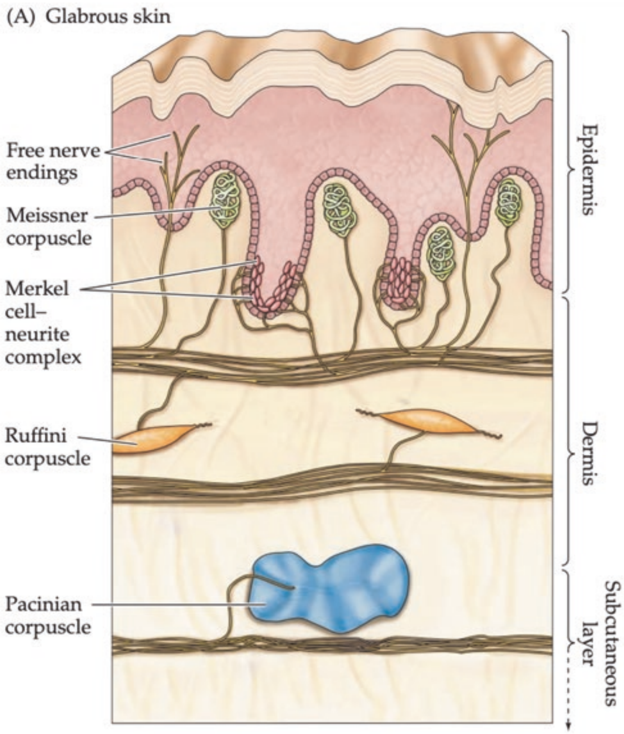

Fig. 3.7 Cross-section of human skin. (From Purves et al., 2018)

3.8.3 Texture: A Definition

Jowitt (1974) built on the previous definition of *texture* provided by Szczesniak (1963) to read that texture is "the attribute of a substance resulting from a combination of physical properties and perceived by the senses of touch, sight, and hearing." Physical properties may include size, shape, number, nature, and conformation of constituent structural elements. The appreciation of texture involves the subtle interaction between both motor and sensory components of the peripheral and the central nervous system.

3.8.4 Visual Texture and Oral Tactile Texture

Food texture is an important sensory evaluation parameter that is used as an indicator of food quality. Texture is a composite property and is related to the physical properties of foods and their complex relationships. In certain foods, the perceived texture is the most important sensory attribute (i.e., crispy, crunchy foods like cheese snacks). In other foods, the texture, while important, is not the primary sensory characteristic (i.e., soup). Quite often, sensory assessments of texture are made on the basis of sensations perceived when the food sample is manipulated in the mouth. The sense organs involved in mastication and texture perception are located in and around (1) the superficial structure of the mouth, (2) the roots of the teeth, and (3) the muscles and tendons of the mouth and jaw.

Texture evaluation can also be undertaken by looking at the surface of a food product. Characteristics such as shine (or sheen) and lumpiness provide visual texture cues.

Oral tactile texture attributes are those texture attributes perceived within the mouth. One scheme used for texture classification (Szczesniak, 1963) is still used today. In this classification scheme, three categories of textural characteristics were proposed:

1. Mechanical characteristics – related to the reaction of food to stress or force (Szczesniak, 1963). Information about the firmness, toughness, crispness, or fibrousness of the product may be gained when a sample of solid food is manipulated in the hand by squeezing, bending, or cutting it with a knife. The behavior of a liquid or semisolid food when shaken, stirred, or poured may yield information about its viscosity, smoothness, or stickiness. For butter or margarine, interpreted behavior during the course of spreading provides key information on the textural properties of the product (Wilkinson et al., 2000).
2. Geometrical characteristics – related to the size, shape, and orientation of the particles in the food, specifically the size and shape of the particles (Szczesniak, 1963). Soft, rounded or hard, flat particles with a size above 80 μm exhibit gritty properties or characteristics. Particles that are hard, angular, and within the size range of 11–22 μm are also gritty (Tyle, 1993).

3. Other characteristics – related to the perception of moisture and fat content of the food (Szczesniak, 1963). In the specific case of fat globules, Richardson and Booth (1993) reported that panelists were able to distinguish between average fat-globule size and distance distributions in a range of 0.5–3 μm.

3.8.5 Mouthfeel

Mouthfeel is another oral tactile attribute that tends to change less dynamically than other texture characteristics. Szczesniak (1979) classified mouthfeel attributes into nine groups: viscosity (thick, thin), feel of soft tissue (smooth, pulpy) and carbonation (tingly, foamy bubbly), body (watery, heavy, light), chemical (astringency, numbing, cooling), coating of the oral cavity (clinging, fatty, oily), resistance to tongue movement (slimy, sticky, pasty, syrupy), mouth after-feel related (clean, lingering), physiological (filling, refreshing, thirst quenching), temperature (hot, cold), and extent of wetness (wet, dry).

3.8.6 Touch in the Sensory Evaluation of Dairy Products

The sense of touch, including product texture and mouthfeel, is also an important aspect for quality sensory evaluation of dairy products. The perception of rubberiness or springiness of cheese and the creamy, icy, or sandy mouthfeel of ice cream are indicators of product quality. For the evaluation of the external surface of some dairy products, evaluators may use their fingers to assess the tactile perception. This type of evaluation provides information on the relative springiness or hardness of a product.

Cheese Sample size and serving temperature are important in evaluating hardness and chewiness of cheeses. Cardello and Segars (1989) investigated the effect of sample size on various texture attributes of cream cheese, American cheese, and other dairy products. The sample sizes ranged from 0.125 to 8 cm^3. Study results showed that both hardness and chewiness increased as a function of sample size, thus reflecting the dependence of texture attributes on sample size. Drake et al. (2005) investigated the effect of the serving temperature on the perception of flavor attributes of Cheddar cheese when tested by a trained panel. Three serving temperatures were selected (5 °C, 12 °C, and 21 °C). Results showed that panelists found it more difficult to evaluate the cheese when the serving temperature was 21 °C as compared with 12 °C or 5 °C (see Chap. 9 on Cheddar cheese).

Milk Sample size is important in evaluating liquid dairy products, such as milk. The taster should take small sips (i.e., 8–12 ml), keep each sip in the mouth for a couple of seconds, and then wait 15–60 s before tasting again. The first and second sips are the most sensitive. To effectively evaluate a solid sample, the recommendation is for at least 28 g of sample (Poste et al., 1991).

Butter Some potential defects of oral tactile texture in butter are gummy. In this type of defect, butter presents a gumlike texture and does not melt in the mouth. For mealy or grainy, butter has a grainy texture that is noted upon smashing it between the tongue and the palate (roof of the mouth) (Alvarez, 2016).

Ice Cream In ice cream, the most objectionable and easiest to detect texture defect is *sandy*. This defect is present when pressing a thin layer of ice cream against the palate and hard regular sized particles/crystals of lactose do not dissolve quickly (Alvarez, 2016).

When a texture attribute changes over time, it is referred to as phase change or melting. Many foods undergo a phase change in the mouth due to increased temperature in the oral cavity, with such notable examples as chocolate and cheese. Phase change is also important in evaluating ice cream. The ice cream effect was proposed by Hyde and Witherly (1993). This effect states that the dynamic contrast (the moment-to-moment changes in texture contrasts within the mouth) is largely responsible for the relatively high palatability of ice cream. In the development of low-fat products, the concept of dynamic contrast needs to be seriously considered, because when fat is removed, the melting attributes change markedly.

3.9 Chemesthesis

3.9.1 Chemesthesis: A Definition

Multiple sensations that are chemically induced can be perceived in the oral and nasal cavities and also in the external skin. These chemically induced sensations do not classify into the traditional classes of tastes and smells. These types of sensations are called chemesthetic sensations or qualities (Lawless & Heymann, 2010); they can also be referred to as trigeminal chemosensation or irritation (Töle et al., 2019).

Sensations such as the burn of hot peppers and spices, the tingle and prickling of carbonation, and the sharp coolness of peppermint are all referred to as chemesthetic qualities. Chemical irritants such as horseradish, ginger, ammonia, menthol, and onion stimulate the free nerve endings in the mucous membranes of the mouth, nose, and eyes.

3.9.2 How Chemesthesis Works/Perception

Chemosensation occurs in sensory epithelia in the nose and mouth. The detection of pungent chemicals, or chemesthesis, is mediated by oral and nasal afferents of the trigeminal nerve (V) (Cooper et al., 2020) (Fig. 3.8). Trigeminal chemical stimulation evokes the noxious or irritating sensations of burn, heat, cold, pungency, and/or pain in the mucosa of the eyes, nose, and mouth (Amerine et al., 1965; Töle et al., 2019).

The information about the texture, temperature of food, and the content of irritants is conveyed in the trigeminal fibers in the mouth. Trigeminal fibers originate from cell bodies in the trigeminal ganglion and terminate in the main and spinal trigeminal nuclei of the brain stem (Töle et al., 2019). The trigeminal pathway then

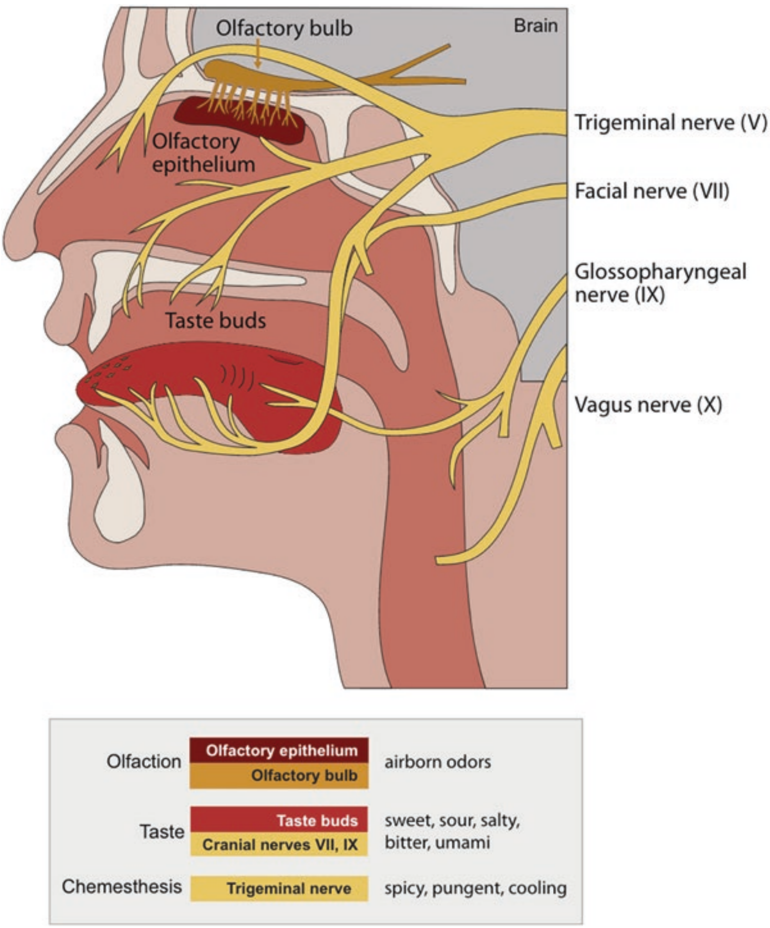

Fig. 3.8 Chemosensory anatomy. (From Cooper et al., 2020)

ascends to a thalamic relay nucleus and from there to a cortical region in the post-central gyrus, which is part of the primary somatosensory cortex (Small & Green, 2012).

Irritant stimulation stimulates strong defensive reflexes in the body, including sweating, tearing, salivary flow, and pain. Ammonia, for example, affects the nose and eyes and other mucous surfaces of the body. Pepper and ginger stimulate taste receptors and heat-sensitive pain receptors in the mouth. Peppermint evokes coolness and sting due to menthol simulation of cold fibers and pain fibers, while pepper evokes burning through capsaicin stimulation of heat-sensitive pain fibers. During sensory evaluation, panelists often have difficulty separating chemical sensations from tactile sensations, as the trigeminal nerves also signal tactile, thermal, and pain sensations.

3.9.3 Trigeminal Thresholds

For the majority of compounds, the trigeminal response requires a concentration of the irritant that is an order of magnitude higher than that which stimulates the olfactory or gustatory receptors. Trigeminal effects assume practical significance when the olfactory or gustatory threshold is high, which may be the case for certain compounds or for people with partial anosmias. The effects may also be significant when the trigeminal threshold is low, as for example with capsaicin.

Among individuals, a wide variety in pain response and tolerance exists. Some individuals derive enjoyment from a certain degree of pain, such as the consumption of excessively hot chili or hot coffee. In these situations, a certain degree of thrill-seeking and desensitization are involved, in addition to psychological differences in the desirability of pain (Prescott & Stevenson, 1995). Consumers of hot spices frequently rate the extent of burn sensation from capsaicin lower than nonconsumers do (Prescott & Stevenson, 1995).

In a recent study, Byrnes and Hayes (2015) investigated gender differences in the influence of personality traits on spicy food liking and intake. The authors explored if personality factors may play a role in determining an individual's sensitivity to and preference for foods that contain capsaicin. In a laboratory setting, the participants of the study evaluated a number of foods and sensations with a generalized liking scale; after leaving the laboratory, they filled out an online personality survey, which included Arnett's Inventory of Sensation Seeking and the Sensitivity to Punishment and Sensitivity to Reward Questionnaire. One of the main findings of the study was that differential effects of the personality traits were seen in women versus men. In women, sensation seeking was more strongly associated with liking and intake of spicy foods, while in men, sensitivity to reward was more strongly associated with liking and consumption of spicy foods. These differences suggest that when comparing women and men, there may be dissimilar mechanisms leading to the intake of spicy foods; specifically, women may respond more to intrinsic factors, while men may respond more to extrinsic factors (Byrnes & Hayes, 2015).

3.9.4 Temporal Quality of Chemesthetic Sensation

Chemesthetic sensations do possess a temporal quality in that they generally take longer to develop and decay compared to tastes and smells (Lawless, 1984). This time lag may be explained by physiology; most mucosal pain receptors lie within or beneath the epithelium rather than in direct contact with the oral environment. Another component of chemesthesis is desensitization, in which sensitivity is diminished following exposure to sufficiently high concentrations of an irritant. Desensitization occurs primarily after stimulation has stopped (Green, 1993) and can last for a day or more (Karrer & Bartoshuk, 1995). Research has also shown that given high enough concentrations at frequent consumption, recovery fails to be complete and chronic desensitization sets in (Green, 1996).

Until recently, chemesthesis was regarded as a unidimensional warning system that signaled only the presence and strength of chemical irritants (Silver, 1987). However, human perceptual studies have provided evidence that chemesthesis adds to the enjoyment of a particular food or beverage by contributing distinctive qualities.

The trigeminal response to mild irritants, such as carbonation, mouth-burn as caused by high concentrations of sucrose or salt, as well as the heat of snacks, may contribute to rather than detract from product acceptance. For example, pepper is often used as an ingredient because of its combination of sweet taste and slight irritant action, which is heightened if the pepper gets into the nose. The combined coolness and sting of peppermint, the tartness of citric acid, and the burn of cinnamon all may contribute to product acceptance (Green, 1996).

3.9.5 Chemesthesis in the Sensory Evaluation of Dairy Products

Spicy dairy products are a growing trend in the dairy industry; therefore, conducting sensory evaluation on this type of products has become very relevant. Schlossareck and Ross (2019) investigated the consumer's and the electronic tongue (instrumental/analytical technique) ability to discriminate among paneer cheese samples containing different levels of capsaicin (1.875, 3.75, 7.5, 15, and 30 ppm). Over a period of 2 days, consumers ($n = 110$) evaluated the paneer samples. The difference from control test was used to conduct this evaluation. Consumers were able to distinguish the spicy paneer sample from the control (0 ppm) at 3.75, 7.5, 15, and 30 ppm ($P < 0.05$). The authors reported differences were found among sample 3.75, 7.5, and 15 ppm ($P < 0.05$). However, no significant differences were found at the lowest (between control and 1.875 ppm) and highest capsaicin levels (between samples 15 and 30 ppm) suggesting that a minimum concentration between 1.875 and 3.75 ppm capsaicin may be required to result in consumers identifying the spiciness.

In a follow-up study, Schlossareck and Ross (2020) evaluated aftertaste intensity and liking of spicy paneer cheese (0, 3.75, 7.5, and 30 ppm capsaicin) by consumers ($n = 79$) for 15 min, at 1 min intervals. The authors also explored the influences of consumer consumption patterns on spicy aftertaste. They observed significant differences ($P < 0.05$) across aftertaste time periods (beginning, middle, and end) and within consumer consumption categories. Overall, the more capsaicin content in a sample of spicy paneer, the longer the sensation lasted, with a more intense spicy and overall aftertaste. Some of the main results in the study showed consumers in different categorization groups rated intensity of the samples differently and reported liking the highest capsaicin paneer sample (30 ppm) differently. Additionally, consumer's spice level preference did not affect the time to abatement of the intensity of the spicy aftertaste perceived by the consumers (Schlossareck & Ross, 2020).

In the subsequent chapters of this book, detailed discussions of several categories of dairy products, from liquid to solid, are included with descriptions of practical techniques that have proved successful in the evaluation of dairy products' quality with respect to appearance and color, body and texture, and aroma and flavor. Coupled with knowledge about the physiology of taste, odor, and mouthfeel (i.e., flavor) provided in this chapter, and a greater understanding of factors that influence dairy products' quality provided in subsequent chapters, dairy manufacturers, quality assurance personnel, and consulting scientists will be better equipped to reliably provide high-quality products to consumers.

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Chapter 4
Dairy Products Evaluation Competitions

Stephanie Clark

4.1 Introduction

Scorecard judging is a useful and practical tool for conducting the sensory evaluation of dairy products. Scorecards contain standard terminology, which is associated with established sensory descriptors that are described in subsequent chapters of this book. Scorecards have serves as recording instruments for various county, state, regional, and national dairy product evaluation competitions. Completed scorecards may serve as records for processing plants, for routine and/or official grading of dairy products, and for commercial dairy processors to receive feedback on products entered in contests.

A scorecard is best defined as a tabulated list of the factors that contribute to, or describe, the quality of a product, with a numerical value assigned to each factor. The factors are generally arranged on a scorecard in alphabetical order and oftentimes are categorized. For instance, the flavor attributes are commonly grouped; an alphabetized list of body and texture attributes is typically grouped; appearance and color attributes are also grouped, with or without consideration of packaging.

Obviously, a scorecard for one product (e.g., milk) reads quite differently from a scorecard for another product (e.g., yogurt) due to the inherent properties and differences in the various products. A so-called ideal product is designated as a “perfect” score, which may be scored as “100,” or “10” or another preset number. For instance, the “ideal” flavor scores on Collegiate Dairy Products Evaluation Contest scorecards are based on a score of “10”; body and texture and appearance and color scores are based on an ideal of “5.” In contrast, in the American Cheese Society Judging and Competition, a perfect score includes the combination of an “aesthetic judge” score of 50 and a “technical judge” score of 50, for a total of 100.

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U.S. Department of Agriculture
Bureau of Dairy Industry
ScoreCard for Milk and Cream
(Approved by the American Dairy Science Association)

Place _______
Class _______ Exhibit no. _______

	Perfect score	Score allowed	Remarks
Bacteria	45		Bacteria found per cubic centimeter
Flavor and odor	25		Cowy, bitter, feed, flat, strong, cooked
Sediment	10		
Temperature (street samples) or acidicity (prepared samples)	15		Degrees or percent
Bottle and cap	5		Bottle Cap
Total	100		

Exhibitor _______
Address _______
Signed _______
Date _______

Fig. 4.1 A reproduction of the US Department of Agriculture Scorecard for Milk and Cream. (Clark & Costello, 2009)

Deviations in quality from the ideal result in demarcations on the scorecard and demerits in the total score. In some instances, these scorecards may include data from instrumental, microbiological, and/or sensory analytical techniques (Fig. 4.1). Additionally, more detailed scorecards may be used to evaluate dairy plant processing and sanitation practices or to more objectively determine product quality and/or shelf life. Although scorecards that include such data can comprehensively present or represent the relative quality of products, product compositional analysis protocols do not lend themselves to completion within a singular time period. Thus, "abridged" or student scorecards, which only include sensory analysis assessments, can provide meaningful sensory quality data in a single seating (Nelson & Trout, 1951).

There are two main types of dairy product evaluation competitions: (1) those that reward dairy manufacturers for outstanding dairy processing and (2) those that reward student judges for their accurate sensory evaluation of dairy products, as compared to an expert judging panel. This chapter is devoted to describing various US Cheese Competitions (the former) and Collegiate Dairy Products Evaluation

Contests (the latter). This chapter is not an exhaustive summary of all the various dairy product contests and sensory evaluations that take place in the USA and the world each year. Readers should gain a greater understanding and an appreciation for what preparation, knowledge, and application of developed skills goes into the training, organizing, and competing successfully in dairy products evaluation competitions, as well as what steps are involved in conducting a dairy products judging or competition.

4.2 Dairy Products Grading and Scorecard Evaluation

The official grading of dairy products did not commence until the latter part of the nineteenth century. Establishment of product grades (with their attendant scorecards), as well as standards for respective dairy products, paralleled quite closely the technical growth of the dairy industry and development of dairy product markets. Because consumers rely so heavily on sensory perceptions when purchasing products, evaluation and grading of dairy products is important if processors intend to satisfy consumer desires. As early as the 1920s, Kelly and others (1929) touted the benefits of milk and cream contests by stating, "The dairyman who furnishes a product of high quality is rewarded by recognition of his service, and the dairyman of less careful habits is spurred to greater endeavor. In extreme cases those who insist on producing an inferior product are eliminated, for consumers are more discriminating when they become better informed about milk qualities."

The scorecard used in the early twentieth century, developed by the US Department of Agriculture (USDA) and approved by the American Dairy Science Association (ADSA), included consideration of bacteria, flavor and odor, sediment, temperature, acidity, and the appearance of the bottle and cap or closure. A perfect score was assigned 100. A reproduction of this scorecard, minus the scoring directions, is included in Fig. 4.1. Today, industry compliance with Grade "A" standards, defined in the USPHS/FDA *Grade "A" Pasteurized Milk Ordinance* (USFDA, 2019), essentially eliminates the need for scorecard evaluation of bacteria, sediment, temperature, and acidity. Milk quality evaluation focuses on flavor attributes. Examples of contemporary scorecards that are used to evaluate dairy products and the attributes associated with those products are included in Chaps. 5, 6, 7, 8, 9 and 10.

The beginning of the twentieth century marked the establishment of brands and trade names for dairy products, particularly butter and cheese. This development necessitated a set of quality standards recognized by manufacturers, and the subsequent need for the grading of finished products by experienced, competent, and consistent judges. Officially assigned USDA product grades, attached to many private labels, enjoy prominent significance when seen on butter, cheese, and nonfat dry milk.

While dairy products can be analyzed for chemical composition, microorganisms, vitamin content, enzymatic activity, color, physical properties, etc., these determinations do not measure the true or actual eating quality or sensory perceptions realized by consumers. Establishing the so-called eating quality of a dairy product requires the application and “correct” interpretation of such sensations as mouthfeel, taste, and aroma. The alert consumer experiences components of flavor (taste, aroma, and mouthfeel) when the product is taken into the mouth. While two samples of butter may have identical basic chemical composition, color, firmness, and spreadability, one sample may be highly relished by consumers, while the other product may leave a poor impression due to characteristics of flavor not observable by routine chemical tests. Thus, grading and scorecard judging have a critical role in the dairy industry. Although the essential parameters that constitute the eating quality of dairy products cannot be easily measured chemically or physically, they can be determined using sensory evaluation techniques, such as those used by competent judges or trained panelists (Bodyfelt, 1981; Bodyfelt et al., 1988).

Milk producers, who are partners with dairy product manufacturers in establishing a demand for uniform-quality dairy products, recognize that *dairy products cannot be of higher quality than the raw material from which they are made* (Bodyfelt, 1980, 1983; Bodyfelt et al., 1988). Without definite knowledge as to what constitutes desirable appearance, flavor, body, and texture attributes in finished products, the successful production of high-quality raw material can be challenging. Knowledge about origins of certain off-flavors and various desirable flavors plus specific methods to minimize or eliminate objectionable off-flavors should enable the production of milk (Gamroth & Bodyfelt, 1980) and milk products suitable for inclusion in high-quality finished products, which should ultimately influence dairy product sales. The increased sales of dairy products depend upon the production and distribution of high-quality foods that impart a delicate and balanced, pleasant flavor sensation to consumers’ palates.

The contests described in this chapter all have one goal in common: to promote excellence in dairy manufacturing. The scorecards used in the Collegiate Dairy Products Evaluation Contest have been developed and fine-tuned by hundreds of academic and industry experts over a period of 100 years. Although designed for six different dairy products (detailed in Chaps. 5, 6, 7, 8, 9 and 10), the commonality among the scorecards is their ability to communicate deviation from a standard or ideal product concept. Students properly trained for the Collegiate Dairy Products Evaluation Contest gain skills to enter the dairy industry while possessing the tools not only to evaluate product quality but also to remedy deviations from standard quality parameters.

It is important to stress that scorecard judging involves assessment compared to a standard or ideal product concept. A product sample that is assigned the highest score in the Collegiate Dairy Products Evaluation Contest cannot be guaranteed to attain the greatest sales in the market. For instance, light-oxidized milk has become quite common in the marketplace because of the convenience, product visibility, and cost savings of high-density polyethylene (HDPE) milk containers. Most of the clear or transparent plastic milk containers used in the marketplace (with the exception of H. P. Hood’s LightBlock® and some other examples of light-protective containers) permit transmission of ultraviolet light through the packaging material, thus initiating both light oxidation and vitamin degradation. Light contributes to partial loss of vitamins A, riboflavin (B_2), C, D, and some amino acids (Bradley Jr. 1980; Bradley et al., 2006). With the passage of time, a majority of US consumers have thus become accustomed to this particular milk flavor, and they do not generally consider this as a flavor defect. Compared to an assigned score of "10" for ideal milk, a declared light-oxidized milk receives a score of "6" or lower in the Collegiate Dairy Products Evaluation Contest. Nonetheless, more US consumers drink packaged milk from translucent HDPE containers (that presumably have some degree of light oxidation) than any other packaged form of milk in the marketplace.

Surprisingly and unfortunately, some cheese judges, upon the mere detection of a sulfide note in a medium-aged Cheddar cheese, downgrade the sample, since it tends to possibly deviate from the expected mild nutty character. However, many consumers would actually select a sulfide-containing cheese over another cheese devoid of such character. This is where a "balance of reason" needs to occur; once a given Cheddar cheese achieves a certain point of maturity (e.g., aging), it is generally expected to exhibit some degree of "flavor complexity," compared to a mild cheese. Medium-aged Cheddar's expected flavor intensity typically includes flavor notes such as nutty-like, modest acidity, diacetyl and other carbonyls, and hopefully a hint or more of a sulfur-like aroma in the end.

The American Cheese Society Judging and Competition and other dairy product contests combine technical and aesthetic judging to determine award-winning products. As will be described later, technical judges subtract points for defects, while aesthetic judges add points for features that may help sell the product. While scorecard judging in the Collegiate Dairy Products Evaluation Contest involves only the use of numerical scores, the evaluation forms used in other dairy product competitions contain spaces for feedback in addition to numerical scores. The American Cheese Society Judging and Competition and other dairy product contests are designed to recognize excellence and encourage processors to improve.

Ultimately, consumers are the judges, not necessarily of dairy product quality, but of what they like, and they make their final judgment when they exchange money for a product. Nevertheless, recognition of superior quality from some contests is sometimes noted on the product label or other promotional material and may permit the manufacturer to eventually achieve a higher price for a product. On the other hand, some state- and regional-based contests prohibit the use of any contest or product evaluation "results" or "winnings" within any form of packaging, promotions, advertising of any form (e.g., the Oregon Dairy Industries Association).

4.3 The Collegiate Dairy Products Evaluation Contests

In 1916, the first National Collegiate Dairy Products Evaluation Contest was held in Springfield, MA. That year, butter was the only product evaluated because of its commercial importance at that time. Milk and Cheddar cheese were added to the

1917 competition, and vanilla ice cream, cottage cheese, and strawberry yogurt gained inclusion in 1926, 1962, and 1977, respectively.

Since 1916, over 95 Collegiate Dairy Products Evaluation Contests have been held throughout the USA and Canada (contests were not held in 1918, during WWII, 1942–1946, or 2020–2021). Although the number of team competitors is limited by official rules, many schools train more students than can officially participate in the competition each year. Thus, while over 3000 students have participated since the inception of the contest, many times that number have undertaken and received this valuable dairy product evaluation training. The record year for greatest college participation in the contest was in 1956, when 33 colleges and universities entered student teams. During the nearly 100 national contests conducted, over 65 different schools have participated (Table 4.1), with an average of 18 schools per contest. In

Table 4.1 Teams that have participated in the Collegiate Dairy Products Evaluation Contest, between 1916 and 2022

Aims Community College	Iowa State U.	Oregon State U.
Alabama A & M U.	Kansas State U.	Pennsylvania State U.
U. of Alberta (Canada)	U. of Kentucky	Purdue U.
Alfred U.	Laval (Canada)	Quebec (Canada)
U. of Arizona	Louisiana State U.	U. of Rhode Island
U. of Arkansas	U. of Manitoba (Canada)	Rutgers U.
Auburn U.	U. of Maryland	San Francisco Univ. at Quito (Ecuador)
Brigham Young U.	U. of Massachusetts	South Dakota State U.
U. of California (Davis)	Michigan State U.	Southern Illinois U.
U. of California (Fresno)	Middle Tennessee State U.	U. of Tennessee (Knoxville)
California Polytechnic State U.	U. of Minnesota	Tennessee State U.
Clemson U.	U. of Missouri	Texas A & M U.
College of the Sequoias	Modesto Junior College	Tuskegee U.
Colorado State U.	Moraine Park Tech. Institute	Utah State U.
U. of Connecticut	Nanjing U. (China)	U. of Vermont
Cornell U.	U. of Nebraska	Virginia Tech
U. of Delaware	U. of New Hampshire	Virginia State U.
U. of Florida	U. of New Mexico	Washington State U.
Florida State U.	North Carolina State U.	U. of West Virginia
The French National Dairy College (France)	North Carolina Agri. & Tech. State U.	U. of Wisconsin (River Falls)
U. of Georgia	Northwest Missouri State U.	U. of Wisconsin (Madison)
U. of Guelph (Canada)	The Ohio State U.	U. of Wyoming
U. of Idaho	Oklahoma State U.	
U. of Illinois	U. of Orange Free State (South Africa)	

addition to the cooperation of college and university faculty and students, 125–150 dairy industry companies participate in and support the contest each year by donating, transporting, and storing dairy product samples; providing employees as official contest judges, proctors, and scorers; and donating the required supplies and space. This contest requires a great deal of planning, organizing, coordination, staffing, appropriate facilities, and product samples preparation.

Throughout the years, some regions of the country have held and conducted regional (eastern, western, southern, and midwestern) contests prior to the National Collegiate Dairy Products Evaluation Contest. Of these regional contests, only the Midwest Regional Contest survives. The Midwest Regional Collegiate Dairy Products Evaluation Contest is typically held 1 or 2 weeks before the national contest.

For decades, the National Collegiate Dairy Products Evaluation Contest took place in the fall. Since 2017, the contest has been held in the spring, alternating between Milwaukee and Madison, WI. College students judge the quality of dairy products in six product categories: butter, Cheddar cheese, cottage cheese, vanilla ice cream, milk, and strawberry Swiss-style yogurt. Originally raw whole milk was evaluated, then pasteurized whole milk, and now 2% fat pasteurized milk is evaluated, based upon its dominance in the marketplace. For cottage cheese and yogurt, the fat contents of the products have evolved from only their full-fat versions to include a range of low, reduced, and full-fat versions in the contest. Yogurt also allows with natural and/or high-intensity sweeteners, as well as Greek-style yogurt.

According to the official rules of the contest, "Any undergraduate student of a land-grant, state or provincial agricultural college or a college of corresponding rank who: (a) is regularly matriculated in a program leading to a Bachelor of Science degree or its equivalent; (b) has never competed in the Collegiate Dairy Products Evaluation Contest as a contestant or alternate; (c) has never acted as an official judge of dairy products; and (d) has not taught the manufacturing of or the judging of dairy and other food products, is eligible to compete in the contest." Three students from any one college or university constitute a team. Students from credit-transferable 2-year agricultural colleges are also eligible, provided they meet the criteria in (b), (c), and (d). One or two additional undergraduate or graduate students from a school may compete if they meet the criteria, but compete for individual, not team, awards. Additionally, on occasion, study-abroad students participating in collegiate dairy products judging training have been allowed to compete in the contest representing their international institutions.

The first butter judging contest was sponsored by the National Dairy Association. Between 1930 and 2005, the major sponsor of the Collegiate Dairy Products Evaluation (CDPE) Contest was either the Dairy and Food Industry Suppliers Association (DFISA) or the International Association of Food Industry Suppliers (IAFIS) Foundation. Beginning in the 1980s, the IAFIS Foundation became the only association to financially sponsor the contest teams, by providing a generous stipend to each team to offset travel expenses for student competitors. Since the turn of the twenty-first century, however, awards have been provided to top individuals and top placing colleges and university teams, by numerous industry donors, including but not limited to Agrana Fruit US, Inc.; Cheese Market News; Chr. Hansen, Inc.; Dairy Foods; Danone Wave; Edlong; FairLife LLC; Idaho Milk Products; Nelson Jameson; Pecan Deluxe; Tate & Lyle; United States Department of Agriculture; Wisconsin Cheesemakers Association; and Wisconsin Dairy Products Association.

In 2015, the CDPE Contest Board of Directors was established to conduct the business of ensuring sustainability of the CDPE Contest. Formerly, governance was regulated by a standing committee of the American Dairy Science Association. The CDPE Contest Board of Directors guides "strategic development, [is] responsible for the overall public image of the contests or events and strive[s] to enhance working relationships between educational institutions and dairy industries and industry professionals." The CDPE Contest Board of Directors is composed of no more than 15 members, who serve for 3-year terms and with a limit of two consecutive terms. Members include four coaches, five judges, and four industry representatives. The contest superintendent is an ex officio member. Financial management is overseen by the National Dairy Shrine Executive Director.

The CDPE Contest Coaches Committee is responsible for the contest rules and overall policy for conducting the contest. The Coaches Committee develops and revises the official scorecards for the contest. The committee is also responsible for any modifications to the scoring guides.

Prior to 2018, upon completion of each session of the contest, contestant scorecards were turned over to the contest superintendent, who worked with industry volunteers to enter the scorecard results into the official electronic reader. Specially printed, "scanner-ready" scorecards were used, in which contestants filled in drawn "bubbles" to indicate their assigned numerical scores and selection of flavor, body and texture, and color/appearance characteristics per each product sample judged per category. Each scorecard was scanned, and a computer using software written specifically for the contest captured each contestant entry. Now, software has been designed that enables tablet usage. The program effectively computes both individual and team results according to the official contest rules and generates a ranking of individuals and teams from the lowest composite score to the highest. A team of contest officials carefully verifies scores and checks for potential ties and ascertains that the scoring software has broken the possible ties according to the official rules. Individual scores, along with team scores, are returned to each competing team at the conclusion of the awards ceremony.

Since the early days of the contest, the USDA Agricultural Marketing Service (AMS) has typically supplied the superintendent of the contest. The contest superintendent is responsible for organizing the official judges, making arrangements for on-site sample storage and distribution, maintaining current mailing lists for officials and universities, and mailing the scoring guides and team forms to the various possible participating schools, tabulating scorecards, and developing and delivering results for the annual awards program.

The Collegiate Dairy Products Evaluation Contest is typically a 2- or 3-day commitment. Day 1 generally involves travel to the contest site by teams and the Coaches Committee meeting. Day 2 is the day of the contest and awards announcements.

Day 3 may include attending the WCMA Cheese Conference and/or travel home. Contest sites have included the headquarters complex of large national or regional dairy processors (Land-O-Lakes, Publix, Safeway, and H.E.B. Grocery) and dairy convention or meeting sites ranging from Lakeland, FL, to San Francisco, CA, in the USA, to Montreal (1975 and 1989) and Toronto (1998) in Canada. The contest has been held in conjunction with the World Wide Food Expo (1979–2005) or the Pack/Process Expo (2006) in Chicago, IL. Currently, the contest is held in conjunction with WCMA's alternating between WCMA's Milwaukee Cheese Expo (even years) and WCMA's Madison Cheese Con (odd years). The contests and student teams are supported largely by the WCMA, the USDA AMS, and dozens of other donor companies and individuals.

Team coaches must be aware of some important rules before even entering a team into the national or a regional contest. Rules and entry forms are sent to institutions at least 1 month prior to the contest, and entries are due to the contest superintendent not later than 3 weeks before the contest. Eligible institutions may enter as few as one student to as many as seven students. No more than seven students per school are allowed to participate in the contest (i.e., a maximum of three undergraduates, two graduates, and two alternates).

Coaches and students must be informed of the rules. For instance, contestants are only allowed to take a cheese/butter trier and sheath, fanny pack, cup (if desired), clipboard, and black lead # 2 pencils into the contest. Students are not allowed to identify or reflect their respective school affiliations in any way, nor are they allowed to carry bottled water or palate cleansers into the contest. Furthermore, contestants are not allowed to use or apply strong aromatic perfume, cologne, shaving lotion, etc., which could readily interfere with the sensory evaluation of the products. Additionally, the use of cellular phones, paging, and/or internet devices, including PDAs, is strictly prohibited.

The Coaches Committee meeting is held on the day before the contest, in order to disseminate and discuss information related to the current-year contest procedure. Additionally, future contest sites and potential changes to contest rules or scorecards are discussed. The Coaches Committee meeting is attended by contest officials, university team coaches, and official judges. Contest officials, board members, contest superintendent, and proctors may also participate. Official and associate judges are selected by the contest superintendent from one or more commercial dairy enterprises or other impartial (i.e., government) entities.

Head judges of each category contact potential donors for products to be evaluated by student contestants. Products (at least eight different products for each of the six categories) are donated by commercial dairy processors. The processors do not receive awards for high scoring entries, as that is not the intention of the competition, and scores on products are not typically shared with the donors. Some lead judges share official product scores with donors after they have been coded for privacy – the given donor would only ascertain their code to see how their product(s) scored. Identities of other products remain secret. The products are stored under appropriate refrigeration or frozen conditions at one or more dairy processing facilities local to the contest site.

The Collegiate Dairy Products Evaluation Contest is a carefully coordinated event. Official judges of the contest are established industry experts in the product category. Some regional judges also participate in the national contest. However, it is required that judges may not judge the same category in the regional and national contests. All six products are evaluated by at least two, but generally three, judges per product: a head judge and one to two judges. Official judges initially rate each product set without input from coach judges and/or coach observers (described later). Official judges typically evaluate 10–12 different products per category so that the most representative or the most interesting may be selected for the contest. The official judging occurs 1 day prior to the student contest.

On the day of the contest, “coach judges” and “coach observers” arrive early (i.e., 6:45 or 7 am) at the contest site to review the official judges’ evaluations. Coach judges and coach observers are university team coaches. Coach judges and official judges evaluate the products along with the official judges, consult with one another, and meet consensus about product attribute and scores on all eight product samples entered into a given product category. The coach judges (typically ~3 for each contest product) and coach observers (typically 1 for each contest product) are invited to evaluate the set of products. If there is disagreement about either a product attribute or score, the all products judge or contest superintendent is called to serve as a referee. If the particular disagreement cannot be rectified, the lead official product judge will then replace the sample(s) in question by another sample(s) for which there is agreement. The additional responsibilities of the all products judge are to examine all products set out for the contest, noting whether (a) the products selected fairly represent the different sections of the country; (b) the set of samples constitute a good, representative class for student judging; and (c) the products are appropriately judged.

Official scorecards are filled out for each of the six product sets and signed by official judges and coach judges. These six official scorecards are entered into the computer system as the official scores against which all students’ product evaluations are compared and scored (graded). While coach judges can be considered as calibrators of the official judges, coach observers may be considered as apprentices. Coach observers are individuals who may have little experience at the contest; hence, they basically observe the “official scoring” process, in preparation for future contests when they most likely will serve as coach judges.

Meanwhile, student teams meet in assembly with the contest superintendent; contestants and alternates are assigned a contestant number and a group number, are reminded of the contest rules, and are informed of any pertinent or limiting venue, location, or site circumstances. The contestants are divided into six approximately equal groups (since there are six contest products) and informed of the progression of judging by assigned group. Contestants are given iPads, with unique identifiers, to record judgments electronically.

At about 8:00 a.m., contestants are ushered into the contest arena, group by group. Contestants are directed to be seated in chairs that are arranged in general proximity to the tables that contain the contest products. Individual products per category are arranged in sets of eight, within six distinct areas or regions in the contest arena. Contestants are not allowed to commence judging until directed to do so.

For contestants, there is no preset judging order, and the order of judging cannot be predicted, since the product sample display tables and freezer cabinet(s) are set up based upon convenience and/or efficiency, as the contest site may change annually. Ice cream cabinets must be near outlets, while temperature-sensitive yogurt, milk, and cottage cheese are set up in close proximity to refrigerated units hidden behind curtains or walls. Since butter and Cheddar cheese samples are not replenished during the contest, these products can be placed at any non-utilized location within the contest arena. Additionally, student contestants are randomly assigned to groups and are allowed no preference for a starting (or ending) product.

Contestants are allowed 35 min for scoring each product category. Each contestant criticizes, scores, and follows the marking instructions on the computer scorecard in the proper places. A 10-min notice or warning is given prior to the close of each given scoring period. After completion of the judging of each product category, students are directed to return to pre-arranged seats. Students are allotted 2 min to check entries or fill in omitted scores. After the designated time interval has elapsed, students are directed to rotate clockwise to the next product. A 5-min rest period is allowed between the judging of each product. Strictly enforced is the rule that no communication among any contestants is to occur during the contest or the 5-min rest periods. The process continues as described until all six sets of eight samples have been evaluated by all groups of contestants.

All products in each product category selected for evaluation in the competition are labeled clearly with consecutive numbers (1–8). Any markings on the containers that might indicate quality or brand identity are either removed or otherwise blocked from view of contestants and observers.

In the case of milk, for each judging period, fresh 2% milk samples are set out at a temperature of 10 °C (50 °F) at the time of scoring. A new set of milk samples is used for each of the six rotating teams of contestants. Milk is evaluated only for "flavor."

The official ice cream lead judge assures that the ice cream is tempered properly for dipping prior to the start of competition. The generally advised temperature (optimum) range for sampling ice cream is −18 to −15 °C [0–5 °F] (Bodyfelt et al., 1988), but it can be a logistical challenge to maintain this temperature throughout the competition. A more practical, feasible, or likely upper limit for ice cream sampling is <−13.3–12.2 °C (≤8–10 °F). In spite of the best efforts of the official judges, precise temperature maintenance of the frozen samples within the aforementioned ranges across the duration of the contest can be a struggle. The ice cream samples must be scooped by individual contestants, who are expected to not leave the scoop in the ice cream after sampling.

Butter and Cheddar cheese are generally provided as 40-pound blocks (Fig. 4.2). Samples are tempered to 7.2–13.2 °C (45–55 °F) immediately preceding the contest. Butter is evaluated only for "flavor." Butter blocks are sectioned off into 1/sixth partitions to enable every set of students to evaluate the same product without opening a new (and potentially different) block of butter. For each contestant group, a

Fig. 4.2 Student contestants evaluate butter quality in a Collegiate Dairy Products Evaluation Contest

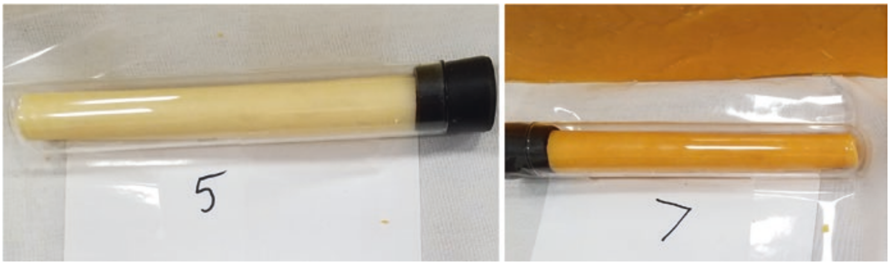

Fig. 4.3 Extracted cheese plugs on display for student contestants in Collegiate Dairy Products Evaluation Contest

fresh or "undisturbed" 1/sixth portion of the butter is revealed for contestant evaluation.

Cheddar cheese is evaluated for "flavor" and "body and texture." For observation by students, a representative plug is drawn from each Cheddar cheese sample in the contest and placed into a clean test tube, sealed, and securely taped in place beside each corresponding cheese sample (Fig. 4.3). This display plug is used for grading sample appearance and must not be disturbed or manipulated in any way during the contest. For Cheddar cheese, the blocks are halved horizontally, and parchment paper is placed between. The cheeses are partitioned so that contestants can only draw plugs from one-quarter of the visible cheese surface area. For each contestant group, a fresh quadrant of the Cheddar cheese is revealed for evaluation. Four sets of contestants draw plugs from the upper half of the Cheddar cheese block prior to the cheese being inverted to the other side (bottom four quadrants) for sampling by the remaining groups.

Cottage cheese samples are of the small curd type. Samples for visual "appearance" evaluation are carefully placed on platters with the aid of spoons, while sample portions for "body and texture" and "flavor" observations are placed in bowls. The appearance samples are not to be handled by anyone during the contest. The appearance samples need to be judged within the first 10 min, after which time the plates are removed from the contest display area. A time warning is announced after the elapse of the first 8 min. Official judges assure that the appearance display is consistent among individual samples of a given sample number displayed across the six time periods. By saving portions of such defects as matted curd, free cream, and/or free whey for placement on observation plates, the official judges thus guarantee fairness among the contestants by maintaining uniformity of "color and appearance" displays.

The official judges of strawberry-flavored, Swiss-style yogurts provide three replicates of each sample in their original commercial containers. Replicates #2 and #3 are covered with foil or a blank carton. Replicate #1 is inverted onto a plate for observation (Fig. 4.4). The contestants are instructed not to disturb the display sample on the plate. These samples are to be judged in the first 10 min of the 35 min

Fig. 4.4 Student contestants are allowed 10 min to evaluate the appearance and color of eight strawberry Swiss-style yogurt samples prior to removal of the cups and plates from the display table. Cups with spoons in them remain for the entire 35 min period

judging period, after which they are removed from the contest area. A warning is given after an 8 min elapse. Replicate #2 contains a spoon(s) for removal of samples by the contestants. Samples for flavor and texture evaluation should be removed by students without disturbing or contaminating the remainder of the cup. Replicate #3 is to be left undisturbed and is used to judge only for the attributes “free whey” and/or “shrunken.” These samples must be judged within the first 10 min, after which they are removed from the contest area. A time warning is given after the elapse of 8 min.

Sometimes, simultaneously with the collegiate contest, coaches may participate in a pre-arranged coaches clinic. These clinics enable coaches to focus on a specific product (e.g., ice cream) and “recalibrate” their product-judging approaches for the designated product. An expert judge (generally a lead judge) in a given product category leads this flavor assessment session, explains definitions used within the industry, and provides suggestions for training students to detect and identify particular attributes. Lively discussion and idea interchange are generally generated because all coaches have unique insights into training and degrees of standardization on descriptors, intensity, and scoring strategies.

With the use of tablets, scoring occurs simultaneously with the contest. A contestant’s score for each sample is given a grade expressed by the difference between his/her score, except as indicated below, and the official score. In essence, the competitor’s objective is to earn zero points or no deviation from the official scorecard. For example, if a contestant scores “flavor” as 7 and the judges’ score is 5, the contestant receives a grade of 2 points. If, however, a contestant recognizes that the sample scores perfect but fails to indicate that score on his/her scorecard, he/she shall receive a grade equivalent to the maximum points cut for that sample. For example, the normal range of score on “body and texture” of cottage cheese is 1–5, so the maximum cut is 5 points. The contestant’s grade, therefore, shall be 5 when she/he fails to indicate the numerical score for that given item. This particular rule holds, regardless of the official score.

The grading of attributes assessment is independent of the grading of product scores and is based on the contestant’s proficiency in recognizing the same quality merits and defects of the various samples as noted by the official judges. Each attribute indicated by the contestant will be involved in the grading. The contestant’s grade on attributes for a single item is scored electronically. Details of the process are beyond the scope of this chapter.

In this contest a “grade” means “points lost”; the contestant with the lowest grade is declared the winner of the product evaluation. Each contestant’s grade on a given sample is the sum of his/her grades on “score” and “attributes” of that sample. His/her grade on a product accordingly is the sum of his/her grades on the eight samples of that product. Student contestants are then ranked. A team grade for each product is thus the sum of the ranks of its three respective members. The team with the lowest sum of ranks is declared the winning team for the product evaluation. For example, a team with team members ranking first, third, and 34th (sum 40) in butter will

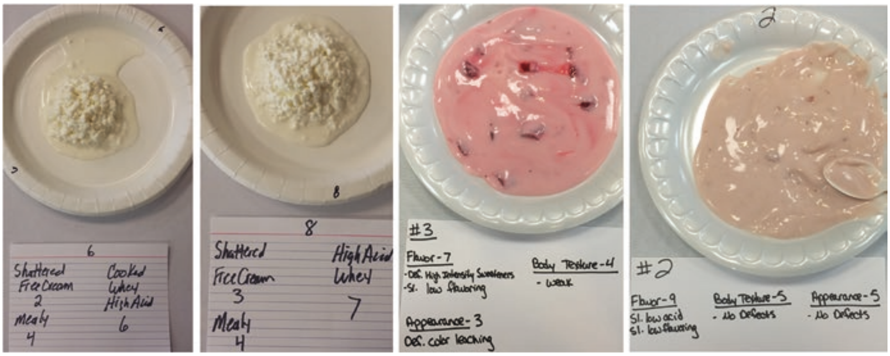

Fig. 4.5 At the conclusion of the contest, official scores and explanations are placed near corresponding entries (all 48 products)

place UNDER a team with team members ranking second, sixth, and 7th (sum 15) because the sum is lower (stronger overall team).

Upon completion of the contest, product official judges display the official scores and respective product criticisms (via a display card) for each of the eight samples per product category in the contest (Fig. 4.5). All coaches and contestants are invited to observe the official scores and product critical evaluations. The official judges stand by at this time to help both the coaches and the contestants understand why the particular decisions were made by the official judging team per each product category and to help convey how to better recognize and score attributes.

At the closing of the event, an awards ceremony is held, where student contestants and coaches are recognized for excellence in the sensory evaluation of dairy products. Among the undergraduate competitors, the top 10 individuals for each product and top 10 overall teams are recognized. To help build suspense within the awards program, the place winners are announced tenth place through first place. Also, special awards and recognition are given to the top three individuals and top three teams per each product category; the top 10 individual and team winners in the all products category are also singled out for recognition. The top performing graduate student in each product category and best overall performing graduate student for all products are also recognized.

In addition, one undergraduate student is recognized each year with the Joe Larson Merit Award. This award acknowledges the student who "best upholds the ideals of the Contest: potential leadership, professionalism, mature behavior, and an understanding of the importance of the sensory techniques applied to dairy products." Along with a plaque, the winning student receives a $500 award, funded by a generous donation from the late Joe Larson, founder and president of the Sparta Brush Company and a long-time, strong supporter of the contest.

4.4 Midwest Regional Collegiate Dairy Products Evaluation Contest

The Midwest Regional Collegiate Dairy Products Evaluation Contest was initiated in the mid-1950s, in conjunction with the International Dairy and Livestock Show. Contest logistics were managed by the Chicago Dairy Technology Society. After the International Dairy Exposition was terminated as part of the livestock show, the Chicago Dairy Technology Society assumed full sponsorship of this contest.

The Midwest Regional Contest is the sole survivor of a number of other regional contests that were organized to provide additional training and competition opportunities for students and teams' preparatory to the annual national contest. Because all the other regional contests have ceased operation, the Midwest contest is no longer strictly regional and attracts teams and contestants from across the USA; however, international teams are not permitted in this regional event. The number of participating teams fluctuates from 6 to 12 each year and averages approximately 8.

The rules of the Midwest contest are identical to the National Collegiate Dairy Products Evaluation Contest except that contestants are not limited to a singular lifetime participation. Contest official judges are recruited from industry and public health associations with extensive experience in the products they judge. The all products judge may be from industry or academia, provided that the judge is not from an institution fielding a team in the contest. Judges are responsible for choosing products used in this contest from commercial sources and only modify or "adulterate" products as permitted by the National Collegiate Dairy Product Evaluation Contest rules.

The contest is traditionally scheduled to precede the national contest by 2 weeks. The Midwest contest was hosted for many years by the Kraft Research Center in Glenview, IL. Along with the physical facilities, Kraft Foods (now Kraft-Heinz) provided products, judges, a free continental breakfast for all workers, as well as a free lunch for all contestants and work volunteers. A post-competition tour of Kraft research facilities was also offered as a part of the Midwestern contest experience. From 2017 to 2019, Continental Dairy Facilities, LLC, MI, hosted the Midwest Regional Collegiate Dairy Products Evaluation Contest, along with a post-competition tour.

The top four individuals in each product and in all products receive certificates of achievement, and the top All Products individual is awarded a trophy. The top teams in each product category earn additional recognition, with a special plaque awarded to the top All Products team. Awards are also made to top performing graduate students, who compete as individuals. All prizes are sponsored/provided by industry sponsors.

4.5 American Cheese Society Judging and Competition

The American Cheese Society (ACS) Judging and Competition recognizes the craftsmanship of artisanal and specialty cheese making (ACS, 2022). The goals of the ACS competition are to (1) recognize quality cheese making and (2) to encourage better cheese making. The coordinators of the contest stress that promoting good cheese making is the goal.

For four decades, the ACS Judging and Competition was conducted in conjunction with the ACS Annual Conference. But by 2019, the contest had grown so large (120 categories and over 2000 entries) that the logistics of holding the Judging and Competition at different locations every year had become unwieldy. In 2022 and ongoing, the ACS Judging and Competition will be conducted in advance of the ACS annual conference, in Minnesota.

Blind-coded entries are judged by pairs of one technical and one aesthetic judge (Fig. 4.6), with each pair scoring each individual entry, based on a cumulative point system. The judges are selected from the academic, dairy industry, dairy science, cultures manufacturing, food retailing, food distributing, food press communities, etc. While the technical judge subtracts 0.5–1 point from a perfect score of 50 for each technical defect (depending on severity), the aesthetic judge adds single points, up to 50 points, for aesthetic qualities and values. For instance, a fresh goat cheese producer may lose points for "musty" and "unbalanced" (technical) off-flavors but may gain points for the appearance of "vivid fresh flowers" on the surface of the cheese. Technical judges' scorecards begin with 3 points for aroma, 25 points for flavor, 15 points for body and texture, and 7 points for appearance and numbers decrease based on defects. Aesthetic judges must award a minimum of 1 and up to 3 points for aroma, minimum of 22 and up to 30 points for flavor, minimum of 3 and up to 7 points for body and texture, and minimum of 5 and up to 10 points for

Fig. 4.6 Pairs of technical and aesthetic judges evaluate entire categories of dairy products. (S. Clark images)

AMERICAN CHEESE SOCIETY	2016 Judging & Competition	Technical Score Sheet

Category B (Soft-Ripened Cheeses)

Entry Code	00	xx	00	Judge's Signature

THE TECHNICAL JUDGE WILL DEDUCT POINTS FOR DEFECTS IN CHEESE QUALITY *

AROMA	3 points maximum	Score

ammoniated _____ animal or barnyard _____ atypical _____ chemical aroma _____ fruity/fermented _____
moldy or musty _____ rancid _____ unclean _____ unpleasantly earthy _____ yeasty _____
other (list): ______________________________

FLAVOR	25 points maximum	Score

too acidic _____ atypical _____ bitter _____ fermented _____ feed _____
flat/lacks characteristic flavor _____ fruity _____ metallic _____ lacks freshness _____ lacks salt _____
old milk _____ rancid/lipase _____ too salty _____ unclean _____ whey taint _____ yeasty _____
other (list): ______________________________

TEXTURE AND BODY	15 points maximum	Score

crumbly (atypical) _____ curdy (atypical) _____ gassy _____ mealy (atypical) _____ open _____
pasty _____ pin holes _____ short _____ spreadability (atypical) _____ weak _____ woody/tough _____
grainy/sandy _____ gummy _____ lacks creaminess _____
other (list): ______________________________

APPEARANCE/RIND DEVELOPMENT	7 points maximum	Score

cracked or disturbed rind _____ excessive rind _____ greasy rind _____ rind rot _____
crooked or lopsided _____ free whey/wet _____ immature mold _____ surface mold _____
uneven mold distribution _____ dull color _____ uneven color _____ seamy _____ slipped rind _____
rough surface _____ excess fines (fresh curds category) _____ *PACKAGING* ** _____
other (list): ______________________________

ADDITIONAL COMMENTS

** DEFECT POINT REDUCTION: SLIGHT = 0.5, DEFINITE = 1, PRONOUNCED = 1.5*
*** PACKAGING POINT REDUCTION: 7 POINTS*
Scoring ranges: 1st 93 to 100; 2nd 86 to 92; 3rd 80 to 85 **SUM OF SCORES**

Fig. 4.7 Technical Judge Scoresheet for 2016 ACS Cheese Competition

appearance. This is based on the assumption that every entry must have some basic level of achievement to reach at least the minimum score. Scorecards, previously on paper (Figs. 4.7 and 4.8) and now (since 2022) computerized (Fig. 4.9), are organized with boxes for noting defects or attributes in products, with space left for additional comments, which are required. Comments are meant to help processors improve product quality.

AMERICAN CHEESE SOCIETY | **2016 Judging & Competition** | **Aesthetic Score Sheet**

Category M (Farmstead Cheeses)

Entry Code 0 0 x x 0 0 **Judge's Signature**

THE AESTHETIC JUDGE WILL ADD POINTS FOR DESIRABLE QUALITIES FOUND IN THIS CHEESE*

AROMA Points: **1** minimum **3** maximum **Score**

fresh cream _____ pleasantly fruity _____ nutty _____ sweet _____ earthy _____ herbal _____
floral/fresh flowers _____ buttery _____ toasted/caramel _____
other comments: ______________________________

FLAVOR Points: **22** minimum **30** maximum **Score**

butter/cream/milk flavors _____ sweet/nutty _____ nice salt content _____ meaty/brothy _____
tangy finish _____ well balanced flavor _____ Nice piquant note _____ toasted/caramel _____
grassy/herbal _____ earthy _____ long finish _____
other comments: ______________________________

new or noteworthy flavor profile (explain):

TEXTURE AND BODY Points: **3** minimum **7** maximum **Score**

smooth/creamy texture _____ nice mouthfeel _____ evenly moist _____ evenly firm _____
evenly smooth paste _____ good openness _____ good crumbliness _____ nice dense paste _____
even distribution of crystals _____
other comments: ______________________________

APPEARANCE/RIND DEVELOPMENT Points: **5** minimum **10** maximum **Score**

nice rind appearance _____ rustic appearance _____ nice color _____ nice shape and size _____
artisan appeal _____ Appealing ash or cloth coating _____
other comments: ______________________________

ADDITIONAL COMMENTS

** POINT VALUES FOR DESIRABLE QUALITIES: DESIRABLE +1, MORE DESIRABLE +2 to +3 DESIRABLE AND UNIQUE + 4 OR MORE*

Scoring ranges: **1st** 93 to 100; **2nd** 86 to 92; **3rd** 80 to 85 **SUM OF SCORES**

Fig. 4.8 Aesthetic Judge Scoresheet for 2016 ACS Cheese Competition

Another key distinction from other dairy products competitions is the fact that all entries are blind-coded to minimize potential for bias. Shipping materials with codes that blind-code the producer and specify the subcategory are sent to entrants for product labeling (Fig. 4.10). Points are subtracted from products revealing identity.

Fig. 4.9 ACS J & C Scorecards are now computerized for efficiency. (S. Clark image)

A great deal of coordination is involved in the successful administration of the ACS Judging and Competition. A committee composed of volunteers and an ACS staff liaison makes up the ACS Judging and Competition Committee, which works all year to review and update rules, ensure appropriate category names and descriptions, review and recategorize entries, select and invite judges, train judges, receive products, oversee the event, announce and distribute awards, etc.

All entries are received by ACS Judging and Competition Committee members and additional volunteers in a 2-day window. Although products initially arrive with identifying information on the external box, once opened, blind-coded products are revealed (Fig. 4.11a). The products are temperature checked, inventoried against the entry information supplied by the producer, and sorted to separate products from their identifying external boxes (Fig. 4.11b). Blind-coded products are categorized by subcategory, placed on speed racks (Fig. 4.12), and taken to designated refrigerated trucks (i.e., smoked cheeses are placed in a single truck), where they are sorted by category and size. Products are removed from the trucks according to a schedule (based upon when they are to be judged) to ensure proper tempering prior to judging. Volunteer stewards take speed racks of tempered products to judges, who evaluate flights, at their own pace, until the entire category is evaluated.

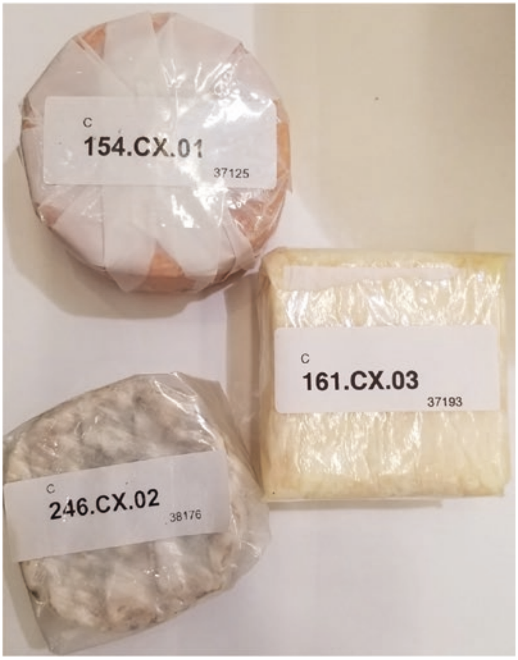

Fig. 4.10 Entries in the ACS competition are blind-coded based on company (in the example below, 154, 161, and 246), on category (i.e., C) and subcategory (i.e., X), and numbered entry for the given company (first entry by company 154, third entry by company 161 and second entry by company 246). Now, with the computerized system, simply the category letters and a 4-digit code track the product throughout the process

A B

Fig. 4.11 Once opened, blind-coded products (**a**) are temperature-checked, inventoried, and sorted to separate products from their identifying external boxes (**b**)

Fig. 4.12 Blind-coded products are categorized by subcategory, placed on speed racks, and taken to refrigerated trucks

Fig. 4.13 Cheeses are staged in preparation for the Best of Show Finalist round in the ACS Judging and Competition

Awards in the ACS Judging and Competition are only earned by the top-scoring products in each class, if the minimum score is attained. In fact, the quality of American products has improved since the inception of the ACS Judging and Competition, such that products must now attain a minimum of 85 points to earn the third place award, a minimum of 90 to earn the second place award, and a minimum of 95 points to earn the first place award. Only the three highest-scoring products receive awards. However, for tie scores, multiple awards can be given. All first place products become eligible for the best of show rounds of judging (Fig. 4.13). The three top-ranking products in the entire ACS Judging and Competition are awarded best of show and runners-up awards.

4.6 The US and World Dairy Product Contests

Hosted by the nonprofit Wisconsin Cheesemakers Association (WCMA), the World Championship Cheese Contest is a technical evaluation of cheese and butter, by class. Since its inception in 1957, the contest (conducted on even-number years) has grown rapidly and is now the largest international cheese, butter, yogurt, and dairy ingredients competition in the world (WCMA, 2022b). The 34th biennial contest, held in 2022, had 141 classes. Entrants may send products in their original packaging, with or without labels; labels are not considered in the evaluation.

Products must be received at the shipping destination by an early spring deadline; judging takes place later in the spring; and awards are presented at the Cheese Industry Conference in April. Judges of the World Championship Cheese Contest are trained experts in cheese evaluation. Approximately 40 US and international cheese experts evaluate products in teams of two. Starting with a maximum possible 100 points, each entry is examined for defects. Deductions are taken for each defect. Defects are noted in the areas of flavor, body and texture, salt, color, finish, packaging, and other possible appropriate attributes. Deductions are made in 0.1-point increments. Thus, each entry is judged on its own merits against what the judge considers perfection for that product. The judging teams work silently and the score from each judge is averaged with his/her partner to determine the final score for each entry. Gold, silver, and bronze medal winners are decided based on the highest average scores in each class. Each entrant in the World Championship Cheese Contest benefits from this professional evaluation. Official score sheets, marked and signed by the judges, are returned to each entrant.

The Gold medal cheeses from appropriate cheese classes are judged a second time to determine a World Champion Cheese. The entire panel of judges participates and the cheese that earns the highest average score is named “World Champion.” The next two highest scores are awarded first and second runner-up. This competition is open to public viewing and typically gains national media exposure within the USA. Previous contest medal winners have built marketing campaigns around their success in this highly competitive contest.

Gold medals and monetary awards are presented to the best of class winners. Silver and bronze medals are awarded to second- and third-place entries. The World Champion cheese maker currently earns a cash award of US $1000. All winners are honored at a gala awards banquet during the International Cheese Technology Exposition.

Since 1981, on alternate years (odd number), the US Championship Cheese Contest is conducted by the WCMA (2022a). The 2023 contest, boasting 118 entry classes, is the 21st biennial contest. It is run almost the same way as the World Championship Cheese Contest.

4.7 World Dairy Expo Championship Dairy Product Contest

Sponsored by the Wisconsin Dairy Products Association (WDPA, 2022), the World Dairy Expo Championship Dairy Product Contest welcomes entries into over 90 dairy product categories. Products range from fluid milk to powder, yogurt to drinkable yogurt, sour cream to dips, and butter to ice cream. An additional class is called "Open Class for Creative & Innovative Products." Some entry examples include smoothies, probiotic products, dairy-based beverages and desserts, novelty cheese products, sports drinks, frappuccinos, calcium-fortified products, cheesecakes, cajeta, etc. All entries must conform to their respective standards of identity and contain a minimum of 25% dairy. Over 1500 products were entered in 2022 (WDPA, 2022). Entry fees support scholarships for students preparing for careers in the dairy industry, culinary arts scholarships, and the National Collegiate Dairy Products Evaluation Contest.

4.8 Conclusion

The contests described in this chapter all have one goal in common: they are designed to promote excellence in dairy manufacturing. The primary objective of the Collegiate Dairy Products Evaluation Contest is to train students in the fundamentals of the sensory evaluation of dairy products in order to prepare them for careers that promote a focus on high quality dairy products. Dairy products contests are designed to recognize workmanship. These contests publicize their excellence to the consuming public. Because consumers rely so heavily on sensory perceptions when purchasing products, there will always be a place for sensory evaluation and grading of dairy products if producers intend to satisfy consumer desires. Knowledge about the relative importance and origins of certain off-flavors and various desirable flavors, plus specific methods to minimize or eliminate objectionable off-flavors, should enable the production of milk (Gamroth & Bodyfelt, 1980) and milk products suitable for inclusion in high-quality finished products, which should ultimately influence dairy product sales.

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Chapter 5
Fluid Milk Products

Valente B. Alvarez

5.1 Introduction

Milk is a nutritious food because it provides essential nutrients, including but not limited to high-quality proteins, minerals such as calcium and phosphate, and vitamins A, D, B_6, and B_{12} and niacin. High-quality milk has an almost neutral flavor profile that is pleasantly sweet with no distinct aftertaste. The flavor is imparted by the natural components such as proteins, fat, salts, milk sugar (lactose), and possibly small amounts of other milk components**.** Whole milk has at least 3.25% milkfat, reduced fat milk 2%, low-fat milk 1%, and skim <0.5%. Fluid milk composition and flavor variations have been attributed to types of feed, seasonal variation, breed, milk handling, storage conditions, processing, and packaging. Therefore, the sensory evaluation of milk, in both the bulk and packaged forms, is of utmost importance to the market (fluid or beverage) milk industry.

The per capita fluid milk sale in the USA was about 63.95 L in 2019 (USDA, 2021). Since fluid milk is consumed regularly by people of all ages and most ethnic groups, this product is constantly being assessed for quality by consumers. If the flavor of milk is not appealing or appetizing, less of it will be consumed. Furthermore, off-flavored milk may cast an unfavorable reflection on other dairy products that are sold or distributed under the same brand name and thus unfavorably affect sales of those products as well.

The sensory characteristics of any dairy product are most dependent on the quality attributes of the milk ingredient(s) used to produce them. An important truism of the dairy industry is that "finished milk products can be no better than the ingredients from which they are made." The quality and freshness of the various milk and

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cream components is most critical to product sales. Most flavor defects of finished dairy products could be substantially minimized, or perhaps eliminated, if all dairy manufacturers would more critically assess the essential quality parameters of all ingredients, especially the milk-based ones.

The differentiation of milk into different quality classes (known as grading) demands keener, more fully developed senses of smell and taste than does the sensory evaluation of other dairy products. Many of the off-flavors present in fluid milk are more delicate, less volatile, or otherwise more elusive than those typically encountered in other dairy foods.

Since milk (or cream) is the basic material from which all dairy products are made, it behooves milk producers, dairy processors, distributors, and other personnel involved with dairy products to be aware of how various flavor defects of milk affect the quality of manufactured products. Processing personnel should have the ability to detect off-flavors in milk and be able to assess or project the impact of these on the flavor quality of finished dairy products.

5.2 Milk Properties and Handling

Physical Properties Two physical phenomena are primarily responsible for the visual appearance of milk. First, milk is a protein-stabilized emulsion of fat in a continuous aqueous phase. Secondly, milk is a suspension of insoluble colloidal mineral particles. The scattering (refraction) of light by the insoluble colloidal minerals, protein, and fat particles are mainly responsible for the opaqueness and white color of milk (Deeth, 1986). By contrast, cream contains more fat globules with associated carotene content; thus, yellowish-like light is scattered, lending a creamy-yellow hue to cream products.

Chemical Properties Fresh milk is composed of water, fat, protein, lactose, and minor mineral components. The lactose, at an average concentration of 4.8%, imparts a mild sweet taste to milk (Kiesner et al., 2005). Milkfat is responsible for the "rich" mouthfeel of full-fat milk in comparison to skim milk. However, overall milk flavor is a complex sensation that is one of the most important attributes for acceptability and preference by consumers. Thus, milk flavor and quality are commonly conducted by human sensory evaluation (Wolf et al., 2013).

Microbiological Properties Milk is typically sterile upon secretion within the secretory glands and is presumably first contaminated with bacteria within the teat canal (Vangroenweghe et al., 2001; Vissers & Driehuis, 2009). Milk handling on the farm results in further contamination and growth of spoilage organisms. Sources of microbiological contamination on the farm include equipment used for automated milking, milk handling lines, and refrigerated bulk milk storage tanks (Hutchinson et al., 2005; Polyanskii et al., 2005; Vissers & Driehuis, 2009). Psychrophilic bacteria (i.e., the genus *Pseudomonas* sp.) are primarily responsible for spoilage or deterioration of milk prior to pasteurization (Poltronieri, 2017). Other bacteria that negatively affect milk quality include lactic acid bacteria, which are indigenous to dairy environments. A study assessing the bacterial quality of milk used in three different fluid milk-processing plants reported that the average raw milk bacterial counts were below the regulatory limit of 300,000 CFU/mL before pasteurization and usually ranged between 12,000 and 60,000 CFU/mL. The bacterial count of processed milk samples did not differ significantly among plants on the initial testing day; however, there was a significant plant-by-day interaction throughout the study. These results indicate that some plants have greater bacterial count differences among test days than others (Fromm & Boor, 2004). The findings suggest that the processing plant as well as processing conditions, production, volume, and sanitation practices significantly influence the final microbial numbers.

Microbial spoilage of fluid milk after pasteurization has been attributed to either Gram-negative bacteria that contaminate milk post-pasteurization or some Gram-positive microorganisms that are able to survive pasteurization (Ternström et al., 1993; Touch & Deeth, 2009). The most predominant microorganisms found in processed milk from three commercial dairy plants were Gram-positive rods that made up 87% of the processed milk microflora, followed in decreasing order by Gram-positive cocci and Gram-negative rods. In the same study, the most common genera found were *Paenibacillus* (39%), *Bacillus* (32%), and *Microbacterium* (14%). The majority of Gram-positive cocci identified were *Kocuria* (5%). The Gram-negative bacteria were *Pseudomonas* (3%) and *Acinetobacter* (1%) (Fromm & Boor, 2004). A similar study found that fillers were the main source of microbial contamination during processing and the common post-pasteurization contaminants were psychrotrophic Gram-negative bacteria (Blaiotta et al., 2017; Gruetzmacher & Bradley, 1999). Milk will develop off-flavors, described as hydrolytic rancidity, fruity/fermented, unclean-like, and/or bitter, due to the growth and metabolism of various microbial contaminants if the raw milk is held too long or at temperatures >4 °C (>45 °F) prior to pasteurization (Walker, 1988; Buchrieser & Kasper, 1993; Tetra Pack, 2021).

5.3 Market Milk

5.3.1 Classes of Milk

In the USA, milk may be divided into two general classes: primarily, market milk (Grade "A") and some limited amounts of manufacturing grade milk.

Market Milk "Market" or "beverage" milk is typically consumed in the fluid form. It is processed, packaged, and retailed or distributed to the consumer, restaurant, hotel, school, or other food service institutions, where it is used for either beverage or culinary purposes. This product form reaches the consumer in the natural, fluid state, as contrasted to milk forms that may be converted into frozen dairy desserts, cheese, butter, fermented milk foods, concentrated milk, or other types of dairy products.

In the USA, market milk is currently "Grade A pasteurized" for all practical purposes. The 2019 Grade A Pasteurized Milk Ordinance (PMO) specifies requirements for the production of Grade "A" raw milk for pasteurization and regulations that pertain to pasteurization equipment and procedures, physical facilities, containers, packaging, sealing, and refrigerated storage of finished products (Fig. 5.1). The pasteurization ordinances adopted by individual states and communities may differ in some respects, and in some cases, it may be more stringent, but the 2019 PMO proscribes that only Grade A pasteurized milk and milk products be sold to consumers, restaurants, food service operators, grocery stores, or similar establishments.

Market milk is used primarily for consumption as whole milk or may be separated by centrifugation and then standardized to produce reduced fat milk (2% milkfat), low-fat milk (1% milkfat), skim milk (<0.5% milkfat, light cream (18–30% milkfat), whipping cream (30–36% milkfat), and/or half-and-half (10.5–18% milkfat). Some of the aforementioned products may be flavored or fermented. This class of milk may be grouped or further categorized with respect to the particular heat treatment to which the milk is subjected in processing, namely, as pasteurized (HTST or Vat), ultra-pasteurized (UP), or ultra-high-temperature processed (UHT).

Manufacturing Grade Milk "Manufacturing grade milk" is basically any milk intended for processing into dairy products other than market (fluid or beverage) milk. Such milk may not fully comply with the specific sanitation and production

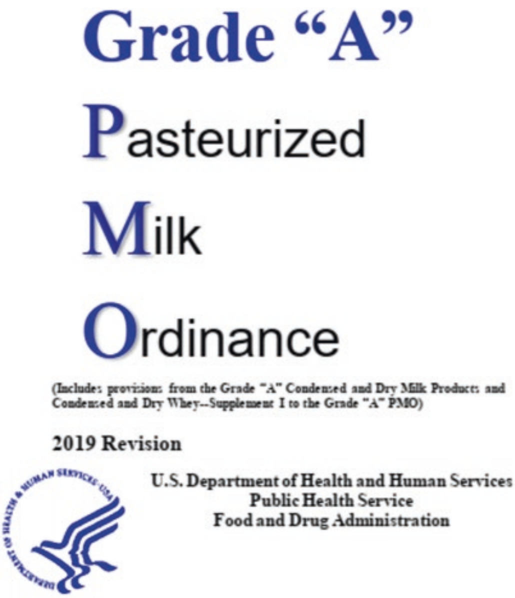

Grade "A"
Pasteurized
Milk
Ordinance
(Includes provisions from the Grade "A" Condensed and Dry Milk Products and Condensed and Dry Whey--Supplement I to the Grade "A" PMO)
2019 Revision
U.S. Department of Health and Human Services
Public Health Service
Food and Drug Administration

Fig. 5.1 The USPHS/FDA Grade A Pasteurized Milk Ordinance (PMO) 2019 recommendations (with appropriate revisions) serve as an important model code for most states and fluid milk and cream products in interstate commerce facilities' standards established for producing Grade A raw milk. Recommended requirements for manufacturing grade milk have been issued by the US Department of Agriculture, Consumer and Marketing Service, under the title "Milk for Manufacturing Purposes and Its Production and Processing," 2019. Currently, most of the raw milk produced in North America meets Grade A requirements and products, such as fluid milk, cottage cheese, yogurt, must meet the Grade A standards.

Classes of Utilization The US federal government, through the Agricultural Marketing Service of the Department of Agriculture, has issued specifications for milk classes of utilization. These are intended to stabilize market conditions, benefit producers, and consumers by establishing and maintaining orderly marketing conditions and to always assure consumers of adequate supplies of pure and wholesome milk.

The classes of utilization are intended to determine a minimum price for each usage category of milk. Milk used in fluid products (i.e., Grade "A" milk) for direct consumption is placed in Class I, the highest priced class. The price of milk is lower, in descending order, for Classes II, III, and IV (i.e., manufacturing milk). A brief description of each class is as follows:

Class I milk is processed into fluid milk products, i.e., Grade "A" pasteurized, ultra-pasteurized, or UHT milk.

Class II milk is processed into fluid milk products in containers larger than 1 gallon, including fluid cream products, cottage cheese products, milkshake and low-fat ice cream mixes (or bases), frozen dairy desserts, frozen dairy dessert mixes distributed in half-gallon containers or larger, whipped cream, sour cream products, yogurt, custards, puddings, pancake mixes, bakery product coatings, batters, and similar products, plus buttermilk used for baking, formulas for infant feeding or dietary use, candy and soup production, bakery products, and sweetened condensed milk.

Class III milk is used to produce cream cheese and other spreadable cheeses; hard cheese and shredded, grated, or crumbled cheese; plastic cream; anhydrous milkfat; and butteroil.

Class IV milk is used to produce butter, evaporated or sweetened condensed milk in a consumer-type package, and any milk products manufactured in a dried form.

5.3.2 Grades of Market Milk

Since the 1980s, health officials and dairy processors have recognized the practicality and economic reality of a "single grade" of milk for human consumption. This single grade is particularly true for market milk. The 2019 PMO refers to the Code of Federal Regulations (CFR), Title 21, Section 131.110, for the following legal definition of milk:

> Milk is the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more cows. Milk that is in final package form for beverage use shall have been pasteurized or ultra-pasteurized and shall contain not less than 8.25% milk solids-not-fat and not less than 3.25% milkfat. Milk may have been adjusted by separating part of the milkfat there from or by adding thereto cream, concentrated milk, dry whole milk, skim milk, concentrated skim milk, or nonfat dry milk. Milk may be homogenized.

The various whole milk products that may require sensory evaluation include those listed below.

5.3.3 Raw Milk

Grade A "Grade A raw milk for pasteurization" is that milk which conforms to the latest regulations and the highest standards established by the US Public Health Service, Pasteurized Milk Ordinance 2019. Grade A milk may also be produced under a given state's regulations, which usually conform closely to the federal standards, but may be slightly more rigorous for certain criteria.

5.3.4 Pasteurized Milk

Grade A Pasteurized Milk This is Grade A raw milk which has been pasteurized in accordance with the regulations of the US Public Health Service Pasteurized Milk Ordinance and Code. Such milk must meet all the regulations, pasteurization confirmation tests, and sanitary requirements for this grade.

5.4 Kinds of Market Milk and Associated Quality Characteristics

Whole Milk "Whole milk" or simply "milk" may be pasteurized, ultra-pasteurized, or commercially sterilized (UHT). Pasteurized milk is milk that has been subjected to pasteurization temperatures for a prescribed period of time in equipment that complies with the requirements of the PMO. With respect to times and temperatures of pasteurization, the 2019 PMO states:

> Every particle of milk or milk product is heated in properly designed and operated equipment to one of the temperatures specified in the following table and held continuously at or above that temperature for at least the time specified:

Temperature (°C)	(Temperature, °F)	Time
63	145	30 min

Temperature (°C)	(Temperature, °F)	Time
72	161	15 s
89	191	1 s
90	201	0.5 s
94	204	0.05 s
100	212	0.01 s

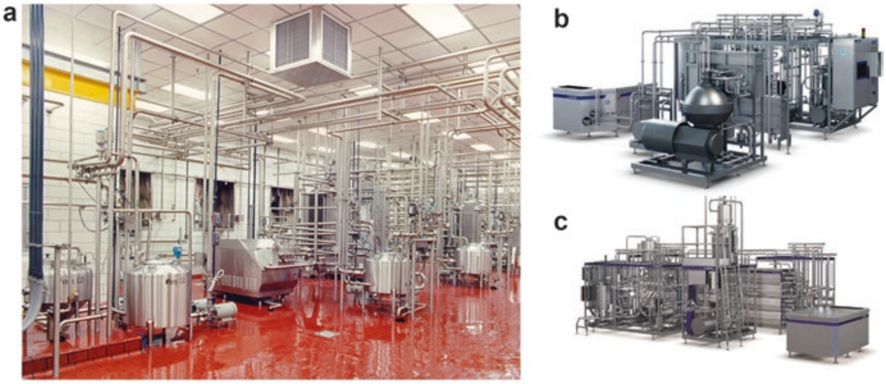
*If the milkfat content is 10% or more, or if it contains added sweeteners, the specified temperature shall be increased by 3 °C (5 °F), provided that eggnog shall be heated to at least the following temperature and time combinations:

Temperature (°C)	(Temperature, °F)	Time
69	155	30 min
80	175	25 s
83	180	15 s

When a minimum 30 min holding time is required, the pasteurization process is known as the "batch," "vat," or "holding" method; with holding times less than this, but greater than 1 s, the process is termed "high temperature-short time pasteurization" (HTST); and with holding times of 1 s or less, the designation is "higher heat-short time pasteurization" (HHST). Ultra-pasteurization requires heating to 138 °C (280 °F) for at least 2 s, either before or after product packaging. The term "ultra-high temperature" (UHT) designates a process for "commercially sterilizing" milk at a temperature of about 149 °C (300 °F) or higher, with a holding time of a few seconds. The sterile product is then aseptically packaged in sterile containers. The equipment used for milk pasteurization or sterilization (Henderson, 1971; Jones & Harper, 1976; Tetra Pak, 2021) varies widely in design and is very complex (Fig. 5.2).

Most modern plants use plate heat exchangers, tubular heaters, or other forms of heat exchangers, as vat pasteurization is considered inefficient by comparison (Tetra Pack, 2021). Most commonly, heating is achieved by an indirect approach through heated metal surfaces, but there are processing units that heat by directly introducing steam into the product. A vacuum chamber subsequently removes the equivalent amount of water added to the milk due to the condensed steam (Tetra Pack, 2021).

Pasteurized Milk This product commonly possesses some degree of either a so-called heated or cooked flavor, especially immediately after processing, but the intensity of the cooked flavor diminishes during storage (Badings et al., 1981; Boelrijk et al., 2003; Drake et al., 2008; Sliwkowski & Swaisgood, 1980; Swaisgood, 1980). The initial flavor intensity depends on the temperature and holding time employed as well as the method of heating. The factors that may influence milk flavor include (1) heating-up and cooling time, (2) temperature difference between the product and the heating medium, (3) velocity of the product in a continuous system, (4) occurrence of product "burn-on" of heat exchanger surfaces, and (5) direct versus indirect heating methods.



Courtesy of Seiberling Associates, Inc. Courtesy of Tetra Pak®

Fig. 5.2 (**a**, **b**, **c**) Examples of typical pasteurization systems for fluid milk products. (**a**): A modern US HTST centralized pasteurization room. (**b**) Tetra Pak® Pasteurizer (**c**) Tetra Pak® Indirect UHT-DE

UHT and Commercially Sterile Milk The 2019 PMO describes commercially sterile and UHT milk as well as aseptically packaged milk. From a microbiological standpoint, a "sterile" label implies the absolute absence of all microorganisms (both pathogenic and spoilage types) in milk products. Commercially sterile milk products can be successfully stored without need for refrigeration for an extended time (up to 9 months). By contrast, the label "ultra-pasteurized" connotes extended shelf life under refrigerated conditions. Depending on the method of sterilization or heat treatment, commercially sterile and UHT products are generally expected to exhibit varying intensities of cooked flavor. (Hansen, 1987). If intense, this flavor defect may be variously described as scorched, scalded, burnt, or caramel. However, with the advent of improved and better engineered sterilization systems, only the more subtle cooked, sulfide-like flavor predominates in high-quality UHT milk. During storage, the intensity of the cooked flavor gradually diminishes, so that under the most favorable circumstances, a sterilized product may taste like pasteurized milk. The discovery that addition of the enzyme sulfhydryl oxidase (Swaisgood, 1980) can reduce the cooked flavor in commercially sterilized milk may have significant future implications for UHT-processed milk. It has been suggested that a commercial process could be developed for treating heat-processed milk with an immobilized form of sulfhydryl oxidase. In one experiment and subsequent flavor panels, the enzyme-treated UHT milk could not be distinguished from pasteurized milk (Sliwkowski & Swaisgood, 1980). A sensory evaluation study demonstrated that UHT milk was less sensitive to LOF than pasteurized milk due to possible masking or the antioxidant effects of volatile sulfur compounds (Harwood et al., 2020). During prolonged storage, particularly when not refrigerated, various storage flavors may be encountered, which result from lactose and protein interaction, protein and/or fat degradation, and staling.

Other means of minimizing sulfide flavors in UHT milk by addition of natural plant components have been described by Josephson and Inventor (1989) and Sederstrom and Peterson (2005) and Molina et al. (2009). None of the preceding methods of reducing cooked flavor in UHT milk have been commercialized.

ESL Milk Extended shelf life refers to the use of processing and packaging technologies to increase the shelf life of milk and food products beyond the pasteurization level. ESL technologies may include UHT or UP, microfiltration, bacterial removal, and aseptic packaging, among others. These alternative preservation strategies extend the shelf life of milk by 30 or even 90 days but also cause important modifications to the sensory quality of milk (Deeth, 2017). ESL technologies open up new opportunities for marketing and shipping of milk to distant places where milk production may be limited or not available. This is the case in the USA where the production of milk in California is consumed in Hawaii or the shipped milk produced in Ohio is consumed in Nevada. At the international level, similar situations can also be found, such as in the case of Asian markets importing milk from Australia and New Zealand (Deeth, 2017; Sepulveda et al., 2005)).

Practically all milk marketed in the USA is both pasteurized and homogenized. "Homogenized" is defined in the 2019 PMO as follows:

> The term "homogenized" means that milk or the milk product has been treated to insure breakup of the fat globules to such an extent that, after 48 hours of quiescent storage at 7 °C (45 °F), no visible cream separation occurs on the milk; and the fat percentage of the top 100 milliliters of milk in a quart, or of proportionate volumes in containers of other sizes, does not differ by more than 10% from the fat percentage of the remaining milk as determined after thorough mixing.

As pointed out previously, the definition of milk in Title 21 of the CFR ends with the simple statement, "Milk may be homogenized." Homogenized milk does not differ in composition or any other provision of the definition from unhomogenized milk, except for being homogenized. However, there are some differences between the two products in their susceptibility to development of certain off-flavors (Richardson et al., 1993; Schiano et al., 2017); for this reason, we shall examine them separately.

Unhomogenized Milk Since pasteurization standards represent the minimal time and temperature requirements, milk is frequently heated in excess of the minimum. However, it is less likely that unhomogenized milk would be heated much above the minimum requirements because the cream line, which is the unique characteristic of this product, is progressively reduced in volume by increasing the intensity of the heat treatment. Therefore, it is also less likely that non-homogenized product will ever exhibit a "pronounced cooked" flavor. Immediately after pasteurization, milk may manifest a distinct "slight cooked" flavor if minimal pasteurization process is applied. Processing at higher heat/time commercial pasteurization may result in "definite cooked" to conceivably "pronounced cooked (scorched)" flavor. During storage, the "cooked" flavor diminishes in intensity and may entirely disappear, especially if significant levels of divalent cations are present in the milk (often derived from water sources or equipment surfaces), as pointed out by Gould (1940) or that it dissipates after several weeks when is replaced by a stale off-flavor note (Gandy et al., 2008; Zabbia et al., 2012). Later studies reported that oxidation of milkfat leads to the development of undesirable flavors in non-homogenized milk. The decrease in milkfat oxidation, after homogenization, is due to antioxidant properties of sulfhydryl compounds formed during heat treatment of milk (Molina et al., 2009; Shipe et al., 1978; Smith & Dunkley, 1962).

Research by Dunkley (1968) supported the tendency of milk flavor changes for non-homogenized milk across storage time. Similar observations and measurements were noted earlier and published originally by Trout (1945, 1950) and subsequently by others (Dunkley et al., 1962a, b; Parks, 1965; Simon & Hansen, 2001; Wishner, 1964). The "redistribution" of protective components of the fat globule membrane via homogenization serves as a "protectant" against the oxidation process. The extent of the oxidative flavor deterioration depends on the storage time, season of the year, the type of roughage fed to cows, and the relative levels of cupric, ferric, and other divalent cations present in raw milk (Hedegaard et al., 2006; Parks, 1965; Shipe, 1964; Tracy et al., 1933).

Unhomogenized milk is particularly susceptible to the cardboard-like or oxidized off-flavor that results from the oxidation of lipids. Oxidation is usually greater in the winter months and/or when pasture or green feeds are not available. Maximum annual fat contents occur in November and December; minimum fat contents occur in August (Goff & Hill, 1992; Hedegaard et al., 2006). Therefore, the presence of antioxidants from pasture, green feeds, and haylage in the spring through mid-fall seasons is important. Antioxidants are practically nonexistent in dried feeds and especially low in alfalfa hay (winter feeding); thus, the susceptibility to milk oxidation is more a function of presence/absence of natural antioxidants in green or greenish feeds than the relative change levels of unsaturated fatty acids due to milkfat composition with season.

Milk flavor results mainly from proteins, lipids, and carbohydrates, which are the precursors of aroma compounds. Milk flavor can deteriorate depending on the way it is handled, processed, and stored (Molina et al., 2009; Nursten, 1997; Strobel et al., 1953). Oxidation (auto-oxidative), and hydrolytic rancidity (lipolytic) reactions are common in milk flavor development. Oxidation of milkfat produces the development of undesirable flavors in non-homogenized milk. Oxidation reactions result from interactions between reactive species of oxygen and lipids. Triplet oxygen and singlet oxygen have been identified as main compounds involved in oxidative changes of milk (Campbell & Drake, 2013; Min & Boff, 2002) Singlet oxygen is the electron-rich reactive species of oxygen formed in the presence of light-induced photosensitizers, such as riboflavin in milk, which absorbs energy from light and transfers it to triplet oxygen to form singlet oxygen. The formation rate of oxidative changes in milk via singlet oxygen is much greater than that of triplet oxygen. Additionally, singlet oxygen oxidation end products differ from those formed by triplet oxygen. Triplet oxygen is diradical and is considered the most stable form of oxygen. This molecule can readily react with other radicals commonly found in foods. Light, heat, presence of metals, enzymes, and chemical oxidants catalyze the formation of radicals in milk. The reaction between triplet oxygen and radicals gives rise to the formation of hydroperoxides. Upon cleavage of the hydroxyl group, flavorless peroxy radicals are formed (Campbell & Drake, 2013). Previous work reported that subsequent cleavage and molecular rearrangement of these compounds lead to the formation of hydrocarbons, alcohols, acids, aldehydes, and ketones responsible for oxidized flavors in milk. Oxidized, cardboard, metallic, tallowy, oil, and fishy flavors were identified as the flavors produced by lipid oxidation reactions (Molina et al., 2009; Shipe et al., 1978; Thomas, 1981).

There are two types of rancid flavor that result from lipolytic activity of microorganisms; "sickening" flavor that results from mixing raw and homogenized milk, churning, intense agitation, or temperature fluctuation during processing; and "unclean" flavor that is produced from foaming residues or by spontaneous lipolysis (Shipe et al., 1978). The rancid (soapy-like) off-flavor that is encountered in raw milk, due to the hydrolysis of triglycerides, should not develop in properly pasteurized milk because lipase is inactivated by pasteurization temperatures. If a lipolytic defect is noted, either this off-flavor was present (1) before the milk was pasteurized, (2) homogenized milk was diverted back to the raw milk HTST balance tank where lipase within the raw milk hydrolyzed the unprotected milkfat of the homogenized product, (3) the milk was contaminated post-pasteurization with bacteria that possess lipase activity, or (4) processed milk contains thermoduric psychrophilic bacteria and spore-forming bacteria. These microorganisms release lipases in milk and are responsible for producing undesirable changes in milk as they survive pasteurization conditions. These enzymes are extremely heat resistant and are responsible for limiting the shelf life of pasteurized milk (Fromm & Boor, 2004; Shipe et al., 1978; Touch & Deeth, 2009). Additionally, psychrotrophic Gram-negative microorganisms are responsible for post-pasteurization contamination of milk. Among these microorganisms, *Pseudomonas fluorescens* has been identified as major contributor of milk spoilage.

Homogenized Milk There are several properties and flavor characteristics of homogenized milk that differentiate it from unhomogenized milk. First, since there is little or no concern about a cream line in homogenized milk, higher processing temperatures may be employed at the option of the manufacturer, resulting in a higher incidence and/or greater intensity of the cooked flavor (Bodyfelt et al., 1988; Lewis & Deeth, 2009). This flavor change occurs not only in ultra-pasteurized or extended shelf-life (ESL) milk and sterilized milk (or cream products), but frequently with pasteurized milk products as well. Homogenization of raw milk creates fat surface area that is susceptible to lipase, which is naturally present and active in milk, particularly at warm temperatures. Hydrolytic rancidity off-flavors will develop if pasteurization does not follow immediately (Deeth, 1986; Fitz-Gerald, 1974). Such milk exhibits distinct hydrolytic rancidity (a strong and objectionable off-flavor [rancid], which is often foul smelling with an associated bitter taste) within a few hours of processing and becomes quite bitter and soapy within 24 h. Homogenization disrupts the fat globule membrane "coating" that serves to protect lipids from the hydrolytic activity of lipase (present in the aqueous portion of milk and cream). Halloran and Trout (1932) showed that all cows' milk is subject to the development of rancidity upon homogenization, unless adequately heat-treated to inactivate the indigenous lipase. The subsequent structure changes of milkfat globules related to industrial homogenization processes were later investigated and reported (Argov et al., 2008). Doan (1933) found that the critical temperature for inhibiting rancidity development in homogenized milk by flash heating was ~63.9 °C (~147 °F). Other studies reported that milk lipase is partially inactivated at pasteurization conditions 72 °C (161 °F), thus higher temperatures 88 °C (190 °F) are required to completely inactivate the enzyme (Chandan & Shahani, 1964; Tetra Pack, 2021). Furthermore, it must be emphasized that raw milk must never be mixed with homogenized milk while processing, or a rancid off-flavor (via the hydrolysis of di- and triglycerides) is almost certain to occur. The presence of a rancid off-flavor in homogenized milk is an indication that either (1) all the milk ingredients were not adequately heat-treated or (2) rancidity existed within the milk prior to the pasteurization process.

Homogenized milk is distinctly less susceptible to the development of metal-induced, cardboardy, or oxidized off-flavor than non-homogenized milk. This lower susceptibility was first noted in studies by Tracy et al. (1933) and later substantiated by other researchers (Cervato et al., 1999; Park & Drake, 2017; Tong et al., 2000)). If homogenized milk products are properly pasteurized, properly refrigerated, and not unduly exposed to light, the pleasant, rich flavor should remain fixed and stable for a considerable time. This period of flavor stability is in excess of that within which non-homogenized, pasteurized milk might be expected to exhibit some degree of flavor deterioration.

Homogenized milk is more susceptible to the development of the light-activated or light-induced off-flavor (sometimes also referred to as "sunshine flavor") when exposed to light, than unhomogenized milk, as initially pointed out by Hood and White (1934). This off-flavor has a burnt-protein (or burnt-feathers) character and should not be confused with the cardboardy taste and puckery mouthfeel sensation of the generic oxidized flavor. Whited et al. (2002) reported that off-flavor development and vitamin A degradation occur in milk after exposure to light. The authors reported that the degradation of vitamin A was proportional to the length and intensity of light exposure and inversely related to the milkfat concentration. After exposure to light, milk rapidly develops a burnt, activated sunlight flavor attributed to singlet oxygen oxidation of serum proteins and free amino acids (Min & Boff, 2002; Molina et al., 2009; Shipe et al., 1978). The most common reaction is light-induced oxidation of cysteine that produces mercaptan, sulfides, and dimethyl sulfides responsible for the light-oxidized flavor defects in milk. Additionally, methional, resulting from methionine degradation, plays an important role in light-induced flavor development. Min and Boff (2002) reported that methyl mercaptan, dimethyl disulfide, and methionine sulfoxide are by-products of light-induced methional degradation in the presence of riboflavin, protein, and oxygen. Lipid oxidation can also occur when milk is exposed to light; the flavor associated with it has been described as cabbagey, burnt, burnt protein, burnt feathers, and medicinal (Molina et al., 2009; Ogden, 1993).

Organic Milk This category of milk is processed following the guidelines for Grade A Pasteurized Milk. However, the US Department of Agriculture has four requirements to define milk as "USDA Organic": (1) cows cannot be treated with bovine growth hormone (BGH); (2) cows cannot be treated with antibiotics; (3) cow feed is grown without pesticides, whether the feed is grass or grain; and (4) cows must have access to pasture. In 2017, organic milk represented less than 1% of the total 798.5 billion liters milk market. Although organic milk can sell for up to double the cost of other milk, the demand for this milk continues to increase (KPMG, 2018). The demand for organic milk has been linked to perceived health benefits or environmental and animal rights issues. This type of milk requires that cows have pasture access and has flavors associated with feed. Also, organic milks are pasteurized or UHT to ensure ESL, so they may have the cooked flavors that are discussed in the corresponding sections of this chapter (Schultz, 2006).

Sedimentation Although sedimentation is not a prevalent issue in pasteurized fluid milk, the following discussion may be helpful as a source of information in case it may occur. In homogenized milk not subjected to sufficient centrifugal clarification, the absence of milkfat separation may prompt destabilized protein, colloidal form of soil, or any possible somatic (body) cells to readily precipitate and form a yellowish to smokey-grey layer on the bottom of the container. When the milk container is agitated slightly, or the milk is heated moderately, this deposit may clump into feathery, wooly, or oily-appearing masses that resemble soil, oil, or extraneous material in milk. A milk judge should be familiar with the possibility of sedimentation in homogenized milk as well as with its characteristic behavior upon handling. Freshly packaged homogenized milk subjected to proper refrigeration and little or no agitation generally shows no sediment formation when evaluated 6–8 h later. However, the same milk examined after the elapse of 24 h, or after some agitation, might show considerable sediment. Obviously, sedimentation is more readily noted in transparent or translucent containers.

Watery Appearance If homogenized milk is allowed to freeze and then slowly defrost, the upper portion usually appears watery due to precipitation of some of the milk solids, including milkfat (Jeremiah, 2019; von Dorp, 1996). A competent milk judge will have become familiar with the behavior of homogenized milk under some of these unfavorable conditions of environment and storage, so that "suspect" milk samples are not unduly criticized for possible water adulteration. Although not water adulterated, such an appearance should be subject to criticism because freezing milk reduces its quality.

Cream Layer, Cream Plug, or Fat Ring If homogenized milk is inadequately processed, temperature abused, agitated severely, or held for an extended time at room temperature, it may form objectionable cream layers, cream plugs, or fat rings (sometimes referred to as "spaghetti") of varied intensity. The occurrence of this appearance defect is more common in cream products than in whole or reduced fat milk.

Vitamin-Fortified Whole Milk The 2019 PMO and Title 21 of the Federal CFR do not contain a separate definition for vitamin-fortified whole milk. Vitamin addition is recognized as optional within the definition of milk, but specific provisions are given only for vitamin A (2000 IU) and vitamin D (400 IU) per quart. Safe and suitable carriers (fat solvents) for vitamins A and D are also permitted. The added vitamins themselves apparently do not impair the flavor of fortified milk, but industry experience has shown that occasionally the vitamin carriers may be suspected of introducing some degree of off-flavor. Certain preparations of vitamin A concentrate have been known to impart a detectable, objectionable off-flavor, particularly to skim milk and low-fat milk, and occasionally to whole milk products. Quality control procedures that include actual flavor trials in milk (in the manufacture of vitamin concentrates) should minimize defective batches of vitamin concentrate. A "hay-like" off-flavor, associated with the presence of added vitamin A (or carriers) in milk and subsequent exposure to light, has been reported in the literature (Schiano et al., 2017; Whited et al., 2002).

Since vitamin-fortified milk is also homogenized, it is expected to behave the same as homogenized milk with respect to flavor and other sensory characteristics. Though vitamin fortification of whole milk is optional, the practice is near-universal among US milk processors.

Low-Fat Milk The legal definition of milk is given in the US Code of Federal Regulations, 21 CFR 131.110. However, 21 CFR 101.62 deals with the labeling of low-fat products. Low-fat milk is milk from which sufficient milkfat has been removed to produce a food having, within limits of good manufacturing practice, one of the following milkfat contents: 0.5, 1, 1.5, or 2%. Low-fat milk is pasteurized or ultra-pasteurized, must contain added vitamin A (not less than 2000 IU per quart), and contains not less than 8.25% milk solids-not-fat and may be homogenized. The addition of vitamin D is optional, but if the vitamin is added, the finished product must contain 400 IU per quart.

Although low-fat milk may lack the typical richness and mouthfeel of whole milk, this is a natural consequence of a lower milkfat content and is not considered a defect per se. The product is evaluated in the same manner as whole milk and may potentially possess the same off-flavors. Thus, a perfect flavor score, if deserved, may be assigned to either a low-fat or whole milk based solely on the absence of off-flavors. Obviously, individual taste preferences may or may not be the same for whole and low-fat milk; preferences will vary with the individual.

Optional ingredients in low-fat milk include concentrated skim milk, nonfat dry milk, or other milk-derived ingredients to increase the nonfat solid content, provided that the ratio of protein to total nonfat solids of the food and the protein efficiency ratio of all protein present shall not be decreased as a result of adding such ingredients. Stabilizers and emulsifiers are also permitted in an amount of not more than 2% by weight of the solids in the optional ingredients actually used. According to the CFR, low-fat milk may be labeled "protein-fortified" if it contains not less than 10% of milk-derived nonfat solids.

When some of these optional ingredients are used, their relative freshness and quality will impact the finished product. The processing history and age of these optional ingredients may affect flavor. Long shelf-life products may develop a "stale" flavor following storage or possibly an oxidized off-flavor. A history of high-heat treatment may be responsible for cooked or caramel off-flavors. By exercising thorough quality control of the added ingredients, any significant incidence of the aforementioned problems is probably avoidable or at least minimized.

Skim Milk The legal definition of milk is given in the US Code of Federal Regulations, 21 CFR 131.110. However, 21 CFR 101.62 deals with the legal requirements for labeling milk as "skim." Skim differs from low-fat milk only in the requirement that its fat content be less than 0.5%. All provisions regarding optional ingredients are the same. Most comments relative to the flavor of low-fat milk are also applicable to skim milk. An off-flavor most commonly described as "lacks freshness," "stale," "chalky," or "storage flavor" is frequently encountered by judges in the sensory evaluation of skim milk samples. The composition of skim milk appears to favor occurrence of this off-flavor; it may partially stem from the ratio of proteins to milkfat found in skim milk. Light-induced off-flavors (LOF) in milk have been associated with the decrease in acceptability by consumers. Off-flavor compounds identified as a result of light exposure of milk include methional, mercaptan, dimethyl sulfide, disulfides, methanethiol, methionine sulfoxide, sulfur compounds, hexanal, and heptanal (Harwood et al., 2020; Schiano et al., 2017). Attempts to protect milk with light-protective packages are important current trends because light exposure of milk is unavoidable during handling, processing, packaging, and distributing (Fanelli et al., 1985; Wang et al., 2020). Sensory evaluation and identification of compounds suggested that dimethyl disulfide was mainly responsible for the light-induced off-flavor of skim milk. Dimethyl disulfide was formed by the singlet oxygen oxidation of methionine in milk (Jung et al., 1998). Heat treatments of milk such as HTST, UHT, and UP influence differently the development of LOF. Trained panelists detected LOF in HTST-processed milk but not in UP-processed milk (Harwood et al., 2020).

Concentrated Milk "Concentrated milk" is defined in 21 CFR 131.115 as the liquid food obtained by the partial removal of water from milk; the milkfat and total milk solids content must be not less than 7.5 and 25.5%, respectively. This product must be pasteurized, will generally be homogenized, and may have vitamin D added (25 IU/fluid ounce). Water is removed under partial vacuum as much as three parts of the milk may be concentrated to one part of concentrated milk. Water is added back by the consumer, and savings are realized in transportation and packaging costs, although processing costs are higher.

Frozen concentrated milk and *commercially sterile concentrated milk* are different and more complex product forms of fluid milk. They are intended for longer storage, which unfortunately provides opportunities for physical and chemical factors to influence sensory properties. Flavor is a function of the processing temperature, storage temperatures, and age of the product. On prolonged storage, the flavor may become stale, oxidized, or caramelized. Even a fresh concentrate may taste somewhat flat upon reconstitution, although the flatness sensation is generally lessened upon storage. Reconstituted concentrated milk is usually evaluated from the standpoint of utilization as a beverage or fluid milk.

Reconstituted Milk Reconstituted milk is the product resulting from either (1) recombining milkfat and nonfat dry milk or (2) dry whole milk with water in appropriate proportions, to yield the milk constituent percentages that typically occur in fluid milk. For this purpose, various forms of milkfat such as butter, anhydrous milkfat, and fresh or frozen cream and nonfat dry milk, dry milk, or concentrated milk may be used as ingredients. Any form of reconstituted milk is practically always homogenized. Even though homogenization (an integral part of the process) inhibits the development of an oxidized off-flavor in milk, an oxidized defect of slight to moderate intensity may be present in reconstituted milk with some degree of frequency. This off-flavor is generally derived from any one of several susceptible dairy ingredients prior to their reconstitution. A wealth of published literature indicates that the source of oxidized, fatty, painty flavors in reconstituted milk from whole milk powder is due to lipid oxidation (Hall et al., 1985; Hall & Anderson, 1985; Hough et al., 1992; Lloyd et al., 2009). Other types of off-flavors associated with reconstituted milk are flat, heated, cooked, and stale.

Evaporated Milk is a special type of sterile concentrated milk with its own definition in 21 CFR 131.130. Although this product can be made by a combination of UHT processing and aseptic packaging, evaporated milk is commonly sterilized in the final container at a lower temperature, but a much longer holding time. The addition of vitamin D (25 IU/fluid oz) is mandatory, and the use of emulsifiers and stabilizers is permitted. The flavor characteristics of this product are influenced by the heat treatment applied, storage temperature, and age. Off-flavors such as cooked, caramel, and stale are frequently observed. This product may display varying degrees of browning and excessive viscosity. Curdiness and fat separation are additional undesirable characteristics.

Half-and-Half and Cream Title 21 of CFR gives definitions for heavy cream (36% milkfat), light whipping cream (30% to less than 36% milkfat), light cream (18% to less than 30% milkfat), and half-and-half (10.5% to less than 18% milkfat). All of these cream-based products are either pasteurized or ultra-pasteurized and may be homogenized. Although not normally consumed as beverages, cream products are listed here since their flavor characteristics are evaluated in basically the same way as milk; they are subject to essentially the same off-flavors. Due to their higher fat content and the optional presence of stabilizers and emulsifiers, the mouthfeel of these products differs markedly from that of milk. In addition to sensory qualities, important functional properties such as whipability (Lah et al., 1980) and coffee-whitening properties should also be tested by recommended or standardized procedures (Harper, 2008; Scott et al., 2003).

Miscellaneous Products The 2019 PMO describes low-sodium milk, whole milk, low-fat milk, skim milk, lactose-reduced milk, and lactose-free milk. Other dietary products may also be encountered where permitted by local ordinances, in the form of mineral- and/or vitamin-fortified milk. This “low-sodium milk” must contain less than 10 mg of sodium per 100 ml to be so labeled. Lactose-reduced products must have sufficient lactose converted to glucose and galactose (a mixture which is sweeter than lactose) by the addition of safe and suitable enzymes to cause the remaining lactose to be less than 30% of its original concentration. Lactose-free milk can be made by different techniques like crystallization, chromatography, and membrane separation (ultrafiltration and nanofiltration) (Harju et al., 2012). Lactose-free milk is also manufactured by using lactase enzyme (β-D-galactosidase; β-D-galactoside galactohydrolase, E.C. 3.2.1.23). The enzyme is usually added after pasteurization of milk. Lactose is hydrolyzed into glucose and galactose. These carbohydrates are sweeter than lactose and are easy to digest and absorb by lactose-intolerant people (Dekker et al., 2019). Hence, some effect on flavor (taste) would be expected. The flavor properties of such products should be evaluated in a manner like milk because lactose-free milk is often ultra-pasteurized for ESL, which can impart cooked flavors.

5.5 Precautions for Evaluating Raw Milk

Raw milk has been, and continues to be, discussed for nutritional and safety reasons in epidemiological literature. Therefore, there are no common rules regarding the sale and consumption of raw milk in the USA. Among the 50 states and Puerto Rico, 24 states do not permit the sale of raw milk directly to the consumer. Twenty-seven states permit the sale of raw milk for human consumption either at the farm where produced, in retail outlets, or through cow-share agreements. The number of outbreaks traceable to non-pasteurized milk increased from 30 during 2007–2009 to 51 during 2010–2012 (Mungai et al., 2015). Consumption of raw milk has been linked to campylobacteriosis, salmonellosis, tuberculosis, brucellosis, hemorrhagic colitis, Brainerd diarrhea, Q fever, listeriosis, yersiniosis, and toxoplasmosis to name a few (Plotter, 2002; Sayler, 2009). Outbreaks associated with the consumption of raw milk occur every year. In 1995, the Center for Food Safety and Applied Nutrition and the US Food and Drug Administration published guidelines that established a list of pathogen organisms transmitted through raw milk and milk products, such as *Salmonella* spp., *Staphylococcus aureus, Campylobacter jejuni, Yersinia enterocolitica, Listeria monocytogenes, Escherichia coli* (both enterotoxic and enteropathic), *E. coli 0157:H7, Shigella* spp., *Streptococcus* spp., and Hepatitis A virus. Due to these facts, milk tasters/judges are “advised/warned” against tasting raw milk unless an appropriate “in-laboratory” pasteurization process protocol is employed.

The 2019 PMO contains the following statement: “Compilation of outbreaks of milkborne diseases by the U.S. Public Health Service, over many years, indicates that the risk of contracting disease from raw milk is approximately 50 times as great as from milk labeled 'pasteurized'." This statement implies that even though raw milk samples should not be swallowed, there is an inherent risk in tasting them. Smelling raw milk samples, rather than tasting them, is substantially less risky, especially if none of the milk comes in contact with the mouth of the person performing the sensory evaluation for possible off-odor(s).

If tasting of the given samples of milk is imperative, then small milk quantities should be "laboratory pasteurized." There is no standard procedure for performing this laboratory pasteurization. Hence, appropriate techniques need to be employed to ensure that every particle of the milk sample has been subjected to the minimum pasteurization temperature for the required time period to render it pathogen free. Some possible heating combinations are (1) 65.5 °C (150 °F) for 30 min, (2) 70 °C (158 °F) for 10 min, or (3) 74 °C (165 °F) for 2 min. The authors stress that the aforementioned temperatures are intended to be actual, correctly measured milk sample temperatures, not temperatures of the water bath or other heating media. Timing should not begin until the sample has reached the required temperature. Some agitation of "heated" milk samples is advised, since all milk particles within any portion of the sample vessel must be properly heated and covered to insure "complete pasteurization" of the milk sample(s). One approach is placement of raw milk samples into appropriate-sized test tubes (identity labeled) and insertion into plastic or metal racks for subsequent immersion into a heated water bath. The tubes must be clean and sterile so as not to impart off-flavors to the samples. There must be no milk residue on the upper portion of the test tubes, or the entire sample will not receive the required heat treatment. Sensory detection of serious off-flavors in raw milk is not affected by any of the above-listed laboratory pasteurization conditions (Bodyfelt, 1983).

5.6 The Milk Scorecard

Scoring the quality of milk by using standardized evaluation procedures, including a milk scorecard, has historically been an important function in the dairy industry. In general, a scorecard is now only used for recording flavor observations, although the importance of other quality factors that were included in the original scorecard should not be ignored. Bacterial counts, milk sample temperatures, and sediment tests can be important data provided by the laboratory; they continue to be components of the overall quality profile for a given milk product. Evaluating the container and the closure is also a valid quality criterion; they should be evaluated when appropriate or required. Flavor on the current scorecard is evaluated on a 10-point scale according to the scoring guide (Table 5.1). A 100-point scorecard similar to the original US Department of Agriculture card (which allows a bacterial maximum of 20,000 CFU/ml and a maximum temperature of 7.2 °C [45 °F]) may still be used by industry and in some clinics, competitions, and state fair judging. Other instruments for recording scores derived from sensory observations may be in use by

Table 5.1 A suggested scoring guide for sediment in processed milk

Amount of sediment[a]	Score
0	3
<0/02 mg	2
0.02–0.025 mg	1
>0.025 mg	0

[a]Stirred sample. Discs with so little sediment do not reproduce clearly enough to be illustrated (See 7 CFR 58.134)

individual organizations and companies or have been developed for specific purposes during producing, processing, or marketing milk. During production, farmers and workers need to know when off-flavors or conditions are present in milk so they can make the necessary corrections to maintain quality, which is the real purpose of all judging and scoring. An example of a milk judging scorecard is the one used in FFA (Future Farmers of America) dairy product judging contests (Fig. 5.3). Judging continues in the commercial dairy plants where milk is processed. The Collegiate Dairy Products Evaluation Contest Coaches Committee first implemented a revised scorecard for electronic grading trials in 1984 in Walnut Creek, CA (SFO), and a revised card was formally approved in 1987 for official contest usage. The scorecard presently used for the Collegiate Dairy Products Evaluation Contest was modified in 2019 (Fig. 5.4).

Familiarity with the scorecard and use of the associated scoring guide is important for the milk product judge. The scoring guide provides a standard yardstick to be applied for day-to-day quality assurance activities and making comparisons of different samples or brands of a given product.

5.7 Some Milk Scoring Techniques

Sample Preparation of Characteristic Milk Flavors The identification of the characteristic flavors of milk requires experience and training. Therefore, it may be necessary to prepare training samples to gain experience in judging milk. Some specific methods for sample preparation are found in the Appendix of this book.

Order of Examination and Scoring A scoring routine, which enables the evaluator to make efficient use of time and which enhances "concentration of thought," should be followed. Furthermore, this routine should enable the judge to make direct comparisons between different samples, with respect to the various categories listed on the scorecard. Before beginning, the name (or other identification) of the evaluator should be placed in the space provided on the scorecard. If not already indicated on the card, the numbers or identity of the samples should be placed consecutively thereon. A basic order of examination might be as listed in the following paragraphs.

Sample Score Cards
National FFA Dairy Foods Career Development Event

Form I

Name ____________________

ID Number ____________________

Chapter ____________________

State ____________________

Write scores only on the line marked for participant's score. Mark (X) in space opposite the defect noted and in proper sample column. **Do Not** write in space indicating official score, grade differences and grade on defects.

Milk Flavor Evaluation

Sample Number

		1	2	3	4	5	6	7	8	9	10	**Total Score**
No Defects	*Student Score*											
10 points	*Official Score*											
	Grade Difference											
Range 1-10	*Grade on Defects*											
	Defects											
(Defects	Acid											
Valued at 2	Bitter											
points each)	Feed											
	Flat/Watery											
	Foreign											
	Garlic/Onion											
	Malty											
	Oxidized/Metallic											
	Rancid											
	Salty											
	Unclean											
	No Defect											

California Mastitis Test (CMT)

Sample Number

		1	2	3	4	5	6	7	8	9	10	**Total Score**
8 points	***Student Score***											
	Official Score											
	Grade Difference											

Milk Sediment

Sample Number

		1	2	3	4	5	6	7	8	9	10	**Total Score**
8 points	*Student Score*											
	Official Score											
	Grade Difference											

Problem Solving **Total Score**

		Total Score
50 points	**Part 1-25 points - (Number wrong)**	
	Part II - 25 points - (Number wrong)	
	Milk Production Test - (Number wrong)	
	Score on Part I	

Fig. 5.3 Farmer's Bulletin 2259 milk judging scorecard used in FFA (Future Farmers of America) dairy products judging contests

Milk

SAMPLE 1

FLAVOR SCORE: **1 2 3 4 5 6 7 8 9 10** NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid	___ 6. Flat	___ 11. Oxidized - Light
___ 2. Bitter	___ 7. Foreign	___ 12. Oxidized - Metal
___ 3. Cooked	___ 8. Garlic / Onion	___ 13. Rancid
___ 4. Feed	___ 9. Lacks Freshness	___ 14. Salty
___ 5. Fermented / Fruity	___ 10. Malty	___ 15. Unclean

SAMPLE 2

FLAVOR SCORE: **1 2 3 4 5 6 7 8 9 10** NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid	___ 6. Flat	___ 11. Oxidized - Light
___ 2. Bitter	___ 7. Foreign	___ 12. Oxidized - Metal
___ 3. Cooked	___ 8. Garlic / Onion	___ 13. Rancid
___ 4. Feed	___ 9. Lacks Freshness	___ 14. Salty
___ 5. Fermented / Fruity	___ 10. Malty	___ 15. Unclean

SAMPLE 3

FLAVOR SCORE: **1 2 3 4 5 6 7 8 9 10** NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid	___ 6. Flat	___ 11. Oxidized - Light
___ 2. Bitter	___ 7. Foreign	___ 12. Oxidized - Metal
___ 3. Cooked	___ 8. Garlic / Onion	___ 13. Rancid
___ 4. Feed	___ 9. Lacks Freshness	___ 14. Salty
___ 5. Fermented / Fruity	___ 10. Malty	___ 15. Unclean

SAMPLE 4

FLAVOR SCORE: **1 2 3 4 5 6 7 8 9 10** NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid	___ 6. Flat	___ 11. Oxidized - Light
___ 2. Bitter	___ 7. Foreign	___ 12. Oxidized - Metal
___ 3. Cooked	___ 8. Garlic / Onion	___ 13. Rancid
___ 4. Feed	___ 9. Lacks Freshness	___ 14. Salty
___ 5. Fermented / Fruity	___ 10. Malty	___ 15. Unclean

Fig. 5.4 Milk scorecard of the National Collegiate Dairy Products Evaluation Contest

Sediment If appropriate or conducted, sediment scoring should be performed first. The kind, the amount, and the size of the sediment particles should be carefully observed and scored. In scoring sediment discs, visual examinations and scoring may be compared with standard charts or photographs of standard discs. However, a mental image of this chart or photograph should become a part of the evaluator's skill, so that continued comparisons of sediment discs with actual visual standards is not always necessary. USDA Sediment Standards are listed in 7 CFR 58.134. Sediment content charts are available from the USDA, AMS, Dairy Programs, and Dairy Standardization Branch (Figs. 5.5 and 5.6).

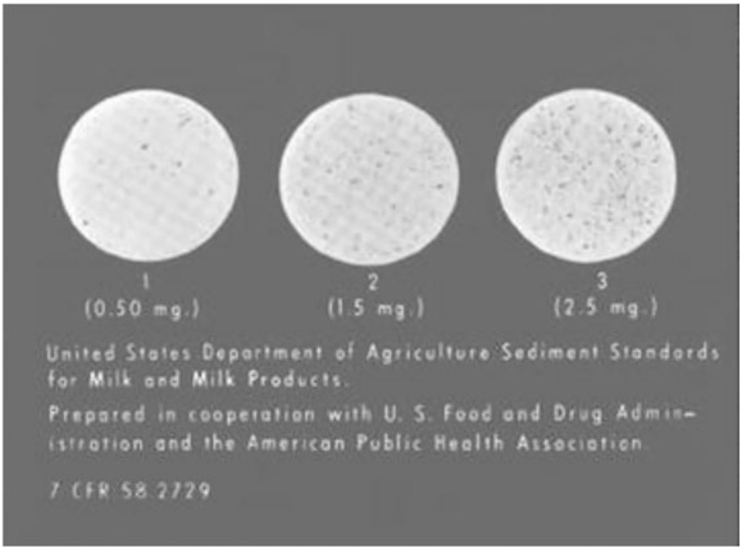


Fig. 5.5 Standard discs that represent known weights of sediment for a given volume of tempered milk sample (one pint)

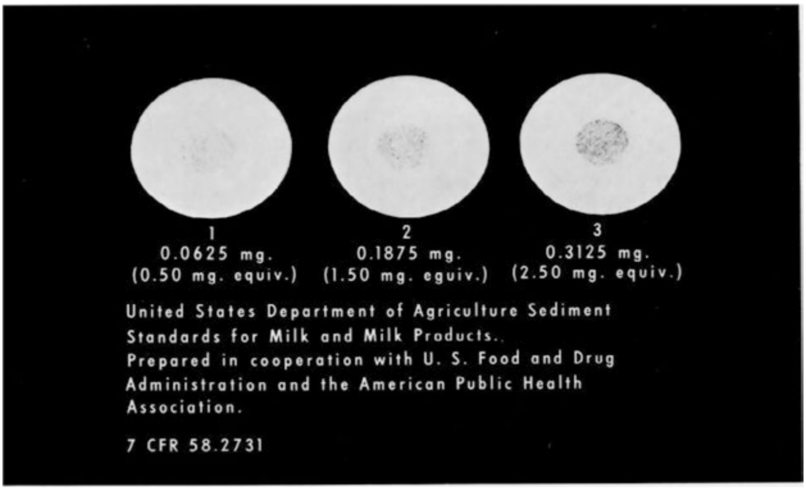


Fig. 5.6 A small grouping of sediment discs that demonstrate various weights of extraneous material per pint of milk

Closure After having evaluated the milk for sediment, the closure (if evaluated) should be carefully observed and scored. A perfect closure has three main functions, namely (1) to contain the milk in the package or bottle, (2) to protect the pouring surface against contamination, and (3) to seal the container against tampering without some visible detection. In order to fulfill the protection requirements for bottles, the cap (if employed) must cover the pouring lip at its greatest diameter.

When appropriate, the evaluator should observe whether the cap is properly seated, so that there is no leakage that might cause microbial contamination. If a cap is covered, this covering should be tight, waterproof, and tamperproof. If possible, it should be determined whether the closure was inserted by hand or by machine. Hand capping is generally prohibited by milk ordinances, due to the greater risk of contaminating milk through associated human contact. Thus, certain observations and judgments should be made relative to the closure itself, namely, whether it fully protects the pouring lip, whether it is properly seated, whether it is leaky, and (should the closure be covered) whether the covering is fastened securely and made of waterproof material and whether the closure adequately seals the container. The 2019 PMO states

> Capping, closing, or sealing of milk and milk product containers shall be done in a sanitary manner by approved mechanical capping, closing, and/or sealing equipment. The cap or closure shall be designed and applied in such a manner that the pouring lip is protected to at least its largest diameter and with regard to fluid product containers, removal cannot be made without detection.

Although plastic bottles are the most common containers, in principle, the same criteria apply to closures for glass and paper containers. An examination of the heat seal of the carton is appropriate for paperboard. It must be adequate to prevent contamination of the milk, but it should not be as rigid or tenacious as to make opening of the carton unduly difficult. Also, excessive heat from the "sealing jaws" of the carton filler may burn or scorch the polyethylene coating. This may lead to an unattractive carton appearance at best and a "burnt-plastic" off-flavor at worst; the latter (flavor) defect is most objectionable to consumers.

Container Multiuse containers should be examined for the extent of fullness, cleanliness, and freedom from dents, cracks, or chips, especially on or near the pouring lip. Any condition of the container that may interfere with contents' safety and wholesomeness should be carefully observed and noted. With practice, this observation may be made quickly and accurately.

Single-service plastic containers have exactly the same requirements for cleanliness and freedom from leakage and damage, but they generally lack the sidewall rigidity to readily determine the precise level of fill. The 2019 PMO contains sanitation guidelines for the manufacture of single-service containers for milk and milk products. Single-service plastic and paper containers are examined for cleanliness, rigidity, freedom from leakage, smoothness, and adherence of paperboard coating. The correct fill level can best be determined by actual measurement of milk volume per container by pouring contents into a graduated cylinder.

Flavor The evaluation of milk for flavor is generally done after the other items of sediment, container, and closures have been considered. At the time of scoring, the milk should be adequately tempered to optimize the detection of any possible odor(s) in the sample(s). Simultaneously, the milk sample should be sufficiently low in temperature that it will increase appreciably when the sample is placed into the mouth. A temperature range of 12.8–18.3 °C (55–65 °F) for the sample has been found to be most satisfactory for scoring milk.

Occasionally, when appropriate or a problem is suspected, the evaluator should remove the cap before mixing the milk and closely inspect the underside of the closure for possible adherence of cream or foam, and then examine the milk sample for the possible presence of a cream plug.

Milk samples for tasting should be poured into clean, odorless drinking containers (i.e., sanitary and nontoxic) that are made of glass (preferably), plastic, or paper. The products should be protected from both direct sunlight and overhead fluorescent lighting to prevent oxidative degradation. Any size between 3.18 cm (1.25 in) and 1.0 cm (0.4 in) is appropriate. The milk judge should make certain that the milk is well mixed by gently swirling the container contents in a circular pattern just before sampling. By placing the nose directly over the container immediately after the milk has been swirled in the container, and taking a full "whiff" of air, any off-odor that may be present can be more readily noted.

Soon after the sample (10–15 ml) is poured, the judge should take a generous sip, roll it about the mouth, note the flavor sensation, and then expectorate. Sometimes, any aftertaste may be enhanced by drawing a breath of fresh air very slowly through the mouth and then exhaling slowly through the nose. Swallowing raw milk as a means of detecting off-flavors is an inadvisable practice.

Agitation (or swirling) of the milk leaves a thin film of milk on the inner surface of the container, which tends to evaporate, thus readily optimizing the opportunity to detect any odor(s) that may be present. If the evaluator is perceptive, even the faintest odors may be detected in this way. If several judges participate in the sensory evaluation, the container when temporarily uncapped and sniffed should always be handled in a sanitary manner. Sniffing the individual sampling cup, after tasting the sample previously in it, is a good option.

5.8 Requirements of High-Quality Fluid Milk

Evaluating Sediment in Milk Consumers want and insist that milk be free of foreign matter, which is certainly a reasonable expectation. The critical factors that determine the entry of foreign or extraneous matter into milk are (1) the sanitation and care during the milking process, (2) the efficiency of milk straining or filtering on the farm, (3) the efficiency of clarification at the plant, (4) the cleanliness of equipment and containers, and (5) avoidance of milk contamination whenever it is exposed to the atmosphere.

Milk samples can be scored for sediment content either by observing the particles of sediment that may have settled to the bottom of a bottle or by observing the sediment collected on a cotton disc. Obviously, direct observation for sediment is only possible when transparent containers are used. When several samples are compared, the container size or the sample size (from which the sediment is obtained) should be standardized.

For the cotton disc method (US Department of Agriculture Sediment Standards for Milk; 7 CFR, 58 2730), one-pint samples are used under standardized conditions of temperature and aspiration. The comparisons with a chart or standard photograph (Fig. 5.5) should be made on the potential sediment found in one pint of tempered milk [35–38 °C (95–100 °F)].

The visual assessment for sediment particles on the bottom surface of bottles (when held above the eyes) is somewhat tedious and inaccurate. When several evaluators are handling the same milk samples, some of the sediment particles are likely to be remixed with the milk, which makes them invisible. In the absence of good light, it is also difficult to observe all possible particles. On the other hand, scoring sediment from the bottom of the bottle offers the advantages of speed and simplicity, since no preparation of sediment discs is necessary. In the routine examination of non-homogenized bottled milk, where emphasis is usually placed on the flavor quality of the milk, the observation for possible sediment on the bottom of the bottle is desirable, but it should be remembered that this method only furnishes an indication of the presence or absence of particles that are too large to be "rafted" upward into the cream layer.

In the sediment disc method, the sediment (or extraneous matter) is concentrated and firmly fixed on a white cotton or lintine disc, where it may be studied more carefully and "filed" for later reference. The sediment discs are prepared by filtering one pint of tempered milk through a round, white cotton pad of 1.0-cm-diameter filtering area. The sediment discs are protected and stored for later reexamination by placing them on a cardboard receptacle (covered with cellophane) or placing them in a clean, covered Petri dish.

For the occasional testing of raw milk from cans, the off-the-bottom method is used, which employs a sediment tester especially designed for this purpose. One pint of milk is collected from the bottom of an undisturbed can of milk, and the sediment is collected on a 1.25-in (3.18 cm) disc. One-pint samples are more frequently collected from bulk tanks for sediment testing, after the milk has been well agitated. The sediment tester for milk from bulk tanks is fitted with a 0.4-in (1.0 cm) diameter orifice, so that the sediment is concentrated in a smaller cross-section. Pasteurized milk may be sampled for sediment only after thorough mixing in the original container.

Each disc may then be compared to a standard chart or photograph that reflects the appropriate sediment ratings. To score "perfect" on sediment, there should not even be a trace of foreign particles on the disc, or any discoloring of the disc, except that due to the natural pigments of milk. Deductions are made in accordance with the amount, kind, and size of foreign particles present, as well as for any smudgy appearance. If the milk were not strained or filtered on the farm, the amount of sediment on the disc would readily indicate the general cleanliness and care taken in production. However, if the milk were strained or filtered, the amount of sediment merely indicates the efficiency of that process or the amount of sediment subsequently accumulated.

Sediment standards for raw milk have been developed by the USDA and are published in the CFR, Title 7, Part 58.134. Standard discs containing known weights of sediment are shown in Figs. 5.5 and 5.6. Discs prepared from milk samples are evaluated by comparing them to these standard discs.

The presence of any sediment in the finished product is serious since the consumer may be quick in registering a complaint. Thus, anything over a trace of sediment may cause the product to be unmarketable and should receive a score of “zero.” Obviously, products in containers ready for the consumer should be scored differently than raw milk. While 0.5 mg of sediment/pint may be “acceptable” for raw milk, this much sediment is excessive and should receive a score of “zero” if found in any finished product. One possible scoring system for finished products is the following: no sediment, 3; more than “no sediment” but less than 0.02 mg/disc, 2; 0.025 mg/disc, 1; and over 0.025 mg/disc, 0 (Table 5.1).

Evaluating Bacterial Content The maximum permissible bacterial counts for raw Grade A and pasteurized market milk are specified in the 2019 Grade A Pasteurized Milk Ordinance. For pasteurized milk, the upper limit of the PMO is 20,000 CFU/ml and is not to exceed 10 coliforms/ml. Thus, a sample that has a standard bacterial plate count (SPC) of more than 20,000 CFU/ml or a coliform count (performed by standard methods) of more than 10 coliforms/ml should receive a score of “zero” for bacteria. As emphasized earlier, a report of the actual bacterial count is usually more meaningful than a bacterial score for most quality control purposes.

The examination of milk for bacterial content is a laboratory procedure that can be performed by a qualified technician who may have no experience in milk judging. The bacterial count of milk potentially reveals the general conditions of sanitation and temperature control under which the milk was produced, handled, and held. High-quality milk should be relatively low in bacteria content, but milk with low bacterial counts may not always necessarily exhibit satisfactory flavor characteristics. If off-flavors in milk are the result of bacterial growth, the bacterial count is usually in the millions per ml. However, serious off-flavors may also be found in milk that is low in bacteria, since numerous milk off-flavors are not due to bacterial activity. Frequently, there is no correlation between milk bacterial count and milk flavor quality, unless there is sufficient growth and development of microorganisms in the milk to form reaction end products such as lactic acid and/or volatile compounds from proteolysis or lipolysis. However, in such instances, the physical appearance of milk may be changed. A significant consequence of this (for quality determination) is that many off-flavors produced by bacteria in raw milk usually persist in the pasteurized milk, even though few of the bacteria are likely to survive the heat treatment of pasteurization.

When evaluating market milk and other milk products for competitive purposes, the scoring system should be based on both the total bacteria and coliform counts. A suggested scoring guide for total bacterial and coliform counts of milk is shown in Table 5.2. A sample may receive a score for bacterial content ranging from “0 to 5,” based on the outcome of either the total bacterial count or the coliform count (or both counts). Typically the score is determined for each separately, and the lower of the two scores is the score assigned to the sample. For example, a sample with 13,000 CFU/ml and 1 coliform/ml would receive a score of “2” on the basis of the

Table 5.2 A suggested scoring guide for bacteria in milk

Standard plate count CFU/ml	Coliforms/ml	Score
>20,000	>10	0
>16,000–20,000	10	1
>12,000–16,000	7–9	2
>8000–12,000	4–6	3
>3000–8000	1–3	4
≤3000	0	5

The score for each of the criteria is determined separately; the lower of the two scores is assigned to the given sample

bacterial count and a "4" on the basis of the coliform count. The lower score of "2" would be assigned to the sample.

Evaluating Container and Closure Multiuse (glass and plastic) containers should have an attractive appearance, be clean, and contain the full volume of milk (as indicated by the label). The bottle contents should be protected from contamination (Bodyfelt et al., 1976; Gasaway & Lindsay, 1979; Landsberg et al., 1977) by a well-made, properly seated, waterproof cap that protects the pouring lip. Attractive milk bottles should be free from dirt and dust and should exhibit no case wear and/or caustic etching (surface abrasions). A chipped bottle lip often results in a leaky or poorly seated cap and may harbor microorganisms due to roughened surfaces.

Single-service paper and plastic containers should reflect cleanliness, recent filling, and freshness and should possess a dry, firm, rigid, and milk solid-free surface. A weakening of the packaging material, as indicated by pronounced bulging of the container sidewalls, should not be evident. There should be no leakage of unopened containers.

Fullness of the Container There is a legal requirement that milk containers must be filled to the expected volume of milk, as indicated by the size of the container and/or label statement. Tolerances and the methods of measurement may vary from state to state, but certain compliance requirements are inescapable. Some containers may have an indicated fill line and can be assessed for fullness by visual observation. These are usually rigid containers, such as those made of glass. When more flexible packaging materials are used, or when the container is opaque so that the level of fill cannot be seen, a volumetric measurement of the contents at a predetermined temperature is necessary. It should be remembered that the density of a liquid varies with temperature and the volume increases with temperature rise.

Bottle Closures As previously stated, the closure has three basic functions: (1) to retain the milk within the container, (2) to protect the pouring lip from contamination, and (3) to seal the container against tampering. The closure is assessed on the completeness with which it fulfills these three functions. The cap is intended primarily to retain the milk within the bottle. In addition, a cap that meets the US Public Health Service requirements for Grade A milk protects the pouring lip of the bottle from contamination; it also protects the filled container against tampering and should leave evidence if it has occurred.

In the past, more kinds of milk bottle closures or caps were used than are currently employed. As the recommendations of the PMO were more widely adopted, many of the then-existing closures simply did not comply. Current container closures generally meet all of these requirements regarding protection of the pouring lip and provide some safeguards against tampering. Table 5.3 lists possible defects that apply to containers and closures of both multiuse and single-service containers.

The term "unsealed" is used to mean "not tamperproof." Closures that meet the requirements of the 2019 PMO satisfy the "sealed" criterion. The term "tamperproof" may be subject to legal interpretation, which cannot be adequately addressed here. Approval of specific containers and closures by appropriate public health enforcement agencies is a necessary requirement, as possible tampering with milk would be a serious matter. When evaluating closures, the presumption that a package is sealed occurs when the closure cannot be removed and replaced without obvious detection. Unfortunately, to make a container absolutely tamperproof would require extreme measures and perhaps prohibitive expense.

Scoring Containers and Closures Since there is no recently accepted system for scoring containers and closures, the following may be used as a suggestion in developing a scoring guide (Table 5.4). A so-called "perfect" container could be assigned a score of "5.0." At the other extreme, any milk container that does not meet the 2019 PMO recommendations should be disqualified and assigned a score of "0."

Table 5.3 A suggested scoring guide for the appearance and integrity of milk containers

	Intensity of defect				
Defect[a]	Slight[b]	Moderate	Definite	Strong	Pronounced[c]
Container: bulging/distorted	4	3	2	1	0[d]
Dented/defective	3	2	1	0	0
Dirty inside	0	0	0	0	0
Dirty outside	2	1	0	0	0
Leaky	0	0	0	0	0
Not full	4	3	2	1	0
Closure defective	0	0	0	0	0
Coating cracked/flaky	4	3	2	1	0
Heat seal defective	4	3	2	1	0
Illegible printing	4	3	2	1	0
Incorrect label/code	3	2	1	0	0
Pouring lip: chipped	4	3	2	1	0
Cover not waterproof	3	2	1	0	0
Unprotected	3	2	1	0	0

[a]"No criticism" is assigned a score of "5." Normal range is 1–5 for a salable product
[b]Highest assignable score for a slight intensity of the given defect
[c]Highest assignable score for a pronounced intensity of the given defect
[d]An assigned score of zero ("0") is indicative of an unsalable product

Table 5.4 Possible defects of milk containers and closures of the multiuse and single-service types

Container closure unsealed	Flaky or cracked coating
Incorrect fill measurement	Closure poorly sealed or leaky
Container dirty on the outside	Defective heat seal
Container dirty on the inside	Lip chipped
Container dented or defected	Lip unprotected
Container leaky	Lip cover not waterproof
Container bulging or distorted	Torn closure cover
Illegible printing on container	Lack of, or incorrect, code or labeling

Containers that are dirty inside and leaky or have closures that are defective or leaky should also be disqualified and receive a score of "0." Most other defects might carry a penalty of 1 point for slight, 2–3 points for moderate, and 4 or 5 points for pronounced intensity. In this scoring scheme, if several defects are encountered, the deductions should be additive.

Evaluating Temperature The temperature at which pasteurized market milk and other fluid products are held is very important in determining the keeping quality and for retention of good flavor characteristics. Even commercially sterile milk, which is microbiologically stable at room temperature, may actually suffer more rapid flavor deterioration at higher storage temperatures.

The 2019 PMO recommendations for storage temperature of Grade A pasteurized milk sets 7.2 °C (45 °F) as the maximum acceptable temperature. In view of the longer keeping-quality demands placed on milk, 7.2 °C (45 °F) should be considered the highest milk storage temperature permissible; however, temperatures below 4.4 °C (40 °F) are definitely preferable for helping extend shelf life. Frequent line temperature checks should be made of milk coming from the cooling section of the pasteurizer, surge tanks, and filler and the product when packaged, in cold storage, in transport, and in retail store coolers and display cases (Bodyfelt, 1974, 1980a; Bodyfelt & Davidson, 1975, 1976; Lewis & Deeth, 2009).

Automation, artificial intelligence, and intelligent packaging are developments that significantly influence dairy processing operations by improving hygiene and protecting and prolonging the shelf life of dairy products, all the while diminishing human involvement. Among these developments are continuous monitoring indicators (CMI) for freshness, gases, package integrity, aroma, color, viscosity, and serum properties, in addition to the widely accepted time-temperature indicators (TTI) (Mirza Alizadeh et al., 2020). These technologies include instrumentation such as barcodes, biosensors, and radiofrequency identification (RFID), an advanced wireless data carrier that uses radio waves for identification and tracking of products. These instruments are powerful tools in monitoring food quality and safety. Research has shown that use of RFID in raw milk transportation can prevent milk deterioration (Dabbene et al., 2014).

Each technology has specific applications. Barcodes are the most economical category and act as data carriers for traceability from field to table. Biosensors have bio-diagnostic elements that convert biological responses into electrical signals that can be traced and quantified. Gas sensors can measure the amount and composition of gases produced by spoilage organisms or gases that enter the package from the external environment and indicate spoilage with a chemical or enzymatic reaction that changes the color of the sensor. Similarly, TTI produces irreversible visual responses/changes such as mechanical transfiguration, color development, movement or change due to time, and temperature-dependent chemical, microbiological, mechanical, or enzymatic factors. In dairy packaging, the TTI enzymatic reaction, which indicates the time-temperature change, is based on the reduction of pH and subsequent color change due to temperature fluctuation caused by the production of an acid by enzymatic hydrolysis (Mirza Alizadeh et al., 2020). Mimica Touch is a dairy freshness indicator for milk packaging with three regions: a permanent smooth surface, written expiration date, and a bumpy surface, which is initially smooth and is converted to a bumpy surface when the food becomes spoiled. In the dairy industry, nano sensors that are made of bio-nanocomposite polymer matrices are used for the detection of microorganisms such as mycobacterium (Joyner & Kumar, 2015).

An applied example of these developments is the Xsense® system that continuously monitors the temperature and relative humidity (RH) of refrigerators and freezers at the Ohio State University's Food Industries Center (Fig. 5.7a–c).

There is no generally accepted scoring system for temperature. What follows is only a suggested approach that may be applied for scoring the temperature of milk products. For in-house quality assurance program purposes, it seems more logical to record or graph the actual temperature(s) (Bodyfelt, 1974) than to assign a score. Integration of a computer data handling system with electronic temperature sensors allows for enhanced efficiency of data gathering and interpretation. If a score is more appropriate, such as in competitions (when samples are picked up at the plant or from a retail establishment), a two-point scale may be employed. A sample that

A Xsense® Control Unit

B Transmission Tag

C Display Report

Fig. 5.7 The Xsense® system is a cloud-based management and reporting system (**a**) that is accessible from an internet browser by users with authorization. It ensures that temperature-sensitive products are stored and shipped properly and safely. The system proactively monitors (**b**), analyzes, and disseminates temperature and relative humidity (RH) data (**c**) that can be reviewed by all responsible personnel. The system also sends alerts of temperature and RH fluctuations from pre-set thresholds and generates recommendations on how to maintain the quality of perishable products throughout the cold chain is above 7.2 °C (45 °F) is not in compliance and should conceivably receive a score of "zero." At the other extreme, samples at a temperature of 4.4 °C (40 °F) or lower could be assigned a perfect score of "2." When the sample temperature is between 4 °C and 7.2 °C (40 °F and 45 °F), a score of "1" would be assigned. Sample temperatures of >7.2 °C (>45 °F) should probably be disqualified from competition, since both quality and public health concerns may be at stake.

Requirements for Grade A raw milk for pasteurization as specified by the 2019 PMO are as follows: "Cooled to 7 °C (45 °F) or less within 2 h after milking, provided that the blend temperature after the first and subsequent milkings does not exceed 10 °C (50 °F)." Thus, the "temperature scoring" of raw milk would depend upon the time elapsed between the milking and the temperature of milk when it is measured. After 2 h, the scoring system would be the same as that used for pasteurized milk, since the requirements are identical. The milk should be disqualified from competition whenever its temperature is above 10 °C (50 °F).

5.9 Evaluating Milk Flavor

Desired Milk Properties Typically, the flavor of whole milk should be pleasantly sweet and should possess neither a foretaste nor an aftertaste other than that imparted by the natural richness due to the milkfat and other milk solids (Bodyfelt et al., 1988; Molina et al., 2009). The evaluator should not assume or expect that a sample of good (high-quality) flavor milk will have a "taste," per se. Judges should remember that when milk clearly exhibits a so-called "taste," there is usually something "wrong" with the flavor of that milk sample. Milk of excellent quality should seem pleasantly sweet and leave only a clean, pleasing sensation after the sample has been expectorated or swallowed. The mixed sample should also be perfectly homogeneous (i.e., exhibit no buttery particles or graininess). When the closure of the unshaken bottle is removed, there should be no evidence of adhering cream, foam, or butter granules, and the milk should not show a cream plug unless non-homogenized.

Placing Samples into Flavor Groups With appropriate training, the evaluator should be able to classify the flavor quality of milk samples into categories of excellent (10), good (7–9), fair (4–6), poor (1–3), and unacceptable (0). The next step for a milk judge might be to rate the samples within the group into which it falls; that is, whether the flavor quality (relative merits) is such as to place it as average, high, or low in that group. Since each group has a range of numerical scores, it should become relatively easy to place a numerical flavor score or grouping on the respective samples. Further assistance has been provided by various professional groups that have developed scoring guides that are illustrated in Tables 5.5 and 5.6, which suggest scores for milk that possess varied intensities of specific defects. The scoring guide for milk shown in Table 5.5 was adopted by the Collegiate Dairy Products Evaluation Contest (CDPEC), now called the Collegiate Dairy Products Evaluation

Table 5.5 The Collegiate Dairy Products Evaluation Contest scoring guide for off-flavors of milk and cream

	Intensity of defect		
Flavor defect	Slight	Definite	Pronounced
Acid	3	1	[a]
Bitter	5	3	1
Cooked	9	8	6
Feed	9	8	5
Fermented/fruity	5	3	1
Flat	9	8	7
Foreign	5	3	1
Garlic/onion	5	3	1
Lacks freshness	8	7	6
Malty	5	3	1
Oxidized—Light	6	4	1
Oxidized—Metal	5	3	1
Rancid	4	1	[a]
Salty	8	6	4
Unclean	3	1	[a]

Note: A slight cooked flavor that is not objectionable may be scored a perfect 10 with no criticism (butter only)
[a]Unsalable

Coaches Committee. To use a guide, the evaluator should be somewhat proficient in the identification of various flavor defects of milk.

Undesirable Flavors Milk is generally considered to have a flavor defect if it manifests an odor, a foretaste, or an aftertaste or does not leave the mouth in a clean, sweet, pleasant condition following tasting (Molina et al., 2009). Some samples may simultaneously have more than one flavor defect. In this case, the assigned flavor score usually corresponds to the most serious defect of the several noted. The scoring guide in Table 5.5 lists the most frequently encountered off-flavors of milk. Whenever a flavor defect is encountered that differs from those listed on the scoring guide (which happens occasionally), it should be described in the most descriptive or associative term(s) possible (e.g., “foreign”) and entered on a blank line of the scorecard. In such a case, the assignment of a numerical score may be difficult, particularly when such a defect may be encountered for the first time. Evaluators must draw upon their experience and sound judgment in assessing the degree of seriousness of uncommon defects.

The description, taste, and smell sensations, and cause(s) of the different off-flavors of milk, follow in alphabetical order (as noted in Table 5.5). In general, off-flavors of milk may be categorized into four major (A-B-C-D) groupings: absorbed (barny, cowy, feed, garlic/onion), bacterial (acid, bitter, fruity/fermented, malty, rancid, unclean [i.e., psychrotrophic]), chemical (astringent, cooked, lacks freshness, light oxidized, metal oxidized, rancid), and delinquency (flat, foreign, salty, unclean). When considering the values associated with the various off-flavors on the CDPEC milk scorecard, bacterial-derived off-flavors tend to receive lowest marks. Understanding the root causes of the respective off-flavors should help the evaluator remedy the situation. The terms *astringent, barny, and cowy* have been removed from the CDPEC milk scorecard, due to general improvements in the quality of the US milk supply. However, since these defects may occur in other countries or in rare instances in the USA, they are included in the following discussion.

Acid Although acid/sour is a basic taste, the "acid" or "sour" off-flavor of milk is detected by both the sense of smell and the sense of taste. When *Lactococcus lactis* subsp. *cremoris,* or other acid-producing organisms, grow in milk and convert the lactose (milk sugar) into lactic acid and other by-products, a distinguishable, characteristic odor is emitted by the formed end products. Most milk judges can readily detect this odor, despite the fact that up to this point, sufficient acid may not have been produced to be detected by the sense of taste. As the fermentation progresses, the acid taste becomes more pronounced, and the odor may become less offensive. Acid milk that is likely caused by temperature abuse imparts to the tip of the tongue a peeling or tingling effect. An acid taste tends to leave both the tongue and the mouth with a general feeling of "cleanliness" or an enhanced ability to taste.

Astringent This sensory defect, "astringent," is not very common in beverage milk. Astringency is best noted by a peculiar mouthfeel after having rolled a sample of the milk about the mouth and expectorating it. In astringency, the tongue and linings of the mouth tend to feel shriveled, almost puckered. Some milk judges that have a relatively high threshold value for rancid taste may possibly perceive this astringent feel at the base and/or back of the tongue when they taste slightly rancid milk. Hence, experiencing an astringency sensation may serve as a hint to such judges to observe more carefully for possible rancidity.

Cowy, Barny, and Unclean Cowy is a characteristic flavor of milk that is mainly attributed to the presence of low-molecular-weight fatty acids, nitrogen heterocyclic compounds, phenolics, γ-lactones, phytol and acetone derivates, and volatile carbonyl products present in fresh milk. Methyl sulfide contributes significantly to the characteristic flavor of milk (Bendall, 2001; Patton et al., 1956). Additional compounds were reported by Bendall (2001) who identified 66 characteristic compounds in fresh milk from cows fed with pasture and supplemented diets. The compounds found in significant concentrations were hept-*cis*-4-enal, 2-acetyl-1-pyrroline, 3-methylbutyric acid, benzothiazole, *cis*-3-methyl-γ-nonalactone, indole, γ-12:2, and γ-16. Higher concentrations of alkyl phenols lead to formation of "cowy" and "barny" off-flavors. Still higher concentrations of alkyl phenols lead to generally unpleasant "unclean"-type flavors (Cadwallader & Singh, 2009; Lindsay, 2002). Usually, a "cowy" flavor defect implies a distinct cow's breath-like odor and a persistent unpleasant, medicinal, or chemical aftertaste. In the past, a number of off-flavors were grouped together under the general heading of "barny." The distinction between "smothered," "cowy," "barny," and "unclean" off-flavors was thought to be one of intensity rather than a difference in perceived sensory characteristics. Currently, the term "smothered" is seldom used. The barny off-flavor is detected by sniffing and/or tasting. A characteristic unpleasant aftertaste is most noticeable immediately after sample expectoration. This off-flavor is suggestive of the fecal odor of a poorly maintained barn and leaves a persistent, unclean aftertaste.

Bitter A pure, unassociated "bitter" off-flavor can be detected by taste only. Compared to acid/sour, sweet, and salty, the reaction time for bitterness is relatively slow; hence, the evaluator must guard against premature judgment. Bitterness is best detected at the base of the tongue (back of the mouth), and this taste sensation tends to persist for a relatively long time. Although a bitter off-flavor may be encountered as a singular defect in milk, it may also be associated with other defects. In some cases, an associated astringency may be noted. Some evaluators find bitterness a distinctive feature of the rancid off-flavor, which will be discussed in subsequent paragraphs. A foreign off-flavor may also exhibit a bitter note, if the foreign substance that entered the milk has a bitter taste. Two common causes of bitterness are specific weeds (consumed as part of the roughage by cows) and certain microorganisms, especially some psychrotrophic bacteria. Proteolysis of milk proteins often results in bitter flavors and further degradation of amino acids produces putrid flavors in milk (Dolci & Cocolin, 2017; Shipe et al., 1978).

Cooked Although "cooked" is the only designation that commonly appears on milk scorecards, this term actually represents a range of possible heat-induced sensations of milk and milk products. Upon storage, the heat-induced flavor of pasteurized milk tends to change both in intensity and character. Immediately after processing, the flavor may be quite intense, but after 24 h has elapsed, there is usually a marked reduction in its intensity. Thus, with respect to the cooked flavor, milk flavor may tend to improve during storage, or at least change in characteristics (Anderson & Oste, 1992; Calvo & De La Hoz, 1992; Fink & Kessler, 1986; Zabbia et al., 2012). This improvement in flavor is not the case with highly heated products that have acquired a "caramelized" off-flavor that may be found in UHT, evaporated, or condensed milk. This flavor defect is produced by a different mechanism of chemical interaction of milk components; the caramellike note frequently intensifies and becomes increasingly more objectionable with increased storage.

Gould (1939) demonstrated that the cooked flavor of milk appeared abruptly within a very narrow limit at a temperature of 76–78 °C (168.8–172.4 °F). Below this processing temperature, heated milk did not appear to develop the cooked flavor. The flavor note that remains in moderately heated milk after refrigerated storage, particularly when higher processing temperatures are used, is generally described as "heated" (Boelrijk et al., 2003; Zabbia et al., 2012). This distinguishes it from the more aromatic sensation suggestive of sulfides, which is more typical of the cooked flavor (Boelrijk et al., 2003; Patton et al., 1956; Zabbia et al., 2012).

In the report of the American Dairy Science Association (ADSA) Committee on Flavor Nomenclature and Reference Standards, Shipe et al. (1978) recognized four kinds of heat-induced flavors: (1) cooked or sulfurous, (2) heated or rich, (3) caramelized, and (4) scorched. The variety of heat-induced flavor that is encountered depends on a combination of the heating time and the attained temperature, the length of refrigerated storage time for pasteurized milk, and the amount of "product burn-on" in the heat exchanger.

Both the heated and cooked flavors are easily identified. Taste reaction time is relatively quick, and the taste sensation that remains after sample expectoration is usually considered to be pleasant. Cooked flavor may especially be noted by the sense of smell. As the sampling container is brought to the lips and in close proximity to the nose, the characteristic volatility of the cooked note should provide the judge with a hint of what particular flavor is present in the milk. The presence of "moderately heated" flavors in milk is not particularly objectionable to consumers (or judges), but a pronounced degree of "cooked" flavor is frowned upon. In extreme cases, the aroma may be reminiscent of hard-boiled eggs. Of particular note, when a heated flavor occurs in milk or cream products, an accompanying oxidized off-flavor is seldom, if ever, present (Calvo & De La Hoz, 1992). This lack of oxidized off-flavor is presumably due to certain formed end products of heated milk that have "reducing ability." Jenness and Patton (1959) reported that heated and dried milk both contain reducing substances involving sulfhydryl (–SH) compounds, ascorbic acids, and substances associated with browning reactions. Thus, in ice cream or butter, a cooked or heated flavor is often recognized as "the flavor of assurance" for the improved keeping quality of milk products, insofar as possible auto-oxidation of milk lipids is involved. Fortunately, natural antioxidants are formed in milk by the heating process. Additional merits of a cooked flavor in milk and cream are that it (1) serves to help mask more objectionable feed off-flavors and (2) may provide improved richness and/or mouthfeel sensations in the product.

Feed Some feeds, especially high-volume roughages, impart aromatic taints to milk if fed to cows within a critical time frame before milking. The 0.5–3 h time period is the most critical (Drake et al., 2008; Hedrick, 1955; Mounchilli et al., 2005). This aromatic taint is especially true of succulent feeds, silage, some commodities, brewery wastes, and some hays (Table 5.6). A "feed" off-flavor is characteristic in that it is aromatic, sometimes pleasant (i.e., alfalfa), and can usually be readily detected by the sense of smell. A characteristic note (and mild aftertaste) of "cleanliness" is associated with most feed off-flavors, when the milk sample is expectorated. This cleanliness note distinguishes the feed off-flavor from cowy, barny, or unclean off-flavors. Feed off-flavors usually "disappear" rather quickly and thus leave the mouth in a clean state of condition. By contrast, cowy, barny, or unclean off-flavors tend to persist with an accompanying unpleasant, somewhat "dirty," aftertaste. Beginner judges may experience some difficulty in distinguishing between a slight barny and a feed off-flavor of moderate to definite intensity.

Obviously, the characteristic odor/taste of feed off-flavors varies with the type of feed consumed by lactating animals. The odor of a given raw milk supply is generally characteristic of a particular feed. In some US dairy regions, a severe feed defect is often observed early in the spring when the all-dry winter ration is

Table 5.6 Feed flavors transmitted to milk in relation to the quantity of roughage and length of interval prior to milking

No.	Feed	Amount of feed (lb)	Interval before milking (h)	Flavor of resulting milk
1	Alfalfa hay	2–6	2	Objectionable feed
2	Alfalfa hay	2–6	4	Occasional feed
3	Alfalfa hay	2–6	5	No criticism
4	Alfalfa silage	5	1	Definite feed
5	Alfalfa silage	15–25	11	No criticism
6	Clover hay	6	2	Pronounced feed
7	Clover hay	15–20	11	No criticism
8	Clover silage	5	1	Definite feed
9	Clover silage	15–20	11	No criticism
10	Green corn	25	1	Slight feed
11	Green corn	25	11	No criticism
12	Dry beet pulp	7	1	Slight feed
13	Oat hay	12	2	No criticism

From: Hedrick (1955)

terminated and changed to one that includes fresh green pasture. Also, severe feed off-flavors are likely to occur when there is a sudden change to a new, more odorous form of roughage, such as from alfalfa hay to corn or grass silage.

To minimize the occurrence of objectionable feed off-flavors, milk producers must be aware of the need to avoid the feeding of highly aromatic roughages in the 0.5–3 h just prior to milking. This time frame is an important production management task if milk of good flavor quality is to be produced.

Current farm management options within the global dairy industry find renewed reliance on pasture feeding, which is often considered more consistent and in line with organic farming protocols. Farmstead cheesemakers are discovering and benefiting from so-called “grassy flavors” within their milk with such extensive reliance on grass grazing or feeding for the primary roughage source. The unique grassy flavors of milk appear to transfer favorably and uniquely to the types of cheeses produced under such production conditions.

Fermented/Fruity Certain microorganisms produce aromatic fermentation end products that seriously taint milk; this off-flavor is variously described as “fermented” or “fruity” (Crow et al., 2002; Hayes et al., 2002; Morgan, 1976; Poltronieri et al., 2017). The off-flavor is quickly and easily detected by its odor, which may resemble that of sauerkraut or vinegar (fermented) or pineapple, apples, or other fruits (fruity). This flavor is considered a rather serious defect; it is often found after extended storage of bulk raw milk, as well as in older pasteurized milk. This off-flavor is commonly caused by the growth of psychrotrophic bacteria, especially certain *Pseudomonas* sp. (e.g., *P. fragi)* (Cormier et al., 1991; Molina et al., 2009).

Flat Since “flat” as a flavor defect is not associated with an odor, the sense of smell furnishes absolutely no indication of its possible presence. However, when flat milk is tasted, flatness is apparent soon after the sample reaches the tongue, partly as the result of a marked change in perceived mouthfeel. This flavor defect can be simulated by adding water to a sample of milk and noting the alteration of mouthfeel of the mixture. A flat flavor should not be confused with a “lack of richness” sensation in milk. The latter usually exhibits a level of sweetness, whereas the former does not. Currently, in the CDPEC, 2% low-fat milk is evaluated, which contains approximately 33% less milkfat than whole milk. For some evaluators, a slight intensity of oxidized off-flavor may be perceived as a flat taste on initial tasting.

Foreign (Atypical) As the name implies, a “foreign” off-flavor is not commonly developed in or associated with milk; in fact, it is most atypical of a fluid milk beverage. In some instances, a foreign off-flavor in milk may be detected by the sense of smell; in other cases, it may not be readily noted until the sample is tasted. The sensory characteristics of this off-flavor differ with the causative agent(s). Foreign off-flavors in milk may be caused by the improper use of various chemicals such as detergents, disinfectants, and sanitizers; exposure to fumes from the combustion of gasoline or kerosene; contamination from insecticides; drenching cows with treatment chemicals; or from treatment of the udder with ointments or medications. Dairy producers must exercise utmost caution in handling various farm chemicals and medications if milk adulteration is to be avoided. The term foreign might also be used to describe white milk that unexpectedly tastes like vanilla (flavored milk put in the wrong container), carrots (contains excessive vitamin A), or fish (fish oils added).

Garlic/Onion (Weedy) “Garlic” and “onion” off-flavors in milk are recognized by the characteristic pungent odor and a somewhat persistent aftertaste (if tasted). This most objectionable flavor defect may be expected in the spring through fall seasons in those regions where pastures or hay crops become infested with weeds of the onion family. In addition to garlic and onion, there are many other weeds that can potentially taint milk when they are consumed by cows, especially if consumed a short time before milking (Molina et al., 2009; Mostafa, 1999). The character and intensity of weed off-flavors depend on the kind of weed and the time elapsed between cow consumption and milking. Frequently, a weed off-flavor is accompanied by a bitter aftertaste.

Milk judges should familiarize themselves with any potential or unique weed problems in their locality. Evaluators and field department personnel should learn the characteristics of each weed off-flavor (when found in milk) and then be able to suggest a feeding routine to dairy producers that will either minimize or eliminate these flavor defects. The flavor score assigned to milk with a weedy off-flavor depends on the intensity and whether it is caused by a common or a noxious weed.

Lacks Freshness (Stale) This mild-to-moderate flavor defect lacks specific characteristics to make description or identification easy. As the designation “lacks freshness" or "stale" suggests, milk with this off-flavor yields a taste reaction that indicates a loss of those fine, pleasing taste qualities typically noted in excellent or high-quality milk. Difficulty may be encountered in attempting to find something specifically wrong with the flavor, yet the astute milk judge senses a certain inherent shortcoming in the milk sample. In some cases, a perceived slight "chalky" taste, perhaps reminiscent of some reconstituted nonfat dry milk, is one way to describe this off-flavor. Stale milk is not as pleasantly sweet and refreshing or as free of an aftertaste as is typically desired in milk. The lacks-freshness defect in milk can be a "forerunner" of either oxidized or rancid off-flavors or off-flavors caused by psychrotrophic bacteria.

Malty A "malty" off-flavor in milk is usually of either definite or pronounced intensity and is quite suggestive of malt. Variations of the off-flavor may be encountered; one variation may suggest a "Grape Nuts®"-like flavor. Some describe the flavor as "the milk left over after eating a bowl of cereal." The malty off-flavor is generally caused by the growth of *Streptococcus lactis* subsp. *maltigenes* bacteria in the milk as the result of temperature abuse [~ 18.2 °C (~ 65 °F)] for 2–3 h (Morgan, 1976; Salama et al., 1995). This off-flavor can be detected by either smelling or tasting the milk. The bacterial population of malty milk will generally be in the millions per milliliter. Hence, this off-flavor is frequently a forerunner of acid or sour milk. It is not uncommon to perceive the malty aroma and the acid taste (or odor) simultaneously. Some variations of feed flavor may also be perceived as malty-like by relatively experienced judges, especially when brewer's spent grains have been fed to the dairy herd as a roughage source.

Oxidized (Light-Induced) This off-flavor has been variously described as burnt, burnt protein, burnt feathers, cabbage-like, and as medicinal or chemical-like by different authorities. Other names by which this off-flavor is known are light-activated, sunlight flavor, or sunshine flavor. When milk is exposed to sunlight or fluorescent light, two different off-flavors may develop. Light catalyzes a lipid oxidation and a protein (amino acid) degradation, both of which are involved in the development of the light-induced flavor defect. The latter reaction requires the presence of the vitamin riboflavin, which is naturally abundant in milk. The riboflavin of milk functions as an efficient photosensitizer and will generate a very reactive form of molecular oxygen, singlet oxygen, upon exposure to light (Choe & Min, 2006; Molina et al., 2009).

The light-induced type of oxidized off-flavor may be detected by smell; its odor is quite different from that of the metal-induced, oxidized off-flavor. The aroma and flavor of light-oxidized milk may manifest as similar to wet cardboard or wet paper. Other mentioned descriptors for light-activated off-flavor have been burnt hair or plastic or a distinct chemical-like note. Difficulties in precisely differentiating between the metal-induced and light-induced off-flavors of milk primarily hinges on the fact that the light-activated form of off-flavor is not typically free of lipid oxidation components. Cadwallader and Howard (1998) and Chapman et al. (2002)

identified characteristic aroma-active compounds responsible for light-induced flavor in milk with different fat levels. Milk exposed to light for 18 h developed a typical light-induced flavor profile that was described as “burnt protein,” “burnt feathers,” “cabbage,” and “mushroom” (Chapman et al., 2002). The formation of volatile compounds and intensity of light-induced aroma development were directly related to the fat content of milk. Higher concentrations of acetaldehyde, pentanal, hexanal, heptanal, 2,3-butanedione, dimethyl disulfide, and 1-octen-3-one were found in 2% and whole milk compared to skim milk (Cadwallader & Howard, 1998; van Aardt et al., 2005). Higher concentrations of compounds derived from light-induced oxidation are often correlated with high-intensity aroma profiles; however, other compounds at low concentrations might yield strong odors in milk. Moderate-to-strong odors are associated with pentanal, hexanal, heptanal, and heptanol, whereas compounds with the highest intensities are dimethyl disulfide, 2-methylpropanal, 1-hexen-3-one, and 1-octen-3-one (Molina et al., 2009; van Aardt et al., 2005). Aroma-active compounds produced from light-induced oxidation can be limited by proper storage, while other aroma compounds might persist or increase over time as a result of a decrease of antioxidant capacity or exposure to light. Concentrations of hexanal and heptanal increased to levels above aroma threshold after 6 weeks of storage. However, 1-octen-3-one content in milk exposed to light decreased significantly after 2 weeks of storage (van Aardt et al., 2005). Hence, true oxidized and light-induced off-flavors tend to overlap each other. This overlap complicates our efforts at detection, or at least detection with full confidence of which form of oxidation a given milk sample may be guilty of possessing. See Table 5.7 for a summary of the similar and dissimilar characteristics of the light-induced off-flavor and the generic oxidized off-flavor.

Oxidized (Metal-Induced) The “oxidized” off-flavor results from lipid oxidation, which is commonly induced by the catalytic action of certain metals. Metallic, oily, cappy, cardboardy, stale, tallowy, painty, and fishy are terms that have been used to describe qualitative differences of the generic “oxidized” off-flavor (Bassette et al., 1986; Havemose et al., 2006; Hedegaard et al., 2006; Molina et al., 2009; Smith & Dunkley, 1962). The oxidized off-flavor is characterized by (1) a “quick” taste reaction when the sample is placed into the mouth, (2) its resemblance to some of the off-flavors mentioned above (Table 5.5), and (3) its relatively short adaptation time (Bodyfelt et al., 1988; Ogden, 1993). When intense, the defect can be detected by smelling; oxidized products are especially perceptible when tasted. This off-flavor is moderately persistent after the sample has been expectorated. A puckery mouthfeel characterizes the oxidized off-flavor, especially when the intensity is relatively high. Unhomogenized or cream-line milk is substantially more susceptible to the development of this off-flavor than homogenized milk, for reasons that are not clearly understood.

Fortunately, the “pure” metallic off-flavor of milk is only encountered occasionally. Its presence may be noted by a definite, peculiar mouthfeel, somewhat like that when a piece of metal foil, a penny, or a rusty metal is placed into the mouth. Both the reaction and adaptation times are quite short. Frequently with the metallic off-flavor, an initial flatness is suggested. The metallic off-flavor is generally associated with the early stages of metal-induced oxidation (cardboardy or papery).

Sources of metal-induced oxidation range from (1) direct contact with certain raw metals, (2) induction by excessive trace metals in the feed source(s) of lactating cows, and/or (3) the presence of divalent cations (Cu, Fe, Mn) in hot water supplies used for cleaning milk-contact equipment on farms. The metals catalyze lipid autooxidation by way of free radical formation, which yield aldehydes, ketones, and other offensive end products within the milk.

Rancid The characteristic odor of rancid milk is derived from the unpleasant volatile fatty acids that are formed as the result of lipid hydrolysis. Lipolytic rancidity is caused by endogenous and/or exogenous lipases that hydrolyze milkfat triglycerides (Fromm & Boor, 2004; Sfakianakis & Tzia, 2017; Shipe et al., 1978). Short-chain fatty acids (butyric, caproic, caprylic, capric, and lauric acids) in the sn1 and sn3 positions of a triacylglycerol are particularly susceptible to hydrolysis by lipase. Rancid off-flavor is complex due to the factors that contribute to its development. Therefore, it is important to point out that the predominant flavor of rancid milk is the volatile perception of free fatty acids, reminiscent of baby burp, feta cheese, or butyric acid. Hydrolysis occurs when (1) raw milk is agitated excessively (or frozen), thus rupturing the milkfat globule membrane that exposes the milkfat to native lipase (or lipases secreted by spoilage bacteria); (2) native milk lipase is not inactivated by heating; or (3) raw milk is mixed with homogenized milk. Lipolytic enzymes in homogenized milk have more surface contact area with the fat globule and thus the rate of hydrolysis of fatty acids from the glycerol bond is increased (Tunick et al., 2016).

Some evaluators find "rancid" milk samples extremely unpleasant; by contrast, other persons may find little or no particular fault or objectionable characteristics in rancid milk. Some individuals appear to be either insensitive or have a relatively high threshold for the taste and odor of free fatty acids and their salts. Some of these persons may, with guidance and practice, learn to recognize the defect but may still not find it objectionable (Table 5.7). Fromm and Boor (2004) reported that concentrations of free fatty acid (FFA) of 0.50 mEq FFA/kg are indicative of the end of shelf life of HTST pasteurized milk. However, data obtained from sensory threshold studies to establish milk quality need to be considered carefully. Differences in flavor threshold perception among consumers have been investigated. Santos et al. (2003) reported off-flavor perception thresholds among 100 panelists, between 0.316 and 0.351 mEq of FFA/kg of 2% pasteurized milk. Moreover, 23% of the panelists detected off-flavors in milk in the range of 0.17–0.20 mEq of FFA/kg of milk. As the FFA concentration increased up to 0.25 mEq of FFA/kg of milk, the authors reported that 34% of the panelists were able to detect off-flavors in milk samples.

There are several characteristics of the rancid off-flavor, as it is perceived, that may be noted in succession. Immediately after placing the rancid product sample in the mouth, the flavor may not be too revealing initially, but a growing awareness of the defect should commence as the sample is manipulated toward the back of the

Table 5.7 A comparison of hydrolytic rancidity (lipolytic), oxidative rancidity (oxidized), and light-activated off-flavors in milk

Factors	Lipolytic (rancid)	Oxidized (auto-oxidation)	Light activated
Substrate(s) or component(s) involved	Tri- or diglycerides of milkfat	Unsaturated fatty acids (i.e., phospholipids)	Protein (methionine)
End products of reaction	Short-chain free fatty acids, salts of free fatty acids (soaps)	Short-chain volatile aldehydes, ketones	Methional
Sensory characteristics exhibited		Papery, cardboardy, metallic, painty, fishy	"Burnt" or chemical odor/taste may eventually become similar to oxidized defect
Chemical mechanism(s)	Soapy, bitter, "sour," "blue cheese"-like aroma, vomit	Peroxide radical formation on adjacent carbon atom of a double bond	"Oxidation" of an amino acid, with the participation of riboflavin
Causes or "triggers" of reaction	Hydrolysis of the ester linkage of a short-chain fatty acid Physical abuse ruptures the milkfat globule membrane, activates native lipases in milk	Oxygen incorporation Divalent cations (Cu^{++}, Fe^{++}, Mn^{++}) Lack of antioxidants Low bacteria counts High grain concentrations in rations	Exposure to sunlight of fluorescent light
Measurement of defect	Mixing raw and homogenized milk	Sensory TBARS[a] Peroxide value	Sensory
Other features	Sensory Foaming of raw milk Freezing of milk Extreme temperature changes Late lactation milk enzymatic	High-heat treatments minimize occurrence, also homogenization Nonenzymatic	Protective packaging and eliminate exposure to light Nonenzymatic

[a]TBARs—thiobarbituric acid reactive substances test for malondialdehyde
From Bodyfelt et al. (1988)

mouth. The perceived sensation should now suggest rancidity—a soapy, bitter, and possibly unclean-like aftertaste. At this stage, highly sensitive evaluators may find this flavor experience somewhat nauseating or revolting. When the sample is expectorated, the soapiness and bitterness (or rancidity) tends to fade only gradually, and an astringency or "roughness" of the interior mouth surface may occur. Most notably, the rancid aftertaste is persistent and unpleasant. For the more flavor-sensitive individual, an intense rancid off-flavor may "come off" as nothing less than "foul," highly objectionable, and/or intense soapy/bitter. More pointed descriptors of intense hydrolytic rancidity in certain dairy foods (especially Cheddar cheese) may be quite reminiscent of baby "throw-up," feta cheese, or pure butyric acid. If an evaluator is unsure whether a milk sample is rancid or not, a drop may be rubbed on the back of the hand, allowed to dry, and sniffed to determine the presence of free fatty acid aroma.

Salty The "salty" taste of milk is perceived rather quickly upon placing the sample into the mouth. The sense of smell is valueless in detecting this off-taste, as there is no odor related to salty milk unless the off-flavor is in association with another defect. Saltiness (like acidity) lends a cleansing feeling to the mouth. Some evaluators note a "warm sensation" derived from the presence of salt in milk. This off-taste is commonly associated with milk from individual cows that are in the most advanced stages of lactation or with milk from cows that have clinical stages of mastitis. These conditions result in an increase of NaCl in the milk and a decrease of other mineral salts. A salty taste is infrequently encountered in commingled milk supplies or market milk.

Unclean (Psychrophilic) Some forms of this off-flavor are becoming less common in raw milk supplies due to the general improvement in farm sanitation and more effective temperature control of milk. In either raw or pasteurized milk, this off-flavor may develop by the action of certain psychrophilic bacteria, particularly when the storage temperature is too high (~7.2 °C or ~45 °F) or milk is stored too long. The end products of bacterial growth that are responsible for this highly objectionable off-flavor may be produced either (1) directly by the bacteria when they grow in the milk or (2) indirectly when they grow on improperly cleaned equipment surfaces from which they are transferred into the milk. Spoilage by psychrophilic bacteria has been the subject of numerous studies (e.g., Bodyfelt, 1974, 1980a, b; Bradley Jr., 1983; Hankin et al., 1977; Hankin & Anderson, 1969; Hankin & Stephans, 1972; Hutchinson et al., 2005; Kadri et al., 2021; Mikolajcik & Simon, 1978; Polyanskii et al., 2005).

The presence of an unclean off-flavor in milk may generally be readily noted by its somewhat offensive odor and a failure of the mouth to clean up after tasting and expectorating the sample. This objectionable off-flavor sometimes suggests extreme staleness, mustiness, a putrid or spoiled ("dirty socks") odor, or foul stable air.

Determination of Slight Differences Among Attributes As pointed out in the corresponding milk off-flavor sections, some flavor defects are easier to judge or ascertain than others. The following is the protocol that the author follows when training students on how to determine slight differences of off-flavors that are difficult to differentiate, such as cooked, malty, and light oxidized. Students learn first what the proper or ideal flavor quality of milk is by tasting to a great extent milk samples considered to exhibit excellent quality. Having in mind the ideal milk flavor quality helps to differentiate samples that do not compare favorably with the ideal. Once students develop confidence in recognizing the flavor of the so-called perfect or near-perfect milk, they practice with prepared samples as shown in the Appendix of this book. For the beginning or initial sessions, milk samples are prepared at the suggested or higher concentration for easiest recognition. After several sessions, when the specific off-flavor is usually readily recognized, the concentration of prepared samples is gradually lowered to make the identification of the given off-flavor more difficult, thus increasing the students' levels of perception. These training sessions are repeated as often as possible and as necessary to help students to become more knowledgeable and confident in detecting those flavor defects that are difficult to identify. Additional helpful activities conducted during the training are the following: (1) the sample is smelled before it is tasted; (2) the length of time of retaining the sample in the mouth is similar for every sample (about 4–6 s); (3) the sample tested is not swallowed during practicing; and (4) the mouth is reconditioned by cleaning and rinsing frequently with clean, warm, or tepid water.

5.10 Tracing the Causes of Milk Off-Flavors: A Guide

The examination of innumerable milk samples for off-flavors has disclosed that certain understandings and techniques are helpful in diagnosing the causes or factors contributing to the formation of milk flavor defects. The causes of most milk flavor defects can be classified in one of several ways. Recognizing the more distinguishing characteristics of each possible defect should help the field person, plant superintendent, or quality control person to trace the given off-flavor to its source; from here, hopefully, the cause may be eliminated or at least minimized.

Distinguishing Characteristics of the General Causes of Off-Flavors Different groupings or classifications of the causes of milk off-flavors have been suggested, including the one mentioned previously in this chapter (absorbed, bacterial, chemical, and delinquency). The following classification, modified from those offered by Hammer (1938) and reviewed by Bassette et al. (1986), may be the most comprehensive:

Bacterial growth
Feed or weed
Absorption (direct and indirect)
Chemical composition of milk
Processing and handling of milk
Chemical changes (enzymatic and catalytic)
Addition of foreign material

Each of these groups of off-flavor causes has some unique or distinguishing characteristics, which aid in the eventual identification of the flavor defect. From this point, hopefully, the source(s) or the "trigger(s)" for the flavor problem can be pinpointed and remedial action taken to eliminate, or at least minimize, the impact of the given flavor defect. The general distinguishing characteristics of the above grouping of milk off-flavors are summarized in Table 5.8.

Table 5.8 Distinguishing characteristics of milk off-flavors by category

Cause of off-flavors	Distinguishing characteristics of off-flavors
Bacterial growth (typically, 3.0–5.0 × 10^6 CFU/ml)	High bacterial count in raw milk. The standard plate count of pasteurized milk will be high if the bacterial growth occurred after pasteurization
Feed or weed	Bacterial count low; usually off-flavor is present when milk is drawn; commonly more intense in evening milk; occurs when cows have had access to offending feed shortly before milking; odor pronounced (except bitterweed)
Direct absorption	Encountered infrequently; occurs after long exposure of the milk to an odiferous atmosphere; odor not present when milk first drawn or handled. Some types of containers are pervious to highly odiferous substances
Indirect absorption (from cows breathing foul air)	Bacteria count usually low; odor of milk suggests "uncleanliness"; odor present when milk is first drawn from the cow. Milk may smell "barny"
Chemical composition of milk	Flavor defect is noticeable when the milk is first drawn; milk may be distinctly salty or cowy; inherent to individual animal, rarely noted in mixed milk; defect more likely from an animal in advanced stage of lactation, with an udder infection, or diseased condition
Processing and handling of milk	Pasteurized "heated" or "cooked" flavor. A sulfur-like odor detectable immediately after processing; flavor tends to disappear with increased storage time
Chemical changes	Off-flavor not present when milk is first drawn; develops readily at low temperatures—Below 4.4 °C (40 °F); bacteria usually low *Three types* (1) Rancidity—In raw milk; bitter, soapy off-flavor; defect more intense in cream than in milk and more intense in butter than in cream (2) Oxidized—Occurs most often in raw and unhomogenized pasteurized milk; cardboardy; metallic; tallowy; odor similar to wet cardboard (3) Light induced—In pasteurized milk exposed to light; odor suggests "burnt" protein
Addition of foreign material to milk	Defect present in either raw or pasteurized milk; rarely increases in intensity during storage; taints varied; may resemble brine, medicine, paint, insecticides, or any other chemical substance with which the milk may have been contaminated

From: Bodyfelt et al. (1988)

Troubleshooting Causes of Off-Flavors To eliminate or minimize the occurrence of a milk flavor defect, its cause or source must first be identified. To find the possible cause, the milk judge should attempt to review the sensory problem by seeking answers to a number of questions, such as those enumerated in Table 5.9.

Although any of the flavor defects discussed may be encountered by the fluid milk industry, the most frequent consumer complaints relate to the keeping quality of milk and cream. Unfortunately, psychrotrophic bacteria are common post-pasteurization contaminants that can easily produce objectionable spoilage

Table 5.9 A list of questions to facilitate the troubleshooting of sensory problems related to milk (order not prioritized)

1.	What does the off-taste of the milk in question resemble?
2.	Can customer complaints be categorized as (1) occasional or (2) general?
3.	Is the defect limited to the raw milk or does it occur following separation (with particular fat levels) and/or pasteurization?
4.	Does the defect occur sporadically or has it persisted over an extended period of time?
5.	Is the defect present immediately after the milk is drawn from the cows?
6.	If the defect is not present when the milk is first drawn, how long does it take to develop a definite intensity?
7.	What are the bacteria, coliform, and/or SPC counts of the milk? Somatic cell count (not bacteria)?
8.	Does the defect occur in commingled milk or only in the milk from individual cows or individual herds (producers)?
9.	What kind and amount of roughage is fed to the cows?
10.	How much time elapses between the time of feeding the roughage and the milking time?
11.	Has the milk come in direct contact with any copper or rusty equipment (also consider CIP, COP, and employee bracelets)?
12.	Do farm water supplies, feeds, or mineral rations include elevated levels of copper, iron, or manganese levels (do not assume—have them checked)
13.	How long has the milk been held in refrigerated storage?
14.	What is the storage temperature history of the milk?
15.	In what type and/or size of containers does the defect develop?
16.	Do various microbiological test results or keeping-quality tests reveal any potential problems?
17.	Can line-sample tests (microbiological results) pinpoint the source of the problem?
18.	Is the milk harvesting equipment sound and functioning properly (no air leaks or excessive agitation)?

These are meant as possible and general questions, depending on circumstances to help resolve issues/problems, not readily “prioritized,” but may have a more “logical order”

off-flavors such as the fruity, unclean, rancid, and bitter off-flavors. With the increased usage of transparent or translucent plastic milk containers, the light-activated off-flavor has become more prevalent (Hough et al. 2002; Molina et al., 2009; Solano-Lopez et al., 2005; van Aardt et al., 2005).

The Seasonal Occurrence of Flavor Defects An awareness and knowledge of the general occurrence of certain milk flavor defects at different months of the year may be helpful in determining the cause. These seasonal differences in milk flavor hinge on the availability of different feeds and on the stage of lactation (Tracy et al., 1933; Stadhouders, 1972; Kilic & Lindsay, 2005; Potts & Peterson, 2018). Also, dry lot feeding (with either none or minimal pasture or green feeds) has become quite prevalent with US dairy producers. Flavor defects of milk from dry lot-fed cows may occur at any time. Increasingly, the stage of lactation also has become less of a factor, as cows are bred to freshen year-round to maintain production quotas throughout the calendar year. The off-flavors closely associated with dry lot feeding are the oxidized, rancid, and feed (silage) off-flavors. Late lactation tends to promote the rancid and salty off-flavors of milk. The evaluator should be alert to the possible occurrence of any flavor defect, regardless of the season.

Organic Milk Flavor The recent interest for organic milk that requires use of pasture for dairy cattle was discussed earlier in this chapter. The interest for organic milk is related to the perception that grass-fed cow's milk has additional health benefits by increasing the unsaturated fatty acid content, including conjugated linoleic acid (CLA). Although the merits of organic milk are still disputed, it is expected that feed may influence composition and flavor of fluid milk. A few studies have investigated the composition of organic milk and compared it with conventional fluid milk. Samples from 31 organic dairy farms were analyzed for gross composition and somatic cells, fatty acids, urea, iron, and selenium contents. Results showed small or no differences in the parameters investigated between organic milk and milk from conventional farms (Toledo et al., 2002). Concentration of contaminants lead and cadmium was very low and did not differ between organic and conventional milk. However, aflatoxin M1 in some but not all samples of organic milk were significantly higher than those found in conventional milk (Ghidini et al., 2005). Ellis et al. (2006) reported that organic milk had a higher proportion of polyunsaturated fatty acids relative to monounsaturated fatty acids and of n–3 FA than conventional milk. Organic milk contained a consistently lower n–6:n–3 FA ratio that is considered beneficial to human health. The study concluded that there was no difference between organic and conventional milk with respect to CLA or vaccenic acid content (Ellis et al., 2006). Slight differences in the content of n–3 fatty acids were found in organic and conventional milk. Organic milkfat contained >0.56% C18:3 n–3, whereas conventional milk contained 0.53% (Molkentin & Giesemann, 2007).

Croissant et al. (2007) identified greater percentages of unsaturated fatty acids, including two common isomers of conjugated linoleic acid in milk from cows fed with pasture-based forage. Analytical results showed differences in the composition of organic and conventional milk. However, these differences may or may not be detected through sensory analysis. Trained panelists that compared sensory properties of pasture-based milk with conventional fluid milk identified greater intensities of grassy and cowy/barny flavors in pasture-based milk compared with conventional milk when evaluated at 15 °C. However, consumers were unable to differentiate between the two types of milk consistently when evaluated at 7 °C, and cow diet had no effect on overall consumer acceptance. The authors concluded that there were distinct flavor and compositional differences between conventional and pasture-based milk, but the differences were such that they did not affect consumer acceptance (Croissant et al., 2007). Currently, organic milk is not judged in the Collegiate Dairy Products Evaluation Contest.

The Flavor of Milk from Individual Cows Milk from individual cows tends to differ in flavor and in its susceptibility to the development of certain off-flavors, especially the oxidized and rancid off-flavors. Theoretically, a relatively high proportion of cows within a herd, whose milk is susceptible to the oxidized or rancid off-flavor, could cause a whole shipment of milk to develop these off-flavors. Usually, however, there is an adequate dilution with normal milk, so that no apparent problem may be encountered due to the shortcomings of one or several cows. On rare occasions, the plant field person may elect to trace the possible source of a given flavor problem to individual cows. However, with large dairy herds, this can be a formidable task; unfortunately, little research has been conducted on heredity factors and their possible effects on milk flavor.

5.11 Chocolate Milk

Of the flavored milk products (including low-fat milk and skim milk), chocolate milk is by far the most popular one in the USA (Mahato et al., 2021; Thompson et al., 2004). Dairy product judges are frequently asked to evaluate these products, although it must be remembered that chocolate character and intensity, color, and viscosity are a matter of consumer preference in a given market. Since it would be presumptuous for the judge to tell consumers what to like and dislike, product evaluation should allow for a wide range of differences in sensory properties that merit a "no criticism" judgment. On the other hand, actual milk off-flavors and other apparent or obvious sensory defects should be noted. Chocolate flavoring tends to mask (cover up) some of the off-flavors that might be present in milk, but any serious ones may be detected. Sour (high acid) chocolate milk, for instance, is perceived as extremely unpleasant by most consumers of this product.

The examination of the container and closure of chocolate milk products should be conducted similar to the approach used for judging milk. These packaging items are subject to the same defects and are given a corresponding evaluation. In evaluating the other qualities of chocolate milk, however, an entirely different set of standards is usually employed. Emphasis is placed on the appearance, color, viscosity, flavor, and freedom from cocoa sedimentation.

Appearance Chocolate milk should show a uniformity of appearance throughout. The defects in the appearance of chocolate milk with which the judge should be familiar are (1) stratification, (2) mottled or curdy, and (3) the presence of air bubbles. These defects should be recognized easily, but when they are present to a slight degree, they may often be overlooked in a casual examination of the product.

Color Chocolate milk may vary widely in its color, but the product should probably not be criticized in this respect if the color ranges from a light to a reddish-brown color, such as ordinarily associated with certain cocoas or chocolate. The intensity of color should neither be so light nor so dark as to lack visual appeal. Possible defects of the color of chocolate milk are (1) unnatural, (2) too light, (3) too dark, and (4) lack of uniformity.

Viscosity Wide differences in opinion exist as to the most desired viscosity for chocolate milk. Some persons believe that chocolate milk should have the same viscosity as normal milk. Other people prefer a thick, more viscous product. When a small percentage of product stabilizer is added, elevated heat treatment is used, and/or the product is homogenized, the chocolate milk will be more viscous than regular milk. Development of a very thick viscosity that the chocolate milk pours like syrup is not desirable nor is a body that creates a “slick” sensation when placed into the mouth. Acceptance of a slightly increased viscosity to inhibit creaming is typical, but a heavy, viscous product should probably be criticized by the evaluator(s).

Flavor Chocolate milk should have a chocolate flavor similar to that of fresh, high-quality chocolate candy. The sweetness should be of medium intensity, so the appetite will not be quickly satiated. Different varieties and manufacturing processes of cocoas and chocolate liquors may be used in the preparation of the syrup or flavoring material for use in chocolate milk. Various attempts may be made to enhance or fortify the chocolate flavor by the addition of one or more of the following adjuncts: malt, salt, vanilla, cinnamon, nutmeg, or other spices; consequently, a variety of flavor notes may be observed. Furthermore, the type of sweetener used may impart a non-chocolate flavor; molasses and excessive corn syrup are examples. Flavor defects of chocolate milk that may be encountered are (1) unnatural, (2) too sweet, (3) lacks sweetness, (4) syrup flavor, (5) lacks chocolate, and (6) harsh (or coarse) chocolate. It should be borne in mind by the evaluator of any chocolate-flavored products that different consumers prefer different types and levels of sweetener and chocolate (Thompson et al., 2004).

Sedimentation The “settling out” or precipitation of chocolate and cocoa solids in chocolate milk is quite common. While not particularly objectionable, it does have the disadvantage of contributing to an unfavorable appearance. In aggravated cases, the dark chocolate can form a distinct layer (or strata) under a light “white-livered” upper layer. Furthermore, the consumer is then obliged to agitate the milk vigorously to make the product homogeneous.

In judging chocolate milk for cocoa sedimentation, the evaluator should raise the bottle slightly above the level of the eyes. Next, the judge should note the amount of sedimentation, the quality or fineness of cocoa sediment, and the ease or resistance with which it remixes with the milk. Homogenized chocolate milk generally shows more tendency toward sedimentation than the same product that has not been homogenized. Sedimentation of chocolate milk in paper containers may be ascertained to an adequate degree of accuracy by first carefully decanting the liquid and then observing the inside bottom of the container.

A more quantitative way to measure sedimentation is to pour the agitated contents of a carton of fresh product into a transparent graduated cylinder and then store this test sample in a refrigerator for the shelf-life period of the product. Observations can be made at appropriate intervals, and the extent of cocoa sedimentation quantitated, if desired.

5.12 Cultured Fluid Dairy Products

Cultured buttermilk and kefir are two fermented fluid milk beverages. Cultured buttermilks may be made from whole, low-fat, or fat-free milk that has been either pasteurized or ultra-pasteurized and then cooled to optimum incubation temperature and carefully inoculated with specifically selected acid and aroma-producing lactic starter cultures (e.g., *Lactococcus lactis* ssp. *cremoris*), allowing it to ripen for 4–6 h (until a pH of approximately 4.6). The fermentation conditions, the substrate requirements, and the ultimate flavor profiles are the same or quite similar. An exception is the manufacture of Bulgarian-style buttermilk, which is traditionally made with whole milk and is inoculated with a *Lactobacillus* sp. and/or *Streptococcus thermophilus* (Bodyfelt et al., 1988) and is generally more acidic (often ≥1.0% titratable acidity) (Table 5.10). The product is then homogenized and packaged. Whatever the specific composition or the lactic culture utilized, the consumer generally expects a smooth and viscous product with a moderate to distinct acidity and preferably a delicate, buttery aroma. The standards of identity related to milkfat, total solids, and titratable acidity for various cultured milk products are shown in Table 5.10.

Kefir is a slightly alcoholic fermented milk product that is traditionally produced by the fermentation of water or milk by microorganisms present in the kefir grain matrix. Kefir has been consumed for centuries in certain regions of the world, mainly for its flavor profile and its potential to improve human health. Recently, consumers are incorporating kefir into their lifestyle as a fermented probiotic beverage that can confer health benefits (Metras et al., 2021). Kefir is categorized by the FDA Code of Federal Regulations Title 21 (Code of Federal Regulations, 1998) as a cultured milk that contains aroma- and flavor-producing microbial cultures.

Dairy kefir is prepared at artisanal level by adding kefir grains (5–10%) as the starter culture to whole, semi-skimmed, or skimmed pasteurized goat, sheep, camel, buffalo, or—most commonly—cow milk. Fermentation takes place at 20–25 °C for approximately 24–72 h. At an industrial scale, kefir is produced by either milk

Table 5.10 Standards of identity for cultured milk products (Kosikowski & Mistry, 1997)

Product name	Composition[a]
Acidified milk[b] Cultured milk[c]	≥3.25% milkfat ≥8.25% solids not fat ≥0.5% titratable acidity
Acidified low-fat milk Cultured low-fat milk	≥0.5% < 2.0% milkfat ≥8.25% solids not fat ≥0.5% titratable acidity
Acidified skim milk Cultured skim milk	<0.5% percent fat ≥8.25% solids not fat ≥0.5% titratable acidity

[a]Optional ingredients for all products include color, salt, citric acid, stabilizers, and flavoring
[b]For acidified products, acidifying agents other than cultures are permitted
[c]Cultured products are made using the appropriate microbial cultures

fermentation with pure freeze-dried commercial kefir culture or, by the "Russian back slopping method," a serial process that starts from the kefir production with grains and is followed by subsequent fermentations with the fermented milk obtained from the grains as a starter (Gonzalez-Orozco et al., 2022).

Sensory attributes of buttermilk and kefir are conferred by the reactions that take place during the fermentation process. Milk lactose is degraded to lactic acid by the lactic acid bacteria present. The lactic acid production causes a drop in the pH (4.0–4.6), which confers a sharp acidic flavor (Gonzalez-Orozco et al., 2022). In the case of kefir, ethanol (0.5–2.0%) and CO_2 are also produced and give kefir a prickly sensation; other aroma-flavor compounds like aldehydes, diacetyl, acetic acid, and propionic acid are also generated during fermentation. Yeasty flavor has also been described as part of the typical flavor of kefir (Irigoyen, 2005).

5.13 Other Uncultured Fluid Dairy Products

Included in this category are skim milk, low-fat milk, half-and-half, light cream, light whipping cream, heavy cream, as well as lactose-free milk, ultrafiltered milk, and other flavored milks (e.g., vanilla, strawberry) of varying fat content. Federal Standards of Identity for these products permit the addition of specific optional ingredients, including characterizing flavors. Many possible products, therefore, are included within this group. As emphasized in the previous discussion on chocolate milk, flavored products can be evaluated for quality, but appropriate allowances must be made for differences in consumer preference. The sensory properties of various unflavored milk products may be assessed by applying the milk scorecard and scoring guide, with a few modifications.

Additional evaluation categories may be desirable for some of these products, particularly in the case of those that have certain functional properties. A logical test for whipping cream is a determination of its whipping properties, since even the best-flavored whipping cream is of little value to the consumer if it will not whip. Certainly, the coffee "whitening power" and freedom from "feathering" in coffee cream (half-and-half) or light cream are important functional properties.

Obviously, cream and skim milk typically taste different from each other, as well as different from whole milk, but this fact is of little consequence in the evaluation for quality. The judge must memorize or "bear in mind" the normal or typical flavor and criticize the product only when flavor defects are present. Generally, many of the same off-flavors may be found in skim milk, low-fat milk, whole milk, and the various creams. They may appear to have different characteristics, but much of that is due to the different flavor background. Flavor-producing chemical compounds that are fat soluble are more concentrated in cream than in skim milk. Since the concentration of an odorant may influence both the intensity and qualitative characteristics of the odor, one may expect to perceive the same off-flavor somewhat differently in skim milk than in cream. Similar reasoning would also apply to aromatic compounds that exhibit greater water solubility. This reasoning helps explain flavor perception differences in low- and high-fat products. In any case, most of the defects in low- or high-fat products will be readily recognized by an evaluator familiar with these off-flavors in milk.

Skim Milk The CFR description of skim milk was given earlier in this chapter. The product can vary in fat content from less than 0.1% to just under 0.5%. Milk solids-not-fat (MSNF) may range from 8.25% to 10% or slightly more. Both flavor and mouthfeel characteristics may be affected by the differences in composition within the ranges for fat and MSNF. In a protein-fortified product, the flavor quality of the source of concentrated milk solids can be a significant factor in determining the sensory characteristics of the finished product.

An assumed form of storage flavor commonly encountered in skim milk is variously described as stale, lacks freshness, chalky, or wet paper. The factors responsible for this off-flavor are not known. Skim milk is the test medium of choice for the sensory examination of preparations of vitamin concentrate used in fortifying milk. If a defective vitamin concentrate is likely to impart an off-flavor, skim milk is a more sensitive detection medium than higher fat milk.

A hay-like off-flavor was first reported by Weckel and Chicoye (1954) in low-fat milk fortified with vitamin A. Fluid milk processors continue to occasionally experience puzzling off-flavors in vitamin-fortified milk, apparently caused by the autooxidation of vegetable oil carriers for the vitamin concentrates. The most common descriptors used by evaluators (when this off-flavor is noted) is hay-like or a peculiar stale note. Low-fat milk and skim milk seem to be more vulnerable than homogenized milk to this off-flavor, which may be imparted by sporadic "off-batches" of vitamin concentrate.

Low-Fat Milk The CFR definition for low-fat milk was provided earlier in this chapter. Since the milkfat content may vary from 0.5% to 2%, the sensory properties of low-fat milk may be similar to skim milk at one extreme or approach the properties of milk at the upper end of the fat range. The label declaration must clearly specify the actual milkfat content to the closest 0.1%.

Half-and-Half Half-and-half is basically defined in the CFR Title 21 Part 131.180 as that food that consists of a mixture of milk and cream, which contains milkfat specifically limited to the range of 10.5–18%. It is either pasteurized or ultra-pasteurized and is practically always homogenized. Optional ingredients may include "safe and suitable" emulsifiers, stabilizers, nutritive sweeteners, and "characterizing flavoring" ingredients (with or without coloring), which could include fruit, fruit juice, and/or natural or artificial food flavoring. The majority of half-and-half on the market is pasteurized, homogenized, and unflavored. The principal uses of this product are as coffee cream and as a cereal or fruit topping.

The sensory qualities of half-and-half should be evaluated with the same approach used for milk; the evaluator should be alert for the same defects. Factors that may impact quality, but which are not typically listed on the milk scorecard are appearance (possible cream or oil separation or a cream plug); viscosity (appropriate for the product of a given composition), this is the same for milk; and feathering (or other developed defects when added to coffee).

The viscosity of half-and-half may be measured instrumentally, by the use of one of several commercially available viscosimeters. Since viscosity is substantially influenced by sample temperature, all measurements must be made at a standardized temperature. The logical temperature to use is 4.4–10 °C (40–50 °F) since this is the typical temperature range at which the consumer will subsequently use the product and observe the viscosity. Both the instrument and the sample should be tempered to the preset standard temperature for conducting the viscosity measurement.

There are three possible defects that may be noted when half-and-half is added to hot coffee: feathering, oiling-off, and off-color (in coffee). Of these, feathering is probably the most commonly encountered and the most objectionable.

Feathering Feathering of cream is considered a defect that develops by formation of undesirable particulates when cream is added to coffee. Cream feathering is related to the acidity of the environment, the use of high homogenization pressures, and heat processing conditions (Scott et al., 2003; Waldron et al., 2020). Feathering is evident in several ways depending upon the intensity of the defect. Such a product may initially appear immiscible in coffee, wherein the cream may rise in flocculent masses to the surface, and thus reflect a lack of homogeneity. Frequently, this defect appears as a light, evenly serrated scum on the coffee surface, after the coffee, and half-and-half mixture has become quiescent. Occasionally, this defect may be so extensive that most of the added cream rises en masse to the coffee surface immediately after the half-and-half has been poured into it, wherein it may appear like distinct chunks of sour cream. When the homogenization pressure is excessive, the half-and-half may be more susceptible to feathering under certain conditions, particularly when the water used for coffee making has high calcium content. Actually, with half-and-half of normal composition, the susceptibility to feathering is not unduly affected by homogenization, even at high pressures. Creams are stable at pressures up to 13.6/3.4 MPa during homogenization (Elling & Duncan, 1996). However, if the milkfat content is high, and the effect of homogenization (and higher homogenization pressures) becomes more apparent. The susceptibility of light cream (to be discussed next) to feathering is considerably enhanced by higher homogenization pressures. Additionally, half-and-half suffering from elevated titratable acidity (~0.12% as lactic acid) may be more susceptible to feathering. The presence of this developed acidity will be reflected as an acid or slightly sour off-flavor in the product. Unfortunately, regardless of the cause of cream feathering in coffee, the consumer usually believes that the cream is sour; hence, this can represent a rather serious defect of half-and-half.

Feathering can be prevented or reduced by the addition of salts before homogenization that improve the stability of cream in regard to clumping. Sodium citrate, disodium phosphate, and sodium bicarbonate prevent feathering in coffee by acting as buffering agents in cream system. The use of two-stage homogenizers is more effective in improving stability of cream. A total pressure of 20 MPa at 70 °C is applied to have a cream with a low degree of aggregation (Hoffmann, 2011). After a second homogenization step, cream recovers its exhibited resistance to clumping as a more dispersed fat globule system exists therein the emulsion system. In addition, increase of solid concentration, in the form of skim milk powder, diminishes the extent of fat clumping in cream. An increase in solid concentration raises the coagulation point of cream and thus improves its stability regarding heat (Doan, 1931; Geyer & Kessler, 1989; Van Der Meeren et al., 2005). The most practical protocol is to homogenize the cream base at the lowest possible range of homogenization pressures in order to achieve non-cream-line half-and-half products.

Oiling-Off and Off-Color These defects are more apt to occur with light cream than with half-and-half, particularly a cream that tends to have an "oily" body. Freezing of the cream product or improper homogenization contributes to these difficulties. Droplets of butter oil may be noted on the coffee surface, and instead of developing a light brown color, the coffee appears slate gray. Also, on occasion, a cream plug, partial churning, and/or coalescence of fat globules may be observed in the product before its addition to hot coffee. When such destabilized cream is added to the hot beverage, oiling-off (and a possible off-color) is most likely to occur. Preventative measures essentially rely on the utilization of no frozen cream sources and application of the lowest functional homogenization pressures possible.

Light Cream Light cream is basically described in the CFR as a cream that contains not less than 18%, but less than 30%, milkfat. With respect to processing and optional ingredients, the definition of light cream does not differ from that of half-and-half. Imitation "cream" toppings (or "coffee whiteners") and half-and-half have essentially replaced light cream in consumer food service markets. All of the potential defects enumerated for half-and-half also apply to light cream. In fact, light cream is generally even more susceptible to these developed quality shortcomings. The body and viscosity of light cream is somewhat more difficult to control than that of half-and-half; thus, this merits a more detailed discussion.

The body of light cream should be smooth, uniform, and reasonably viscous, given the higher percentage of milkfat than half-and-half. When poured into hot coffee, the cream should be readily miscible and exhibit neither "feathering" nor "oiling-off." It should impart a pleasant color to the coffee. Some body defects are readily apparent to the eye, while others may require physical examination of the cream and/or tests that employ the use of hot coffee. The more common body defects of table cream that are readily apparent by direct visual examination are listed in the following paragraphs.

Cream Plug Within various cream products, a cream plug may be exhibited by the following: (1) a lack of uniformity in the cream, particularly at the surface; (2) a layer of frothy and sometimes heavy cream that adheres to the bottle closure; (3) butter particles on the surface of the cream; and/or (4) a distinct, heavy, leathery milkfat plug that obstructs the flow of cream from the container. A cream plug should not be confused with "ropy cream," which is a bacterial spoilage defect of somewhat similar appearance. Cream displaying a definite cream plug often has a distinctly thin body throughout the remainder of the product. When such cream is poured into a hot coffee, droplets of milkfat are generally noted on the surface. This defect varies widely in its intensity. The various intensities of the cream plug defect listed in increasing order of relative defect seriousness and degree of being objectionable because of cream functionality issues are a foamy plug, a large mass soft plug, a buttery-like plug, and a firm leathery-like textured plug.

Oiling-Off The occurrence of oily cream is inclined to be seasonal; it is observed more frequently when cows have just been placed on pasture or green grass. In reality, this defect is closely associated with the cream plug defect; in the aggravated state of oiling-off, a cream plug invariably forms. Cream that has this defect generally appears shiny and usually has a thin body. The presence of a distinct skim milk layer is commonly found with oily cream. As far as prevention or control of the "oiling-off" defect of whipping cream (should it occur) is concerned, a gradual incorporation of green-feeds-produced milk to the overall plant milk supply may suffice to prevent or resolve this product defect.

Separation of a Skim Milk Layer The separation of a skim milk layer is more common within the lower-fat-content cream products. It results from the rising of fat particles (creaming-off). The defect is best described as a bluish, watery-like layer that may be from one-sixteenth to one-half inch in depth, at the bottom of the product container. Its presence in cream connotes to the customer a dilution of the product with skim milk. Presumably, this cream product deformity can be minimized or prevented by assuring the use of only fresh cream sources and assuring gentle cream-handling practices (i.e., restricted pumping, agitating, and no air leaks).

Two qualities must be considered in observing the serum or skim milk layer of cream, namely, the depth of the layer and its distinctness. The latter quality seems to be the more serious of the two. A relatively obscure, deep skim milk layer is probably less objectionable to a consumer than a distinct, shallow layer that displays a pronounced line of demarcation.

Certain associations with a skim milk layer may be noted in cream. Usually, cream with this defect does not exhibit a thin body, but instead manifests a relatively viscous body, considering the amount of fat present. Sometimes an old, stale, or oxidized off-flavor may be noted and associated with a cream displaying this particular body defect. The skim milk layer in light cream becomes more distinct upon extended storage time.

Thin Body Thin appearing body is a quite common body defect of some light creams. It is evidenced by a tendency to drip as it is slowly poured from the container and/or a tendency to definitely "splash" (similar to milk) as the product is poured onto a flat surface, from a distance of 6 in or more. Thin body may sometimes be associated with the cream plug defect, but it will rarely be associated with the separation of a skim milk layer. While this defect may be objectionable on the basis that it suggests to the cream customer a low milkfat percentage in the cream, it is not as serious as certain other body defects.

Defects such as a cream plug, oily cream, and the separation of a skim milk layer can also occur in light cream that is packaged in paper. However, these conditions cannot be observed within an unopened container. The cream itself must be examined, sometimes after decanting the product into a glass container (such as a graduated cylinder) and storing for a time period sufficient for this defect to reform itself within a quiescent state. If cream marketed in paperboard cartons has a thin body, this defect may sometimes be detected (by those individuals with a "trained ear") by shaking the container and carefully noting an apparent difference in sound.

Whipping Cream The CFR recognizes light whipping cream and heavy whipping cream. Except for their respective milkfat contents, the definitions for these products do not differ from those of light cream and half-and-half. Light whipping cream must not have less than 30%, but less than 36%, milkfat. The fat content of heavy cream must not be less than 36%. Whipping cream constitutes a modest volume of the annual total production of Grade A milk and cream products in the USA. However, demand for the various types of whipping creams peaks dramatically during the US seasons of Thanksgiving and Christmas through the New Year's holiday. Interestingly, many US dairy processors no longer produce whipping cream products due to substantially lower demand for the majority of the year, as well as experiencing excessively long storage times which can lead to substantial product losses due to spoilage. The serious potential spoilage problem is deemed to be best assumed by specialized plants that produce ultra-pasteurized versions of whipping cream and then solicit the same milk processors to serve as product distributors of these ESL specialty products. Additionally, much of the US sales for whipping cream products have been lost recently to imitations and substitutes, which come in many forms: powders, frozen, frozen pre-whipped, and toppings in pressurized containers.

In general, a highly desired whipping cream possesses a clean, sweet, nutty flavor, a relatively heavy body (which is uniform throughout), and a smooth texture. The flavor, bacterial count, sediment, container, and closure features and defects may be the same or similar to those encountered in milk, half-and-half, and light cream. The most critical quality criterion is a whipping test. When performed under standardized conditions, it should provide data on the required time to produce the desired stiffness and appearance of whip; whether or not the desired stiffness and dry, velvety appearance is achievable; an estimate of the final overrun; the stability of the whipped cream; and the mouthfeel properties of the whipped cream.

Fat Content of Whipping Cream As long as the percentage of fat in whipping cream conforms to the legal milkfat standard, the product cannot be faulted, despite the possibility of higher percentages of milkfat in other samples. Most research workers concur that the percentage of milkfat in whipping cream should be between 30% and 35%. Such a cream should be expected to respond to whipping and to subsequently yield a reasonably stiff, stable, whipped cream of typical overrun (approximately 100–200%).

Body Defects of Whipping Cream Whipping cream is subject to the same general body defects as light cream, but to different degrees of intensity. The viscosity of whipping cream, although higher than light cream, may sometimes be too low, given the higher percentage of milkfat present; cream plug defects may be accentuated; serum separation may be reduced to a minimum; and the feathering and oiling-off problems (of the lighter creams) may be of little or no consequence.

Whipped Cream from Pressurized Containers A specially formulated whipped cream dispensed from pressurized containers is commonly used by the general retail market. Product formulation, type of propellant gas (usually N_2), and the design of the container and valve are under proprietary control. Upon release of the gas, a saturated, pressurized cream is formed and removed through a special valve. The cream seemingly explodes instantly into a relatively stable, sometimes almost frothy, product similar to traditional whipped cream. The increase in volume is proportional to the pressure at which the cream is saturated before being released; the volume is independent of the milkfat content. The quality criteria for this product are the same as those for whipped cream prepared by traditional methods, namely, flavor, stiffness, dryness, stability (as exhibited by resistance to air cell collapse and drainage or leakage), and overrun.

Eggnog Part 131.170 of Title 21 of the CFR describes eggnog as the food containing one or more of a set of listed dairy ingredients (cream, milk, skim milk, or partially skimmed milk), one or more of the optional ingredients that provide egg yolks (liquid, frozen, or dried egg yolks or whole eggs), and one or more of the listed nutritive carbohydrate sweeteners (sugar, invert sugar, brown sugar, high-fructose corn syrup, and others). Other optional ingredients for eggnog include certain other milk-derived products, such as nonfat dry milk, whey, lactose, etc.; salt; flavoring ingredients; color additives (except those that impart a color simulating egg yolk or milkfat); and approved stabilizers. All ingredients used must be considered safe and suitable. Eggnog must contain not less than 6% milkfat and not less than 8.25% MSNF. The egg yolk solid content of eggnog must not be less than 1% by weight of the finished food. The product must be pasteurized or ultra-pasteurized and may be homogenized.

Important components of the sensory quality of eggnog are flavor, body (consistency), and product appearance (Feet et al., 1963; Hedrick et al., 1962). As in other flavored milk or cream products, consumer preference plays an important part, but typical milk-related off-flavors can arise and become a quality problem. Since milk and its derivatives make up the major portion of eggnog, the evaluator should be alert to any off-flavor or flavor deterioration that may occur during processing and/or storage. The potential off-flavor concerns of eggnog probably more closely resemble those of ice cream than of milk or cream (see Chap. 6 for details).

There seem to be differing views as to the most desired viscosity of eggnog, but industry authorities generally agree that the body should be smooth, somewhat thicker, or heavier than milk, and uniform throughout. The color should be characteristic of eggs and cream, and if particles of sweet spices have been incorporated into the product, they should be uniformly distributed.

5.14 Conclusion

Sensory evaluation of milk and cream products can be the simplest, most rapid, and direct approach to identify their quality and sensory attributes. It is generally conceded that evaluating milk demands well-developed senses of smell and taste. Due to the complexity of the products and for accurate evaluations, it is necessary first to have a good understanding of how the attributes that determine the quality and acceptability of the finished products are associated with their physical, chemical, and microbiological characteristics as well as with the processing conditions. These subjects were presented in detail in this chapter along with some materials and techniques that can be used by coaches or dairy plant personnel. However, an important aspect to keep in mind is that being familiar with sensory evaluation techniques and knowing how to use the grading scorecards is not enough. Experienced grader/taster(s) develop the necessary skills by training and practicing continuously. Upon successful training, personnel or students should be able to discriminate between desirable and undesirable products, trace the causes of an existing or potential problem, and establish corrective actions.

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Chapter 6
Butter

Robert L. Bradley and Marianne Smukowski

6.1 Introduction

The product known as "butter" was defined by the US Congress in 1923, to comply with the requirements of the Food and Drug Act of June 30, 1906 (USA Congress, 1923). Following that definition (US 7 CFR 58.305; US FDA, 2021), and for the purpose of this book, "butter" means the food product usually known as butter and which is made exclusively from milk or cream, or both, with or without common salt, and with or without additional coloring matter, and containing not less than 80% by weight of milkfat, all tolerance having been allowed for.

Butter is generally marketed in the USA according to its quality grade. These butter grades are based on sensory quality and are assigned by competent "official" graders who conduct prescribed sensory examinations of the product. The standards for US grades of butter are addressed in Title 7 of the Code of Federal Regulations, Part 58, and Subpart B (US FDA, 2021), and in the US Standards for Grades of Butter (USDA, 1989). Although there are known regional preferences for certain flavor characteristics, body and texture properties, salt levels, color intensity, and shape and style of package, the basis for the sensory scoring or assessing butter quality remains uniform across the USA.

In addition to milkfat, butter contains moisture, curd (milk proteins, milk minerals, lactose, and other minor constituents), and common salt (usually). Thus, the

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possible off-flavors of butter are not necessarily limited to those associated with milkfat, but flavor defects may also result from the previous action of microorganisms on milk proteins, milkfat, lactose, and/or storage conditions.

Farm-churned butter was once a major source of the US butter supply, but for all practical purposes, this form is nearly extinct. The primary method of manufacturing butter has gradually changed from the traditional batch process to the continuous method of churning. Industry trends are for an increasingly higher portion of butter churned by the more efficient continuous process and for "lightly salted" butter (1.0–1.5% added NaCl).

This chapter will describe the different kinds of butter, grades of butter, techniques for butter grading, evaluation of butter quality, body and texture characteristics, and flavors of butter.

6.2 Ingredients for Buttermaking

A typical butter manufacturing facility starts with fresh milk, which is separated at the plant, or cream transported in as the raw material for buttermaking. During the first half of the twentieth century, farmers typically sold milk and cream to cream-buying stations, which in turn supplied the butter manufacturing plants. At the creamery receiving platform, the milk, and cream had to be carefully graded, since most of it came from small producers who produced the milk and cream over a period ranging from several days to a week. Frequently, only slight attention was given to the cleanliness of the cream separator, utensils, and containers or to the storage temperature of the raw cream and milk.

The vastly improved quality of current US butter supplies is primarily due to the "fresh milk system" of the creamery operation. As the overall quality of the US milk supply continued to improve, low-grade butter has essentially disappeared (Hunziker, 1940; Wilster, 1968).

6.3 Types of Butter

Sweet Cream Butter The majority of the butter in the US market is the "sweet cream" variety. The "sweet cream" designation implies that the apparent titratable acidity of the churning cream did not exceed 0.10% (measured as lactic acid). Currently most cream probably has no "developed acidity." Bulk forms of sweet cream butter that are free of off-flavors normally receive US grades AA, A, or B (when graded), which are described in Sect. 6.5 and Table 6.1 (USDA 1989).

Cultured Cream Butter "Cultured cream butter" is made starting with high-quality sweet cream in which a pleasant delicate aroma was developed by the addition of lactic acid bacteria starter culture prior to churning. The cream is inoculated with a

Table 6.1 USDA classification of flavor characteristics (USDA, 1989)

	Flavor classification		
Identified flavor	AA	A	B
Feed	S[a]	D	P
Cooked	D	–	–
Acid	–	S	D
Aged	–	S	D
Bitter	–	S	D
Coarse	–	S	–
Flat	–	S	–
Smothered	–	S	D
Storage	–	S	D
Malty	–	–	S
Musty	–	–	S
Neutralizer	–	–	S
Scorched	–	–	S
Utensil	–	–	S
Weed	–	–	S
Whey	–	–	S
Old cream	–	–	D

[a]*S* slight, *D* definite, *P* pronounced, "–" not applicable

carefully selected lactic culture for the production of desired aromatic compounds. Cultured cream butter can usually be distinguished by its distinct aroma of diacetyl and other pleasant volatile compounds. Properly made, cultured cream butter has a delicate flavor that is sometimes referred to as "real butter flavor." Some "cultured" butter is made improperly or by a "short-cut" method by adding either starter or starter distillate to the butter at the time of salting and by directly working it into the butter.

Salted Butter The addition of salt to butter is optional as expressed in the Standard of Identity (US 7 CFR 58.305; US FDA, 2021). The salt intensity of butter can vary over a wide range (0.75–2.5%). Most of the butter in the US market is salted and in recent years has been toward more slightly salted (≤1.5%) butter.

Unsalted Butter Contains no added salt and may be made with lactic acid or starter distillate. May have a slight acid note because of the added lactic acid, and this is acceptable. Preferred use for cooking or baking.

Whipped Butter Whipped butter is available for both institutional and home use. The Standard of Identity (7 CFR 58.305; US FDA, 2021) allows for the use of air or an inert gas. The gas (preferably nitrogen) is incorporated by a mechanical whipping process that changes the body characteristics and generally improves product spreadability.

Whey Cream Butter This butter is made from whey cream or a blend of whey cream and regular cream. Whey cream is derived from the separation of milkfat from cheese whey. Whey cream butter has a less desirable flavor character and frozen storage stability than sweet cream butter, the USDA-Dairy Division wants none of this cream in the butter it purchases. The flavor of whey cream butter is somewhat similar to the cheese from which the cream was derived. Most whey cream butter is made from mozzarella, Cheddar, Colby, or Swiss cheese whey cream. However, if the given whey was improperly cared for or the whey cream contains cream derived from Provolone, Romano, Parmesan cheese, etc., the finished butter will be objectionable and undergrade by USDA standards. However, butter containing varying amounts of whey cream is sold in Wisconsin and Minnesota and marked as an A grade for the respective state(s). The unique flavor of whey cream butter is enjoyed and often preferred by many consumers particularly on hot foods such as baked potatoes.

Flavored Butters Sometimes referred to as compound butter, plain butter is mixed with a flavoring, spices/herbs, honey, garlic, onion, bacon, or fruit that is used in the home or restaurants (Fig. 6.1). There may be a concern with the microbial load of the spice/herb addition. When judging or grading these flavored butters, align the samples to be evaluated in order of persistence of flavor. The flavorant should blend compatibly and not overpower the flavor of the butter.

Miscellaneous Spreads Other products which emulate butter are margarine, butter–margarine blends, and "low-fat spreads" made from either milkfat and/or

Fig. 6.1 Butters with herbs, garlic, pepper, and other flavors. (Image: K.E. Kaylegian)

vegetable oil. Vegetable oils are hydrogenated and have differing melting points. Although sensory properties vary widely for all products in this group of "spreads," some generalities still apply for their sensory evaluation. The general prerequisites for high-quality spread-type products are desirable flavor and appearance, the absence of off-flavors, quality of workmanship, and product performance in terms of intended functional properties such as melting, spreading, and non-burning when used for frying.

6.4 Grading Milk and Cream for Buttermaking

Butter made from fresh, sweet cream usually grades higher in sensory quality than those products made from other cream sources (Bodyfelt et al., 1988).

The grade of cream used for buttermaking will reflect the flavor of the butter made from it. Some off-flavors may result from poor quality cream or milk, handling, processing, or churning and are listed in Table 6.1.

There is no advantage in mixing together cream (or milk) of different grades; the most probable result is a reduction in quality of the raw material equivalent to the poorer one. Segregation or rejection of cream by its various grades is a recommended procedure prior to making butter. Due to the potential health hazard of tasting raw dairy products, a laboratory pasteurization procedure should be designed and used for small samples. Developed acidity in cream may require neutralization with approved alkaline chemical prior to pasteurization.

Specifications for cream are defined as follows by the US Standards of Identity and the USDA Butter Grading Standards:

Pasteurization The cream for buttermaking shall be pasteurized either in a vat at a minimum temperature of not less than 165 °F (74 °C) and held continuously at temperature for not less than 30 min or by HTST at a temperature of not less than 185 °F (85 °C) and held continuously for not less than 15 s, or it shall be pasteurized by any other equivalent temperature and holding time which will assure adequate pasteurization (US 7 CFR 58.334; US FDA, 2021).

Sensory Examination Cream received at a receiving plant or substation shall be identified as to the source. Each shipment shall be examined for physical characteristics (floating debris, churned fat), off-tastes, and off-odors. The sensory examination and segregation of the cream used to manufacture butter shall be consistent with the applicable flavor classification of butter set forth in the US Standards for Grades of Butter (USDA, 1989).

6.5 Grades of Butter

Since April 1977, the US Department of Agriculture (USDA) has recognized only three consumer grades of butter, namely, US grades AA, A, and B (USDA, 1989). The US grade C designation was deleted at a time in recognition of the substantial improvements in quality.

The USDA grading system for butter should be examined. The following tables provide an overview of the USDA butter grade scoring. For example, to merit US grade AA, a given butter may exhibit a slight feed or a definite cooked flavor but cannot exhibit any other off-flavors. In the workmanship category (for which pertains to butter body, color, and salt content), a concept known as a "disrating" is used (Table 6.2). For grade AA butter, the total permissible disrating for a "workmanship fault" is only ½ point (Tables 6.3 and 6.4). Thus, for a given butter, the flavor classification may actually be "AA," but the assigned US grade may be lower due to assigned disrating(s) for product workmanship. When more than one flavor is discernable in a sample of butter, the flavor classification of the sample shall be established on the basis of the flavor that carries the lowest classification. When an off-flavor is detected that is not listed in this classification, i.e., rancid (lipase), oxidized, metallic, etc., the grade assigned to that butter is "grade un-assignable" or "below grade."

6.6 Techniques of Butter Grading

The Butter Scorecard The USDA grading system for butter may be inappropriate for some quality assurance activities or for those situations wherein the quality of one product is compared with that of others. A group of products may include some samples for which a US grade is not assignable, but which require identification of defects and assignment of a score that reflects the seriousness of the problem. Useful instruments for assisting in this quality assurance endeavor are scorecards and scoring guides.

An example of a different scoring system is the one used by the National Collegiate Dairy Products Evaluation Contest. This scorecard (Fig. 6.2) is for flavor only, with a perfect score of 10. Body and texture, and appearance and color are not evaluated because product temperature cannot be sufficiently controlled over the duration of the competition and the surface of the butter samples is marred by numerous samplings.

Condition of the Judging Room The room used for scoring butter should always be clean, well lighted, and well ventilated. Ideally, the temperature of the room should be 60–70 °F (15–21 °C). There should be no strong, offensive, or irritating odors within the room or from nearby areas.

Table 6.2 USDA characteristics and disratings for body, color, and salt of butter (USDA, 1989)

	Disratings		
Characteristics	S[a]	D	P
Body:			
Short	–	½	1
Crumbly	½	1	–
Gummy	½	1	–
Leaky	½	1	2
Mealy or grainy	½	1	–
Weak	½	1	–
Sticky	½	1	–
Ragged boring	1	2	–
Color:			
Wavy	½	1	–
Mottled	1	2	–
Streaked	1	2	–
Color specks	1	2	–
Salt:			
Sharp	½	1	–
Gritty	1	2	–

[a]*S* slight, *D* definite, *P* pronounced, "–" not applicable

Table 6.3 USDA flavor classification and total disratings in body, color, and salt characteristics permitted in each grade of butter (USDA, 1989)

Flavor classifications	Total disratings	US grade
AA	½	AA
AA	1	A
AA	1½	B
A	1	B
B	½	B

Tempering Butter The delicate aroma of butter is more readily detected, and the body and texture characteristics are more easily and precisely determined, when butter is at the appropriate temperature. Butter stored at temperatures colder than 50 °F (10 °C) should be moved into the grading room in advance of judging to allow tempering to 50 °F (10 °C). Guidelines for Federal (USDA) Graders state that the temperature of butter at the time of grading is important when determining the true characteristics of body and texture; products should be between 45 and 55 °F (7–13 °C). The required tempering time also depends on the relative size of the butter samples and the temperature of the judging room. One-pound prints will temper in a relatively short time (1/2–3 h), while bulk butter (approximately 55 or 68 pounds (25 or 36.4 kg)) requires a much longer time, like overnight depending on prior storage temperature. Flavor may be evaluated satisfactorily at temperatures above 60 °F (15.5 °C), but the body of the butter is likely to appear somewhat atypical at this higher temperature.

Table 6.4 Examples of the relation of US butter grades to flavor classification and total disratings for body, color, and salt classifications (USDA, 1989)

Example no.	Flavor classification	Disrating body	Disrating olor	Disrating salt	Total disrating	Permitted total disrating	Disratings in excess of total permitted	US grade
1	AA	½	0	0	½	½	0	AA
2	AA	½	½	0	1	½	½	A
3	AA	0	1	0	1	½	½	A
4	AA	½	1	0	1½	½	1	B
5	A	½	0	0	½	½	0	A
6	A	0	½	½	1	½	½	B
7	A	0	1	0	1	½	½	B
8	B	½	0	0	½	½	0	B

Butter			
Flavor	**S**	**D**	**P**
Acid	6	5	4
Bitter	6	5	4
Cheesy	3	2	1
Coarse	9	7	6
Feed	9	8	6
Flat	9	8	7
Garlic/Onion	3	2	1
High Salt	7	6	5
Metallic	4	3	1
Musty	5	4	2
Neutralizer	5	4	3
Old Cream	6	5	4
Oxidized	4	3	2
Rancid	4	2	1
Scorched	7	5	3
Storage	6	5	4
Unclean/Utensil	5	4	3
Whey	6	5	3
Yeasty	4	3	2

Fig. 6.2 Scores designated for flavor evaluation of butter in the Collegiate Dairy Products Evaluation Contest. (https://dairyproductscontest.org/coaches_corner/). *S* slight, *D* definite, *P* pronounced

Fig. 6.3 Example of various types and sizes of butter triers

Use of the Butter Trier Samples are taken by a two-edged, curve bladed tool known as a "trier" (Fig. 6.3). Means for cleaning the trier and disposal of waste butter should be provided. The trier should not be washed in warm water (prior to use, only after use) but should be wiped with a single-service towel or absorbent paper between each sample. Washing the trier in warm water often results in a melted, greasy surface on the first plug of butter taken. This obscures the true condition of the body and makes observation of the color more difficult. Disposal of the refuse should be made promptly after the evaluation is completed.

Obtaining the Sample Since hands will usually come in direct contact with butter during sampling, hands should be thoroughly washed with non-fragrant soap before evaluation. The trier should be cleaned between samples by wiping it with a single-service towel. The number or code of the sample is recorded on the scorecard or grading sheet, and the evaluation process is started. The judge(s) should stand squarely in front of the sample and observe the relative cleanliness and neatness of the package. Next, the cover or packaging material is removed and the sample observed for evenness and neatness of the liner (if present) and/or the squareness of the wrapping material. Also, the surfaces of the bulk butter should be checked for possible discrepancies or quality shortcomings that may have been observed on the trier. The total butter surface should also be inspected for possible mold or yeast growth. The color of the plastic liner should not interfere with the observation of possible mold growth through the liner even though it may be folded over on itself.

The judge should grasp the butter trier firmly in hand and insert the sampling device as near as possible to the center of the butter sample (Fig. 6.4). Some evaluators choose to insert the trier diagonally (at approximately a 45° angle) to gain a better cross-sectional sample. However, considering the way that butter boxes are typically filled, trier insertion straight down at the center is satisfactory. The trier should be turned one-half turn and the plug (core sample) withdrawn with a twisting pulling motion.

Fig. 6.4 Inserting a trier into the center of a block of butter. (Image: K.E. Kaylegian)

Fig. 6.5 Assessing the aroma of butter from the back of trier on a freshly pulled plug. (Image: M. Smukowski)

Sequence of Observations Immediately after withdrawing the plug, and before making any observations for color, the judge should pass the butter sample slowly under the nose, slowly inhale, and note any aroma present. Some evaluators inhale the "fresh" aroma from the back of the trier (Fig. 6.5). Because the metal is usually warmer than the butter itself, this may lead to a clearer sensory observation. A "mental record" of any observed odor should be made by the evaluator. The next step is an examination of the butter sample's color, especially for uniformity. At this point, the judge should examine the body and texture for shortness by pressing the ball of the thumb against the sides of the butter plug (core sample) until it shows a break. The judge should also be concerned with the "nature" of the break, that is, whether it is smooth or jagged. It is important that the judge should note the presence or absence of free moisture (or "beads" of water) on the sample surfaces and the backside of the trier and their relative degree of clarity. Furthermore, the amount

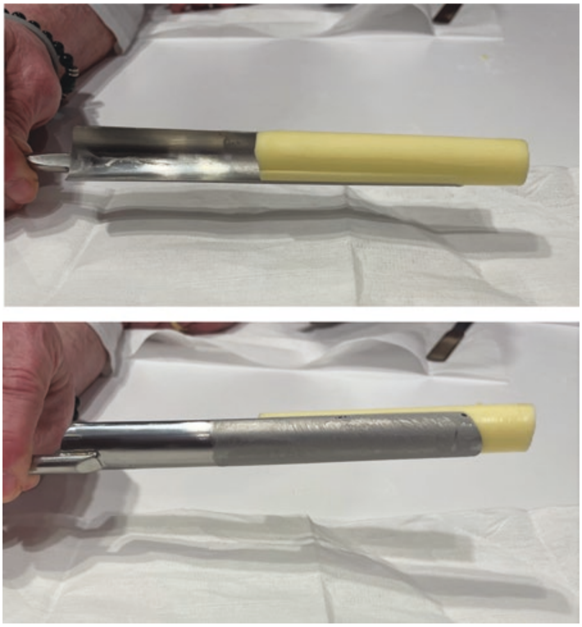

Fig. 6.6 Appearance of an ideal sample of butter from the front and back of the trier. (Image: K.E. Kaylegian)

of butter and any free moisture clinging to the back of the trier should be carefully noted. The appearance of an ideal butter sample on the trier is shown in Fig. 6.6.

Up to this point, evaluation of the butter has been performed primarily by the senses of sight and smell. Now the judges' sense of taste is "brought into action." The evaluator should remove approximately a ½–1 in. piece from the lower end of the butter plug and place it into his or her mouth. This sample is generally obtained by means of a stainless steel knife or spatula (cleaned and prepared in the same manner as the trier). A disposable plastic knife or spoon would serve this purpose in both a functional and sanitary manner. Then the sample should be gently chewed until melted. The melted butter is then rolled around within the mouth until it attains approximately body temperature. Meanwhile, the butter judge should consciously try to feel for the possible presence of "grit" (undissolved salt) between the teeth and/or between the tongue and the roof of the mouth. The evaluator should also note the manner in which the butter melts; a homogenous smooth melting process is desired.

Simultaneous to these other sensory processes, the judge should be experiencing various sensations of taste and smell. The melting (or melted) butter should be rolled around the tongue and the back of the mouth; then, the sample is expectorated. Finally, the judge should carefully observe for the occurrence of any aftertastes and particularly note whether off-flavor sensation(s) persists. The physical scoring process of the sample is now complete, and the set of sensory observations should be recorded on a butter grading sheet. It needs to be emphasized that less experienced butter judges must be especially careful to avoid "imagining a flavor which does not exist" in the butter samples.

6.7 Other Considerations in Butter Quality Evaluation

6.7.1 Package

The package in which butter is sold should be neat, clean, and tidy in appearance and have a good "finish" (smooth, attractive surfaces). With the quality and wide range of current-day packaging graphics, the package should be attractive. This is important regardless of the type of butter package, whether a quarter pound or one-pound print, a three-pound container, or a bulk container. Fingerprints must not be in evidence on any packaging materials. All butter packages should be fastened firmly and neatly. Any inner linings should impart an impression of neatness and reflect a pride in workmanship. In the instance of one-pound cartons, removal of an outer carton should always reveal uniform, neatly wrapped quarter-pound sticks of butter or similar with a one-pound solid block (Bodyfelt et al., 1988).

USDA graders will frequently comment on the general condition of bulk butter containers, but packaging is not one of the criteria used for determining the US grade of butter. However, this should not minimize the importance of providing sound, attractive butter packages for facilitating quality assurance and merchandizing. Butter packages serve to protect the product and, simultaneously, must be clean and neat; brand recognition must have an attractive appearance in order to appeal to and invite purchase by consumers.

6.7.2 Salt

Individuals differ in their preference for the amount of salt in butter. Some consumers prefer a highly salted butter (>2%), while some prefer a lightly salted butter (1.0–1.5%), and some culinary applications require unsalted butter. Many consumers demand and use unsalted butter, exclusively. Different buttermakers seem to incorporate varying percentages of salt. A level of 1.5% is common in butter today.

Butter should be examined for possible undissolved salt when first placed into the mouth; otherwise undissolved salt will quickly go into solution with saliva; hence, it may not be detected. The presence of "grittiness" or "grit" (undissolved salt) can be detected most easily by biting gently between the molars. If undissolved salt is present, a gritty effect is usually noticed at once. Although a rarity, undissolved salt on the surface or wrapper of an exposed sample does not necessarily indicate the presence of undissolved salt in the interior of the butter.

If butter is not "worked" sufficiently during the manufacturing process, then water droplets that contain salt may reside on the surface of the butter. As the water evaporates, salt in the form of white crystals remains on the surface of the butter. In order for the butter to merit a perfect score, salt in the interior of the butter must be completely dissolved. Salt only dissolves in the droplets of water distributed throughout the finished butter. A sharp, salty taste sensation usually indicates excessive salt in the butter, particularly when the butter is well "worked" (blended). This is generally indicated by the absence of visible water droplets on the trier or butter plug (the product is devoid of "leakiness"). Also, a sharp salty taste may be an indication that the butter contains at least some whey cream, although this is not the only criterion for butter-containing whey cream.

6.8 Color and Appearance

A uniform light, pale yellow color seems to most often meet the demand for expectations of US consumers. As a rule, the shade of butter color is of little consequence in scoring, providing the color is a natural shade of yellow and within the USDA color standard (Fig. 6.7). The yellow color range in the standard (Fig. 6.7) is commonly associated with butter, especially if the intensity is no higher than the natural color of the butter produced when cows consume green feed as a source of roughage (higher carotene content imparts a deeper yellow color to butter). The primary item to observe in scoring butter for color is the uniformity of color throughout the product. However, the Grading Standard indicates that butter color may be adjusted because of seasonal variation in color attributable to the availability of green feed.

The butter judge should be aware of the following possible color and appearance defects in butter:

Black, green, red, white, or yellow specks
Bleached, dull, pale color
Lifeless color-faded surface
High-colored surface compared to butter underneath

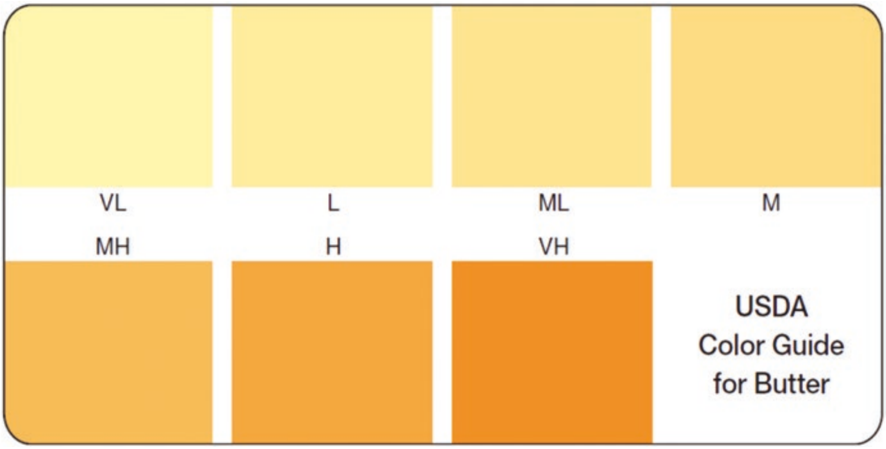

Fig. 6.7 USDA color guide for butter. *VL* very light, *L* light, *ML* medium-light, *M* medium, *MH* medium-high, *H* high, *VH* very high

Lack of color uniformity, generally due to mixed churnings
Mold and/or yeast discoloration
Mottled color
Color streaks
Unevenness of color
Unnatural color
Waviness of color

Poor buttermaking workmanship, particularly over- and underworking of butter during the manufacturing process, is responsible for most color and appearance defects. The size, number, and distribution of water droplets markedly influence the color of butter. The same color aberrations are apparent in whipped butter because of the size of air cells and dispersion. Microorganisms, including mold, can cause serious quality deterioration problems in butter. Butter that is inadequately protected against moisture evaporation tends to exhibit an intense or high-colored surface. There have been instances of escaped refrigeration gases (ammonia) reacting with the color pigments and flavor of butter. Contamination with extraneous or foreign substances poses serious problems of esthetics that go beyond color or sensory effects. Occasionally, even questions of wholesomeness and toxicity may be raised as a consequence of product adulteration or contamination.

The more common color defects of butter can essentially be eliminated by proper working at the time of manufacture. Generally, the flavor of poorly worked butter is not as good as the flavor of the same butter, had it been properly worked. Furthermore, butter with color defects due to insufficient working usually does not store or keep as well as butter that was adequately worked. Salt is needed to control microbial problems associated with possible off-flavor development. A 1.5% salt produces about 0.9% salinity in the water droplets. This then produces water that may control bacteria. Therefore, a color defect may serve as a hint to the judge to be more on the alert for possible flavor defect(s) that may be associated with the cause of this appearance shortcoming.

The color attribute "mottled" refers to spots of lighter and deeper shades of yellow, caused by an uneven distribution of moisture due to insufficient working. "Streaks" are recognizable as an area of light color surrounded by more highly colored portions. "Waviness" is an unevenness that appears as waves of different shades of yellow. Insufficient blending of two different butter sources is the usual cause.

6.9 Body and Texture

Immediately after examining a trier sample of butter for aroma and color, the body should be examined. The judge should notice the plug surface and the back of the trier for the possible presence of "beads" of water, for smoothness, for solidity, and for the appropriate degree of firmness. Next, the evaluator should press the ball of the thumb (good sanitary practices must be observed) against the sample surface and notice how the plug "breaks" or responds. If a break in the plug appears on withdrawal from the sample, this is termed "short," and the same "short" applies to cracks or "breaks" from pressing with your thumb or spatula.

The evaluator should determine whether the physical features of the plug seem to disappear. High-quality butter should melt evenly. The evaluator should note the mouthfeel characteristics of the sample with the tongue and the palate as it is melting. The body of good-quality butter should be *firm* and exhibit a distinct waxy, close-knit texture. When broken, the appearance of quality butter should present a somewhat jagged, irregular, wrought ironlike surface.

The physical–chemical system that determines characteristic body and texture of butter is quite complex. Since milkfat is a mixture of fatty acids and triglycerides that melt at different temperatures, butter at normal handling temperature is a mixture of both crystalline and liquid forms of milkfat. The type of feed that cows consume influences the relative proportion of high-to-low melting triglycerides in the milkfat. The fat of the butter also exists in the form of globules and free fat. Both the size of fat crystals and the diameter of fat globules influence butter body and texture. Seasonal differences in milkfat composition, primarily due to different feeds, may be partially compensated for by varying some manufacturing steps. In much of the USA, butter tends to be harder (firmer) in the winter season due to a smaller amount of oleic acid in the triglyceride structure. Generally, milkfat is softer in the summer because it contains a larger proportion of oleic acid; hence, the butter body may tend to be weaker and/or leaky in butter made in summer months. Butter is a water-in-oil emulsion, in which milk proteins and possibly milk minerals may play a stabilizing role.

Manufacturing steps that influence the body and texture of butter include (1) time and temperature of tempering of the cream, (2) churning temperature, (3) extent of working, (4) the method of adding coloring and salt if added, and (5) the manufacturing equipment and churning method used.

6.9.1 Body and Texture Defects of Butter and Their General Causes

The terms "body and texture" refer to the physical properties of butter. These physical properties primarily depend upon the composition of milkfat, structure of fat globules, rate of fat crystallization in cream and butter, amount of liquid fat, as well as the number and size of the fat crystals in butter. Although the term "body" refers to the general makeup or consistency of the butter mass, and the term "texture" relates to the arrangement of the liquid and crystals that make up the mass, they are so closely related that they are not considered separately when evaluating the physical properties of butter. The major body and texture defects of butter are as follows:

Crumbly
Greasy
Gummy
Leaky
Mealy/grainy
Ragged boring
Short
Sticky
Weak

Crumbly The fat crystals in a "crumbly"- or "brittle"-textured butter lack cohesion and do not hold together. Some of the butter usually adheres to the back of the trier and reflects a rough, ragged appearance. As the term "crumbly" suggests, the butter appears dry and readily falls apart, rather than appearing waxy and homogenous when pressure is applied to the plug. A crumbly texture suggests that the butter has been under worked; however, if it is worked more, the body usually becomes sticky. Finished butter that has been warmed and then cooled slowly to develop large crystals may become crumbly. Also, some difficulty may be experienced in removing a complete plug of butter with a trier.

Crumbliness in butter seems to be the result of relatively large fat crystals and a deficiency in liquid fat. The defect is more often observed during late fall and winter months. The temperature to which cream is cooled after pasteurization, the length of the holding period, and churning practices are factors to be considered in limiting this defect, and the rate of cooling butter after packaging and boxing (Wilster, 1958; Wilster et al., 1941; Zotolla, 1958).

The temperature of butter samples during this evaluation is an important factor in detecting crumbliness, since a normal body may appear crumbly at a lower sampling temperature, while a crumbly butter may appear normal at a markedly higher temperature.

Greasy A "greasy" butter consistency may be identified by the extreme smoothness and immediate melting when a sample of butter is placed into the mouth. Also, this defect may be suggested by the extreme ease with which a trier sample is removed from the product. Instead of a clean, clear feeling in the mouth after expectorating (as when a desirable waxy sample has been tasted), the mouth may be left with a sensation of greasiness. The most likely cause of greasiness is overworked butter, particularly when the body of the butter is already too soft. A higher proportion of low-melting point triglycerides is the physical–chemical factor responsible for this defect. This defect is more prevalent in the summer months.

Gummy "Gummy"-bodied butter tends to stick to the roof of the mouth and may leave a gumlike impression. This defect is more prevalent during the winter months.

Gumminess in butter is apparently due to an abnormally high percentage of high-melting triglycerides, which cause a firmer or harder milkfat and can interfere with butter spreadability; a slower cooling of the cream, a higher churning temperature,

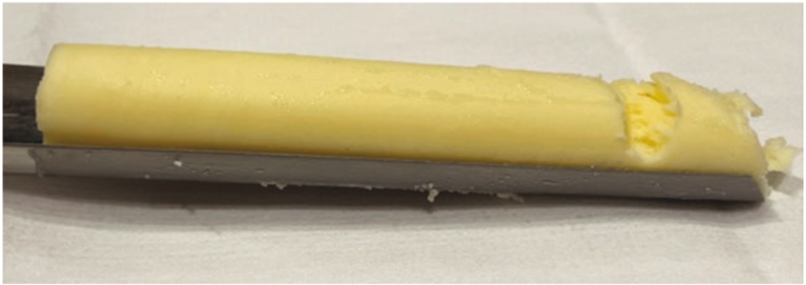

Fig. 6.8 An example of "leaky" butter; note moisture droplets down the center of the plug. (Image: K.E. Kaylegian)

and a longer working time are some of the manufacturing steps that have been found to aid in control or minimization of this defect.

Leaky Butter that exhibits beads or droplets of moisture on the plug and/or the back of the sampling trier is criticized as being "leaky" (Fig. 6.8). Such butter fails to retain moisture within the product mass due to the larger size of water droplets. Leakiness is usually caused by insufficient working. The butter has not been worked to the point where the water droplets are reduced sufficiently in size to be evenly distributed throughout the butter mass (Hunziker, 1940; McDowall, 1953; Totman et al., 1939; Wilster, 1968). Butter that has been in frozen storage for a period of extended time will frequently show some degree of leakiness. To minimize the problems associated with this defect, cubes of frozen butter when printed should first be microfixed, a process that softens the thawed butter and re-establishes the water-in-oil emulsion.

Fortunately, the above problems associated with leaky butter have nearly disappeared with advent of the use of a continuous churn. However, traces of free moisture can occasionally be found, in artisan butter or cold butter. Microfixing will correct the problem of leaky butter.

Mealy/Grainy A "mealy" or "grainy" texture is easily recognized when a sample of partially melted butter is compressed between the tongue and roof of the mouth or a distinct "grainy" sensation is perceived. This is considered a somewhat serious defect. Such butter lacks a smooth, waxy texture characteristic of good-quality butter. A mealy (grainy) texture may be caused by improperly neutralized high-acid cream, allowing milkfat to "oil-off" at some stage in the pasteurization process.

Improper melting of frozen cream or remelting butter rework in a vat where it may separate without proper agitation may result in a grainy textured butter. The buttermaker is in a position to prevent or control the mealy/grainy defect by proper selection and processing of cream, appropriate churn and techniques, preparation and control of the amount of rework used.

Ragged Boring Usually a full trier of butter cannot be drawn from butter that has a sticky–crumbly texture; it is also somewhat difficult to replace the ill-shaped plug into the formed trier hole. The butter simply seems to roll from the trier, rather than the trier cutting a distinctly formed plug. Butter that exhibits this sampling difficulty is referred to as "ragged boring." This is considered a serious body defect as this condition would interfere with cutting butter into individual serving-size patties. This defect also unfavorably affects butter spreadability. To correctly determine ragged boring, butter must be evaluated at between 45 and 55 °F (7–13 °C); otherwise "ragged boring" may be observed in good butter at lower evaluation temperatures.

Factors that cause the ragged boring defect in butter include the rate of cream cooling after pasteurization, the holding temperature of cream after pasteurization, and prior to churning, the churning temperature, or any processing condition that tends to interfere with the formation of a well-made, close-knit butter texture.

Short A "short" body in butter refers to a product that lacks the desirable characteristics of plasticity and waxiness. This defect is noted when the plug is difficult to remove from the block or has a tendency to break sharply when moderate thumb pressure is applied or even when a plug is removed from the block as seen in Fig. 6.9. A butter sampled at less-than-typical temperature (<7 °C) for scoring and a short-textured butter exhibit marked brittleness. Other factors that may be involved in short-textured butter are (1) high-melting point fats (that contain relatively small fat globules), (2) an extremely low curd content in the butter, (3) manufacturing processes wherein part of the milkfat is melted (hence, normal butter granules are not formed), and (4) rapid cooling of recently made butter to an extremely low temperature.

Sticky As the term implies, a "sticky"-bodied butter adheres (sticks) to the trier and appears to be quite dry. Usually it is difficult to secure a uniform, smooth-surfaced plug from such butter (Fig. 6.10). The butter plug will appear "ragged" or "rough."

Fig. 6.9 An example of "short"-bodied butter

Fig. 6.10 An example of “sticky” butter. (Image: K.E. Kaylegian)

This is particularly the case when the trier is cold. Since users want a butter that spreads relatively easily, a sticky body is quite undesirable. As stated earlier, when crumbly or brittle-textured butter results from being overworked, the entire mass tends to become sticky. In fact, sticky body and crumbly texture are often present concurrently in butter. A sticky body is primarily a feed-related defect; it appears to be more prevalent in areas where alfalfa is the major roughage fed to milk cows. Various temperature treatments of cream and butter, as well as churn working conditions, markedly affect the occurrence of the sticky defect.

Weak A “weak” body is typically indicated by an exaggerated softness of the butter when it is exposed to ordinary room temperatures. This is not a particularly serious defect, but it is a body/texture characteristic of butter that is, overall, not in good favor with most butter graders or buyers. A weak-bodied butter often produces an imperfect plug. When the ball of the thumb is pressed against a plug of “weak” butter, difficulty is encountered in defining a distinct “breaking point” for the plug. Weak body is due to a state of incomplete milkfat crystallization, which results in an excess of milkfat in the liquid form within this butter. Incomplete crystallization of the milkfat may be caused by inadequate tempering of pasteurized cream or a relatively high proportion of low-melting point triglycerides. However, a weak-bodied butter generally spreads well. Churning at too high a temperature and incorporating too much air or nitrogen during whipping may also lead to a weak-bodied butter.

Based on natural variations in the composition of milkfat of different suppliers due to diet and milkfat producing regions of the country, usually butter judges allow for some leeway or range in butter body and texture characteristics. Consequently, a weak body in butter is not generally considered a serious defect.

6.9.2 Correlation of Body and Texture Defects

Sometimes, two samples of butter may have distinctly different body and texture characteristics, but due to regional preferences or grading interpretations, each sample may be given a similar or perfect (if warranted) body and texture score in the grading process. As a rule, the body and texture of butter from different butter-producing regions will not be exactly the same, even though made within the same season of the year. Tolerances in grading allow for these different characteristics. If a body/texture defect is noted when grading butter, it should be either sufficiently intense or readily obvious to be recorded on the grading sheet. Also, it is not unusual to have two or more body and/or texture defects occur in the same butter sample. For instance, butter with a leaky defect may also exhibit a mealy texture; sticky-bodied butter may also exhibit a crumbly texture. Due to the occurrence of these dual defects, two criticisms are sometimes noted. However, in such cases both of the defects must be sufficiently obvious, intense, or serious for the dual defects to be recorded.

6.10 Flavor of Butter

The ability to consistently detect various off-flavors and assess their intensity is probably the most difficult skill to develop when evaluating butter. To evaluate butter flavor, the judge should recall the aroma that he or she mentally recorded at the time when the trier plug of butter was obtained. The evaluator must be ready to correlate, if possible, this perceived aroma with the taste sensation that is about to be experienced. The judge should then remove about a 1 in. (2.5 mm) portion from the end section of the butter plug with a knife, spoon, or spatula. If obtained properly, this portion of butter should represent the approximate center of the butter sample. The judge then places this small quantity of butter in the mouth and brings the butter into a liquid state as soon as possible. The evaluator continues to manipulate the sample within the mouth until the butter sample reaches approximately body temperature.

It is most important that the butter judge take particular notice of the first hint of a taste or smell to make an appearance. The evaluator needs to observe whether the first taste sensation disappears or not.

The judge should mentally record, as the sensory procedure progresses, whether there is a succession of detected flavors. Do the first flavors dissipate and other flavor notes appear? The evaluator should bear in mind that the sense organs of taste and smell are quite delicate, and with certain flavor sensations, the sensitivity of these delicate organs is easily dulled. In this way, the flavor notes are either less readily perceived or may no longer be observed. To help prevent sensory fatigue, a butter sample should not be kept in the mouth too long. Also, if the evaluator encounters a strong lasting off-flavor such as oxidized or rancid, rinsing the mouth with a good sample prevents carryover of the strong flavor to the next sample(s).

After the judge notes the various flavor sensations that may be present, the sample is expectorated into a container or sink provided for that purpose. This generally completes the sequence of observations with the butter sample. However, it is most important that any aftertaste be carefully noted. The evaluator should observe any taste sensation that remains in the mouth and note the relative degree of pleasantness or unpleasantness as well as the extent of flavor persistence.

Following the sensory evaluation, depending on the current practice, the evaluator should replace the remainder of the plug into the same hole from which it was obtained, and the plug reinserted on level with the butter surface. Next, the trier hole should be smoothed with a knife or spatula, which will help keep the butter surface neat in appearance and restricts the access of air and mold spores to the sample interior.

6.10.1 Characteristics of the Various Flavor Defects

High-quality butter should have a mild, slightly sweet, clean and pleasant flavor, and a delicate aroma. A characteristic feature of such high-quality butter is that the appetite seems to "crave more of the product." To manufacture butter with "first-class" flavor, the raw materials definitely must be free of objectionable flavor defects. This is also true of cultured cream butter, which is expected to exhibit a distinct culture flavor and an aroma with moderate levels of diacetyl, the delightful buttery-like aroma as the principal component. A slight to definite level of "cooked" flavor is allowed and often preferred by a majority of experienced butter judges. The so-called cooked flavor attribute of butter is somewhat reminiscent of scalded milk or the smell of milk heated in a double boiler.

Acid An acidic or sour off-flavor in butter usually develops from either churning high-acid cream, over-ripened cream, excessive use of lactic starter culture, use of too much lactic acid in unsalted butter, or excess retention of buttermilk in the butter wherein lactose is fermented. When buttermilk is retained (frequently indicated by a milky drainage), it is designated as a "buttermilk flavor" defect. An acid off-flavor in butter is characterized by a biting tart taste on the sides of the tongue, as well as an associated aroma, due to the presence of volatile acidic components. Generally, this acidic taste is easily and quickly detected when the butter is placed into the mouth; however, this flavor sensation usually clears up quickly and leaves little or no aftertaste.

Aged/Old Cream An "aged" off-flavor in butter is best described by the terms "lacks freshness" or "stale." The lacks freshness sensation can typically be detected by smelling or by noting a moderately persistent aftertaste. The aged off-flavor may be confused with either "storage" or "old cream" off-flavors. If butter, especially "printed" butter, is to be held for an extended time, it should be stored at 0 °F (−18 °C) or lower to minimize the development of aged off-flavor. Failure to promptly process milk or cream (even if it is of high quality) can result in a loss of freshness and the aged flavor defect. This defect is the result of cream contaminated with proteolytic and psychrotrophic bacteria that grow and produce various metabolites as degradation products. USDA-Dairy graders distinguish between the aged and storage off-flavors in determining US grades; however, only the "storage" criticism appears on the grading sheet for the Collegiate Dairy Products Evaluation Contest.

Briny/High Salt USDA-Dairy graders identify this defect as "sharp salt" under the category of salt, rather than noting a "high salt" ("briny") problem as a flavor defect. Regardless of the category for designating this defect, a distinct to pronounced salt taste in butter prevails beyond a "range of ordinary acceptability." Usually, the cause is simply the addition of too much salt, though uneven distribution of salt may also produce this defect. If such is the case, then it should probably be criticized for high salt. Whey cream butter may tend to exhibit more high salt contents because of cumulative combinations of salt from (1) the whey and (2) the added salt.

Cheesy A "cheesy" off-flavor in butter has a striking resemblance to the aroma and taste of ripened Cheddar cheese. The presence of this off-flavor is easily detected from an initial sensory observation, due to both the intensity and peculiar cheesy characteristics. From the instant of placing the sample in the mouth, through manipulation of the sample and subsequent expectoration, to the last lingering aftertaste, the "cheesy" flavor defect is unique and readily noticeable. The cheesy off-flavor is persistent; the mouth definitely fails to "clean-up."

In some extreme cases, a cheesy off-flavor in butter may somewhat resemble the odor of limburger cheese or putrid meat. Cheesy-flavored butter is usually considered to be an extremely serious defect. Quite often, a bitter aftertaste will accompany the cheesy flavor defect, due to proteolysis and some of the resultant peptide end products. If butter has developed mold growth even if mycelial only, metabolites may give the butter the flavor of blue cheese and even develop a rancid flavor; thus, cheesy or cheesy/rancid could be the appropriate flavor descriptor(s). Obviously, this is deemed to be a very serious defect of butter.

Coarse Butter which lacks that sweet, pleasing, delicate flavor that is generally associated with fresh milkfat is generally criticized as being "coarse" in flavor. The lack of butter flavor refinement is typically noticed when the sample is first placed into the mouth. A "coarse" off-flavor does not give rise to a pronounced, undesirable flavor sensation; the butter just seems to lack the overall pleasant flavor sensation or the balanced taste and aroma characteristics that are anticipated in the highest quality product.

From a practical standpoint, however, whenever butter is found to lack a fine, delicate, smooth flavor, the "coarse" criticism is employed when no other criticism appears justified or appropriate. Thus, the criticism "coarse" for butter is similar to the criticism "lacks fine flavor" which is applied to other dairy products. "Coarse" is primarily reserved for that butter that has reasonably good sensory properties but just seems to fall short of the top or best-quality product. Butter characterized with the "coarse" flavor criticism often implies that individual lots of high-quality cream may have been blended with various proportions of some older, lower quality cream sources or low-quality rework was added, thus leading to that moderate harshness of off-flavor referred to as "coarse." The flavor sensation may be observed at the back of the mouth where "bitter" is observed.

Cooked A "cooked" flavor is generally associated with high-quality and the best or better grades of butter. This flavor note in butter should be easily recognized when the sample on the trier is passed under the nose or when a portion of the sample is first placed into the mouth. Unless the flavor is pronounced, its presence, as noted by tasting or smelling, is of relatively short duration within the storage/distribution time of the butter. Provided that other off-flavors are not present, butter exhibiting a slight to definite "cooked" flavor "cleans up" completely and leaves absolutely no aftertaste, other than a rather pleasant one.

A cooked flavor in butter, which can be described as a smooth, nutty-like, custard-like character, is produced by pasteurizing sweet cream. It is not unusual (and frequently desirable) to have a definite cooked flavor in freshly churned butter. If the butter is free of an associated "coarseness," and it is not "scorched" (i.e., pronounced cooked), this flavor sensation in butter is not objectionable; in fact, it is generally considered delightfully aromatic and pleasing (often reminiscent of scalded milk). US butter grades allow a definite cooked flavor in the highest grade (AA) of butter. Typically, much of this flavor note dissipates from the product before the butter reaches the consumer. Pasteurization at higher temperatures also enhances the keeping-quality of butter. The required high-heat treatment destroys microorganisms that grow and possibly produce metabolites that could be noted in a profile of possible off-flavors. Reducing compounds, such as sulfhydryls, formed from the high-temperature heat treatment of the whey proteins in cream are effective antioxidants.

Feed The presence of different "feed"-derived off-flavors can usually be detected by the aroma and verified on the palate when the butter is melted. With most feed flavor defects, the mouth usually cleans up quite soon after the sample is expectorated. Most forms of dry feeds, such as hay, many of the grain concentrates, citrus pulp, silage, green alfalfa, and various grasses generally lead to no worse than what is referred to as a "normal" feed flavor note in butter. Even when fed in large quantities, these feeds only have a slight objectionable effect on butter flavor. Green alfalfa tends to produce a characteristic, mild, sweet flavor (with a possible instantaneous bitter-sweet tinge). When cows are placed on fresh grass pasture in spring or early summer, the butter produced may exhibit a characteristic "grassy" off-flavor. A slight or "normal" feed flavor is allowed in US grade AA butter. Rarely, some feed sources may impart an objectionable "bitter" off-taste to butter.

Proper feeding routines for dairy cows can do much to eliminate or minimize feed off-flavors in butter. Generally, if cows are not fed between 0.5 and 3.5 h of milking time, feed off-flavors are substantially minimized in subsequently produced butter. If large quantities of highly aromatic feeds are fed, the period of time between feeding and milking should be increased beyond 3.5 h. Vacuum treatment of cream during pasteurization will minimize these flavors. When a cooked flavor is imparted to cream (and the resultant butter), it tends to mask any feed off-flavors in butter for at least 1 month after product manufacture.

The feeding of strong-flavored vegetables and other strong-flavored feeds may cause the milk and the subsequent cream and butter to acquire the same flavor as that of the vegetable or feed consumed by the cows. Feed flavor is often caused by the feeding of cabbage, turnips, potatoes, or silage from silo bottoms within 30 min to 3.5 h prior to milking. Sometimes the off-flavor descriptor applied is "tainted cream," an objectionable off-flavor, which can be intense in the resultant butter. These flavor notes are so typical of each "causative" vegetable that when encountered are easily recognized by both the senses of taste and smell. A "vegetable" off-flavor in butter is actually a form of the more commonly recognized feed flavor defect.

"Weedy" off-flavors in butter typically result from churning cream that has an absorbed weed flavor, which sometimes occur due to seasonal pasture feeding patterns. Specific weeds cause characteristic off-flavors in butter, and some weeds may be more prevalent at different times of the year. Weed off-flavors are more pronounced after samples are warmed to room temperature. Usually the flavor note that is typical of a weed remains in the mouth after the sample has been expectorated. In the past, a distinction was made between common and obnoxious weeds in identifying this flavor defect. Obnoxious weeds are those that produce a particularly unpleasant off-flavor. The assigned sample score reflects the degree of seriousness of the imparted off-flavor. Wild onion and wild garlic are examples of weed off-flavors. The Collegiate Contest scorecard does not have a separate category for "weedy" but lists "feed" and "garlic/onion" separately.

Flat Butter that simply lacks a characteristic, full, pleasing "buttery" flavor is criticized as being "flat." The absence of typical butter flavor is noted when the butter is first placed into the mouth. The lack of flavor character is most readily noted as the butter melts in the mouth upon tasting. The flat defect is associated with the lower flavor profile of lightly salted or unsalted butter. Unsalted butter may exhibit several flavor notes in sufficient intensities for detection, but the lack of salt generally suppresses rather than enhances the flavor notes. In a product with a flat flavor defect, there is little or no characteristic butter flavor. A flat defect is generally caused by an apparent lack of volatile acids or low content of other flavor compounds like diacetyl, other carbonyls, and various volatile compounds that are partially responsible for a desirable "buttery" flavor.

Dilution of churning cream with water or excessive washing of butter granules during manufacture and/or low salt content may result in a flat flavor. Certain feeds may also be more conducive to production of milkfat with less characteristic flavor. Pasteurizing at a higher than legal minimum temperature develops a higher cooked flavor in cream and is obviously the simplest expedient for masking the flat flavor defect in butter.

Foreign Atypical off-flavors derived from the careless use of cleaning and sanitizing chemicals, absorption of combustion products, odors absorbed from gasoline, iodine, chlorine, kerosene, fly spray, paint, varnish, etc., are unacceptable in butter. Unfortunately, since milkfat can function as an excellent solvent for the chemicals, any cream or butter contamination must be avoided. Even atmospheric vapors from these kinds of compounds can be a serious problem in terms of possibly imparting foreign or chemical-like off-flavors.

Garlic or Onion "Onion" or "garlic" off-flavors not deliberately added are occasionally found in butter. They are easily detected from their distinctive odors. Both of these off-flavors can be feed contaminants and are most pronounced when samples are warmed to body temperature. The flavors of garlic and onion are surprisingly similar when detected in butter by tasting and/or smelling. Both are quite odorous, as well as distinctly persistent in aftertaste; both are equally objectionable and out of place in either fresh or stored butter, and both have some of the same chemical compound constituents.

Malty The "malty" off-flavor that is occasionally encountered in butter resembles the odor of malted milk or Grape Nuts® cereal. The flavor sensation generally persists after the sample has been expectorated. The malty off-flavor results from the outgrowth of *Lactococcus lactis* ssp. *maltigenes* in either milk or cream that has been cooled inadequately. This implies that storage temperatures of milk or cream were probably in excess of 55–60 °F (13–15.5 °C) and increased acidity of the milk or cream subsequently occurred. Hence, a combined malty and high-acid off-flavors are most probable.

Metallic As the name indicates a "metallic" off-flavor is the flavor sensation perceived when a copper penny is held between the teeth. This flavor defect conveys a slightly astringent and puckery sensation to the mouth interior. The metallic note may be detected as soon as the butter is placed into the mouth; the sensation perceived by the palate generally becomes more intense as the sample melts and is liquefied. To some people, the initial taste perception experienced with the metallic defect seems flat. This off-flavor persists after the sample has been expectorated; a somewhat bitter taste or other objectionable aftertaste may appear at the end of the tasting period and resembles the flavor derived from holding a copper penny between your teeth. This off-flavor is a precursor to "oxidized" off-flavor.

Neutralizer The presence of a "neutralizer" off-flavor in butter can be observed immediately after the sample has melted in the mouth. However, this defect is often more readily perceived just after the sample has been expectorated, and air is inhaled through the mouth. The aftertaste of added "acidity neutralizer" in butter is persistent. This flavor note, depending on intensity, may be soda cracker-like or somewhat alkaline, suggestive of bicarbonate of soda or similar compounds. The soda neutralizers may also produce an associated bitter-like aftertaste, sometimes referred to as "limey-like." A neutralizer off-flavor in butter results from the addition of concentrated solutions of neutralizer needed to counter high levels of lactic acid formed in the cream. This defect is becoming substantially less common with the reduction of temperature and storage time abused creams. However, whey cream remains a problem wherein contained cheese cultures actively develop lactic acid.

Old Cream Cream that is fresh, sweet, clean, and without production or handling defects or undesirable off-flavors (as developed by certain psychrotrophic bacteria) is certainly preferred for making butter. As cream ages, it gradually loses the desirable, delicately balanced flavor characteristics that should be transmitted to butter. After reaching several days of age, some cream sources will exhibit a typical "old cream" off-flavor, which carries through into the resultant butter. The old cream defect may also be caused by exposing cream to improperly washed equipment, unclean storage equipment, and/or inadequate cooling. Lactic acid development frequently accompanies old cream off-flavor. Butter manufactured from old cream is characterized by staleness or lack of freshness and a characteristic aroma that is somewhat reminiscent of the unpleasant "background" odor noticed in a creamery or dairy plant that has not practiced the best sanitation. When a butter sample with this defect is first placed into the mouth, the flavor seems "to lag," not making "an appearance" until the sample is melted. Usually, the old cream defect is most noticeable when the sample has been eliminated from the mouth; the off-flavor lingers and does not clean up readily. When the defect is "definite" to "pronounced" intensity, it can be readily detected by sense of smell.

Oxidized The oxidation of unsaturated fatty acids to form a group of aldehydes in dairy products creates a series of different off-flavors that fall under the generic term "oxidized." However, since different flavor sensations are perceived in various stages of development of oxidized butter, terms such as "metallic," "oily," "tallowy," "painty," and/or "fishy" have been used to describe the observed defects. The term "oxidized" best describes the light-induced form of oxidized flavor that is common to milk and other dairy products. A characteristic cardboard-like flavor and often an associated puckery mouthfeel are the usual distinguishing features. The so-called oily stage, painty, and fishy off-flavors in butter are uncommon with current cream and butter manufacturing and handling practices.

Rancid (Lipase) The "rancid" off-flavor of butter is unmistakably objectionable and may be soapy and/or bitter. Rancidity of butter somewhat resembles the strong, disagreeable off-flavor of Romano cheese, darkened, decayed nuts, baby breath, gym bags, or dirty sneakers. The odor is pungent and is that of volatile short-chain fatty acids. Hence, the odor may generally be noted from carefully smelling the contents of the withdrawn trier. Often this off-flavor gives the taste impressions of soapiness and frequently, definite, or intense bitterness. A rancid off-flavor is the result of hydrolysis of milkfat through the enzymatic action of lipase, which liberates fatty acids. A rancid off-flavor is attributed to the free, short-chain fatty acids and the resultant salts of these fatty acids (e.g., technically a soap).

Pasteurization of cream that contains high levels of free fatty acids does not eliminate the rancid off-flavor (Woo & Lindsay, 1984), but a vacuum pasteurization treatment will significantly decrease the level. A characteristic of the rancid off-flavor (useful for recognition) is a certain astringent mouthfeel, perceived at the base of the tongue and upper throat. This mouthfeel persists after the sample has been expectorated. Those individuals who may have a relatively high threshold for the characteristic odor of fatty acids may still be able to recognize rancid butter by this particular mouthfeel sensation; otherwise, they are advised to wait for the delayed bitterness and the unclean-like aftertaste.

Scorched In contrast to cooked, a “scorched” off-flavor in butter is considered objectionable. Causes include pasteurization at severely high temperatures (in excess of 200 °F [93 °C] and/or with longer than minimal holding times), possibly in the presence of developed acidity. When not extreme, scorched may manifest as caramellike. At extremes, product “burn-on” may occur on heating surfaces due to inadequate agitation in vat pasteurizers or too high a temperature differential across the heater section. For improperly neutralized cream, a defect may develop that is known as “scorched-neutralizer” which resembles the off-flavor of old nut meats. Also, to cover or partially “mask” the whey flavor in butter made from a blend of whey cream and sweet cream, manufacturers will often pasteurize at a higher temperature than required by law. This may contribute a “scorched” flavor to the cream and thus to the finished butter.

Storage Butter held for considerable time (>6 months to several years) in frozen storage may gradually absorb odors from the storeroom environment. Under these circumstances, the delicate flavor characteristics of high-quality butter are lost, and the consequent flavor deterioration is referred to as the “storage” defect. After extended storage, butter made from fresh, clean, flavored, sweet cream seems to undergo this chemical change much more slowly (exhibit less flavor deterioration) than butter that was made from lower quality cream.

The particular off-flavor that results from this overall loss of product freshness is difficult to describe, since a storage off-flavor appears to be a composite of several deteriorative processes. The desirable sensory characteristics that are attributed to “product freshness” are distinctly absent in butter that exhibits the storage flavor defect. Even butter of the highest sensory quality will gradually deteriorate during storage, especially if odorous foods or materials are stored in close proximity to the butter or if storage temperatures are too high. Protective wrappers mitigate this problem flavor since is a surface defect initially.

Unclean As the term implies, the “unclean” off-flavor is indicative of poor cream handling conditions and/or improper sanitary care of the storage and production equipment in which the cream and butter are processed. Possibly, slow cooling rates of the milk or cream, and/or elevated storage temperatures, may have promoted the outgrowth of spoilage bacteria (psychrotrophs), which produce end products that are responsible for causing this unpleasant off-flavor. Sometimes this flavor defect is referred to as an "unclean," or "dirty dishrag" off-flavor. This flavor defect in butter manifests itself as a most unpleasant odor that intensifies as the sample is melted. This off-flavor persists for some time after the sample has been expectorated.

The term "utensil" still appears in the USDA-Dairy grade classification, but its use should be discontinued. It represents an anachronism that is no longer relevant to current methods of cream handling and butter manufacture. Furthermore, this defect is caused by spoilage bacteria and not by "utensils," which might have harbored the bacteria.

Whey Butter made from cream separated from cheese whey exhibits flavor characteristics that are generally similar to the type of cheese that was the source of the whey cream. The nature and intensity of the "whey" off-flavor depend on the freshness and quality of the whey and the proportion of whey cream to sweet cream that may have been blended to produce the butter. Practice with known or authentic samples is usually required to insure correct identification of this attribute. A whey off-flavor is somewhat similar to the combined coarse/acid flavor defects of butter, plus an associated moderate odor and aftertaste suggestive of the given cheese whey. A whey off-flavor may be similar to the old cream defect; however, flavor notes of both "coarse" and "acid" are prevalent in this flavor defect. Some manufacturers label "whey cream butter" as "old-fashioned style" butter or may employ another fanciful product name.

Yeasty A "yeasty" off-flavor is detected in the early stages of development by its typical fruity, vinegary, yeasty, and/or bread dough aroma, which is apparent when the sample is first smelled or taken into the mouth. As the sample melts, the odor becomes more and more distinctly yeasty (bread doughlike). This flavor defect in butter occurs infrequently, but when it does happen, it is most often noted in butter produced during the hot summer months. By-products formed by yeasts that have grown in poorly handled, abused cream are responsible for this off-flavor. Old, yeasty cream may also impart a bitter flavor to the resultant butter. A yeasty off-flavor is a serious defect since the cream from which the butter was made had undergone considerable decomposition. Rejection of such cream at intake would be the desirable, obvious approach.

6.11 Frequency of Sensory Defects in Butter

There are no known statistics available to quantify or document the continuous improvement in butter quality over recent decades. However, anyone who has been involved in the sensory evaluation of butter for a decade or longer would most certainly conclude that the overall quality of US butter has vastly improved. The one development most responsible for this significant flavor improvement is the marked change from farm-churned cream to factory-churned cream and subsequently farm-separated cream to plant-separated cream (from fresh milk). Simultaneously, technological advances in butter manufacturing have substantially reduced defects that were previously attributable to substandard workmanship. Continuous churns have served to significantly reduce “personnel errors” through semiautomation and better and more reliable process control. Two other significant factors are the universal replacement of wood (circa late-1950) with stainless steel and the contribution of dairy industry automation that has sufficed to eliminate manual contact with the finished products. Annual summaries of the frequency of defects encountered by USDA-Dairy graders provide only an approximate assessment of current butter quality, since not all butter is graded.

While the delicate flavor of butter can be markedly influenced by the feed of the bovine, flavor is amazingly consistent around the country. The evaluator quickly finds out that 1.0–1.5% salt added to butter adds a whole, new dimension to perceived flavor.

Understanding scoring techniques is vital. Flavor is the most significant portion of any evaluation with body, texture, salt level, color, and appearance having lesser effect on total points awarded. Remember flavor scores are not additive. Flavor takes the score of the most serious defect if more than one is apparent.

6.12 Summary

Butter is a unique product. High-quality butter is a delicately flavored and complicated food product. If butter is not manufactured precisely, a number of unfavorable sensory attributes might be found in the finished product that would not be acceptable by consumers. Hence, applicable quality assurance precautions must be taken during the production of milk, cream separation, and the subsequent stages of butter manufacturing.

Both unsalted and salted butter have unique flavors that have never been duplicated, particularly the heated butter flavors. Flavored and compound butters made with herbs, spices, peppers, and other condiments continue to grow in popularity.

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Chapter 7
Creamed Cottage Cheese

Dave Potter and Doug Vargo

7.1 Cottage Cheese Defined

Creamed cottage cheese is a soft, unripened cheese that is usually made by coagulation of pasteurized skim milk by added lactic culture or acidulants, with or without the addition of minute quantities of milk-coagulating enzymes (as curd conditioners). The coagulum is cut into various-sized curd particles by special sets of knives, heated (cooked), and held for a sufficient time to facilitate firming of the curd and removal of the whey. Once the curd has developed the appropriate consistency (firmness or "meatiness"), the whey is drained. Then the curd is washed; creamed (usually) with a salted dressing in which other flavoring agents, cultures, and preservatives may be added; and packaged.

Cottage cheese is consumed as a fresh product and without preservatives will last a maximum of 2–3 weeks. Consequently, the flavor attributes of this product depend on a combination of the sensory qualities of skim milk and cream dressing ingredients, as well as properties of the lactic cultures employed in the manufacturing process. The overall sanitation procedures and temperature control exercised in manufacture also play a key role in determining product shelf life and sensory quality of this relatively perishable dairy product. Today, it is common practice among US cottage cheese processors to incorporate either a liquid diacetyl flavor, potassium sorbate, a dried fermentate produced from *Propionibacterium shermanii* (Sandine, 1984), and/or some CO_2 into cream dressing (Chen & Hotchkiss, 1991; Hotchkiss & Chen, 1996) for better flavor and shelf life extension before addition to the curd. This process has shown to routinely extend the shelf life of commercial

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cottage cheese to up to 6 or 7 weeks. There remain few manufacturers who will incorporate specially selected lactic cultures (*Streptococcus lactis* subsp. *diacetylactis* and/or *Leuconostoc* sp.) into the cream dressing to increase the "cultured aroma" (and coincidentally inhibit psychrotrophic spoilage bacteria, i.e., competitive exclusion). Hence, the addition of carefully selected lactic microorganisms to the dressing can simultaneously serve to significantly enhance flavor along with added liquid components such as diacetyl to increase the shelf life of creamed cottage cheese.

7.2 Cottage Cheese – An American Original

Creamed cottage cheese is an American (or US-original) cheese. In fact, it is generally presumed that cottage cheese is but one of only a few cheese types that have their actual origins in the USA. Several other cheese types considered to be US developments are Monterey Jack, Colby, and string cheese. Prior to the first or second decade of the twentieth century, skim milk, a by-product of farm milk separation, was either fed to pigs and/or chickens. The prime end product of separation – cream – was shipped to the local creamery for ice cream or butter manufacture. In a way, skim milk generated at the farm was often considered a waste product. The eventual commercial development of a viable cottage cheese industry in the Pacific Northwest in 1915 sufficed to change the nation's disposition of skim milk. A new segment of the cheese industry was born when Mr. and Mrs. Charles West of Tigard, Oregon, said "let's build a factory" to manufacture and sell this new product we have mastered – creamed cottage cheese. Thus, commercialization of fresh creamed cottage cheese in the Pacific Northwest (Angevine, 1964; Davies, 1942; Olsen, 1980) was the place and date (1915) of origin by this enterprising husband and wife team, and the springboard for would-be cottage cheesemakers in the upper mid-western USA. This initial development of the US cottage cheese industry and early technical expertise (the early pioneers and heroes) for the quality manufacture of this product is explored in more detail at this chapter's conclusion.

7.3 First Steps in the Development of Cottage Cheese

Centuries ago, most milk generally soured soon after it was collected from lactating animals, since timely cooling was practically nonexistent. It was also duly noted that "soured milk" does not readily undergo undesirable proteolysis and other unwanted physical and chemical changes. Hence, harvested milk was typically handled in a manner to insure souring and thus preserve it for several days or longer. Each tribe, ethnic group or locale with lactating animals, developed its own method of handling or treating the milk; consequently, the final products varied. This helps explain why a variety of cultured (fermented) milk and cream products originated, each known and referred to by a unique name. The unique common denominator was that each product required either the natural presence or the addition of lactic-acid-producing bacteria to accomplish the preservation process.

Additionally, some of these products, such as kefir, underwent an alcoholic fermentation. In many countries (probably most countries), fermented milk foods are distinctly favored over fresh, fluid milk. This frequent preference for "sour milk" is based on a combination of public safety, preferred flavor and texture, and purported therapeutic effects. Where inadequate facilities for transport, storage, refrigeration, pasteurization, and/or distribution of milk exist around the world, many health authorities prefer that milk turns "sour" in the earliest stages of handling. In this approach, the presence of high populations of harmless lactic acid bacteria and their metabolic end products discourage and/or control the outgrowth of food spoilage and disease-producing bacteria (pathogens). In many countries, nutritionists and pediatricians prefer certain fermented milk products over fresh milk as a weaning food for infants (National Dairy Council Newsletter 1996).

In other locales, fermented milk foods are blended with cereals and other food ingredients to provide a nutritionally balanced food for the populace. For those countries where few or none of the above-described conditions or health philosophies exist, the acceptance of cultured milk products (such as cottage cheese) relates more to "slimming diets or a protein alternative to meat," cost considerations, adaptation of ethnic foods, recent food trends, and new technologies of food processing and distribution. In numerous countries, fresh fluid milk is the dominant product of commerce, but certain cultured milk foods enjoy increasing attention, modification, and modest popularity.

Cottage cheese most likely originated for the following several reasons:

1. A ready supply of a raw material that was often otherwise wasted – skim milk.
2. The process of converting skim milk into a cheese was simple – place the skim milk in a pot on the back of the warm stove top in the kitchen (or cottage).
3. The "skim milk cheese" lent itself to enhanced flavor by "dressing" it with whole milk or cream. All of the flavor comes from the creamed dressing.
4. The flavor profile for this new cheese product was "mild" and fresh tasting – thus providing flavor appeals to many prospective customers.

7.4 Types of Cottage Cheese

According to the US FDA Code of Federal Regulations (CFR Title 21. Part 133.128), "Cottage cheese is the soft uncured cheese prepared by mixing cottage cheese dry curd with a creaming mixture…The milkfat content is not less than 4 percent by weight of the finished food, within limits of good manufacturing practice. The finished food contains not more than 80 percent of moisture." Thus, creamed cottage cheese is the general term used to designate the fresh, soft, uncured, high-moisture cheese made from pasteurized skim milk, or occasionally from either reconstituted nonfat dry milk or plain condensed skim milk. The inquisitive observer will note several distinct types, forms, or styles of cottage cheese in North American retail outlets. Various descriptor names as "schmierkase" (the name initially employed by nineteenth century German immigrants) and "pot cheese," and then later-used names such as "farmer-style," "country-style," "old fashioned," "sweet curd," "small curd," "large curd," and "popcorn cheese" have been employed to describe the products that result from variations in cheese manufacture. Some regional versions of cottage cheese have been labeled as New York-style, Michigan-style, and California-style (Kosikowski & Mistry, 1997).

Several other product names used to designate certain cottage cheese types or variations of cottage cheese have been "Dutch-," "pressed," "baker's-," and "hoop"-type cheese (Kosikowski & Mistry, 1997), and a unique Louisiana-style known as "Creole cream cheese" (an uncooked and congealed curd with half-and-half added as a dressing (Potter, 2007)).

Creamed cottage cheese marketed in US and Canadian commercial channels can be classified according to the following methods of producing the curd or cream dressing:

1. *Producing the curd*, whether by
   (a) Lactic acid development by lactic culture only (acid curd).
   (b) Lactic acid, plus a slight amount of milk-coagulating enzyme.
   (c) Addition of approved food grade acidulants such as phosphoric and glucono-delta-lactone acid (which must be called "direct set" or "acidified" cottage cheese).
2. *Breaking or cutting the coagulum* by
   (a) Rigorous stirring (i.e., farmer-style, old-fashioned, Michigan-style, or pot).
   (b) Cutting with designed knife sets of varied wire spacing:
      1. Small curd (0.6–0.9 cm (1/4 in.))
      2. Medium curd (0.95–1.6 cm (3/8–5/8 in.))
      3. Large curd (1.27–1.9 cm (1/2–3/4 in.))
3. *Method of creaming* (or not) by
   (a) Traditional addition of cream dressing (˜9–10% milk fat) at a typical ratio from 43% dressing to 57% curd to 52% dressing and 48% curd, resulting in at least 4% milk fat in the finished product in the carton.
   (b) Addition of a lower milk fat "dressing mixture" (˜3–4% milk fat content) to attain a 1% or 2% milk fat content in the final product (low-fat cottage cheese).
   (c) Addition of a skim milk-based dressing (nonfat cottage cheese).
   (d) Occasionally, addition of either "whipped" or other higher fat cream dressings may be added to the curd to achieve a special effect (usually marketed under a coined name for the product).
   (e) Treatment of the cream dressing by

1. The addition of a lactic culture to the creaming mixture.
2. The addition of a liquid "starter distillate" or diacetyl flavor component.
3. Direct addition and fermentation of an aroma-producing lactic culture (*S. lactis* subsp. *S. diacetylactis* and/or *Leuconostoc* spp.) to the creaming mixture.
4. Addition of a dried cultured fermentate produced from *Propionibacterium shermanii* (primarily via the Microgard™ or Durafresh™ process) directly to the creaming mixture for a two to three-fold increase in shelf life (Salih et al., 1990; Sandine, 1984).
5. Addition of a chemical preservative such as potassium sorbate or sorbic acid.
6. Incorporation of carbon dioxide (CO_2) into the cream dressing (or the dressed cottage cheese) as an effective technique of increasing product shelf life up to 6–7 weeks or 52 days (Chen & Hotchkiss, 1991; Hotchkiss & Chen, 1996).

7.4.1 Other Products or Processes

Cottage cheese curd (without cream) is referred to or labeled as "dry cottage cheese curd." Plain curd may be sold wholesale in bulk for later creaming, packaging, and retail distribution or used as an ingredient substitution for other cheeses such as ricotta. Dry unsalted curd is also sold in retail packages for use in cooking, baking, and salads and for use in special "low-salt," "low-fat," "low-cholesterol," and/or "reduced calorie" diets.

Uncreamed cottage cheese is often evaluated by employing nearly the same product evaluation procedures used for the creamed product. Much attention is given to the body and texture of dry curd, but one will not find it to have much flavor. Most likely, a distinctive flat or plain dull flavor will be obvious to most evaluators of dry cottage cheese curd. Most dry curd cottage cheese is virtually devoid of aroma, unless an especially selected diacetyl-producing culture was used for curd manufacture. This causes other problems during curd manufacture such as gas production and floating curd. The flavor of dry curd cottage cheese should be clean and pleasantly acidic and show little persistence after the sample has been expectorated.

7.5 Sensory Evaluation of Creamed Cottage Cheese

7.5.1 Visual Observations

Cottage cheese is examined for sensory properties in a manner similar to other dairy products – by a combination of sight, mouthfeel, taste, and smell.

Initially, creamed cottage cheese is visually examined (without pre-stirring to optimize the first observations) for the possible presence or lack of "free whey" and non-absorbed (free) cream dressing, as well as a set of curd appearance features such as curd identity and the amount of fines present. If facilities and time are available, the equivalent of a large tablespoonful of creamed cottage cheese can be "rinsed or washed" in a beaker or a small vessel of cold water (7.2 °C (45 °F)). The spoonful of curd is allowed to settle and the milky water decanted. This process is usually repeated 2–3 times until a practically dry (surface) curd is attained. The washed curd is then closely observed for the relative shape and size of the curd particles. Close examination of "washed" cottage cheese curd in this manner commonly reveals appearance defects (fines) that may have escaped identification otherwise (i.e., by observing only unwashed cottage cheese). Subsequent observations are expanded upon in the following sections.

7.5.2 Sensory Attribute Categories of Cottage Cheese

High-quality creamed cottage cheese is expected to possess many of the following listed three major categories of sensory attributes (Elliker, 1949; Connolly et al., 1984; Kosikowski & Mistry, 1997; Bodyfelt et al., 1988).

7.5.2.1 Color and Appearance

After the initial observation in the intact container, the creamed cottage cheese should be mixed with a large spoon or ice cream scoop; then a representative sample should be removed from the cup and placed in the center of a white plate. The sample should be allowed to sit for no longer than 10 min before observations are made.

The general appearance or visual impression of creamed cottage cheese should be attractive and pleasing "to the eye." The curd particles are expected to be separate and distinct, moderately uniform in both size and shape (Bodyfelt et al., 1988; Tong et al., 1994); the overall product should exhibit a glossy, creamy-white color. In creamed cottage cheese, the bulk of the cream is expected to be absorbed by the curd particles, with a minimum of "free" or separated cream. The cream dressing should be reasonably viscous, relatively foam-free, and able to adhere or cling to the curd particles. A limited amount of excess dressing should form a uniformly smooth coating on the curd particles and be void of any separated water (free whey). Preferably, highest-quality cottage cheese exhibits little or no particle shattering (curd dust) and/or curd matting (lumps). However, the lack of any apparent shattered curd in finished products as an objective within most cheese plants is considered most difficult to attain (Tong et al., 1994).

Most appearance and color defects of creamed cottage cheese can be rather obvious to the alert evaluator. The terminology for these various appearance criticisms is specific and descriptive. The occurrence of such cottage cheese defects frequently stem from deviations of generally recommended manufacturing procedures. Table 7.1 lists the more common color and appearance defects of creamed cottage cheese, their possible cause, and methods of control. Figure 7.1 illustrates various appearance and color defects of creamed cottage cheese.

The Collegiate Dairy Products Evaluation Contest scoring guide for various sensory defects of creamed cottage cheese (including flavor, body and texture, appearance, and color) is presented as Table 7.3. This scoring guide serves as the standardized guideline by which the contestants in the National and Midwest Collegiate Dairy Products Evaluation competitions assign scores for the slight, definite, and pronounced intensities for the respective defects noted for flavor, body and texture, and color, and appearance of cottage cheese samples.

The curd particles should be reasonably uniform in both their size and shape, regardless of the curd size (small or large) or the given product type. "Shattered curd," to some level of intensity, seems to occur in the vast majority of all commercial cottage cheese. The finest sizes of particles resulting from "curd shattering" are called either "grit," "fines," or "cheese dust." Other than subjective visual appraisal,

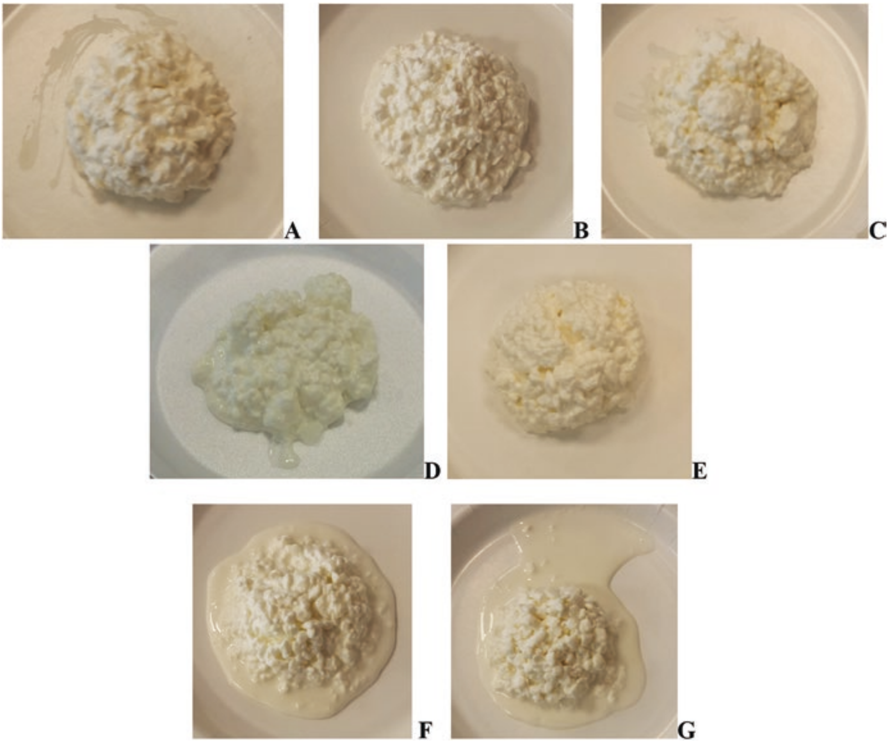


Fig. 7.1 Examples of some appearance and color defects of creamed cottage cheese: (**a**) shattered curd (score of 4); (**b**) shattered curd (3); (**c**) and (**d**) matted curd (3); (**e**) lacks cream (4); (**f**) free cream (4); and (**g**) free whey (2)

Table 7.1 Common color and appearance defects of creamed cottage cheese and their probable causes and remedial measures

Color/ appearance defects	Probable causes	Remedial measures
Free cream	1. Excessive cooking which causes a firm, rubbery curd; this prevents dressing adsorption	Reduce cooking temperature to avoid too firm a curd
	2. Insufficient washing of curd (contact time)	Allow wash water to remain in contact with the curd for a longer time
	3. Cutting pH of curd too high	Cut curd at a pH of 4.65–4.70
	4. Too rapid temperature rise during cooking of curd (causes surface denaturation and loss of dressing permeability)	Exercise better control of curd cooking (i.e., do not cook too fast)
Free whey	1. Undercooking of curd retains an excess amount of whey	Increase cooking temperature to help expel more whey
	2. Insufficient washing of curd	Increase curd washing or draining time
	3. Cutting pH of curd too high	Cut curd at pH of 4.65–4.70
Lacks uniformity	1. Uneven cutting of coagulum	Repair/replace knife wires, avoid overlap when cutting
	2. Too aggressive/abusive agitation during cooking	Use proper cutting techniques, train personnel in careful cutting, agitating, and curd cooking methods
Matted	1. Cutting pH of curd too high	Cut curd at pH of 4.65–4.70. Employ a "standardized" method of cooking and stirring out
	2. Insufficient/inadequate agitation especially during the first hour of cooking	
	3. Curd cooked too rapidly	Initiate cooking slowly and gradually, accelerate pace at midpoint of the cooking stage
	4. Missing wires in the knife sets	Repair or replace knife sets
Shattered curd	1. Excessive heat treatment of the skim milk	Use minimum pasteurization conditions (temperature and time)
	2. Excessive acidity (pH too low) at cut	Cut curd at pH of 4.65–4.70
	3. Total solid content of skim milk too low	Maintain total milk solids >8.75%
	4. Overly severe vat agitation	Stress gentle, careful agitation
	5. Excessive quantity of coagulator used	Use minimum coagulator amount
	6. Rough handling of curd during draining, pumping, and packaging	Restrict/minimized curd handling to a minimum, if possible; use gentle measures

Source: Adapted from Connolly et al. (1984). Courtesy of the American Cultured Dairy Products Institute., Washington, D.C

Table 7.3 The Collegiate Dairy Products Evaluation Contest scoring guide for the sensory defects of creamed cottage cheese (suggested flavor, body and texture, and color and appearance scores for designated defect intensities)

Flavor	Slight	Definite	Pronounced
Bitter	7	5	1
Cooked	9	8	6
Fermented/fruity	5	3	1
Flat	9	8	7
Foreign	7	4	1
High acid	9	7	5
High diacetyl	9	7	6
High salt	9	8	7
Lacks fine flavor	9	7	6
Lacks freshness	8	7	6
Metallic	5	3	1
Oxidized	5	3	1
Rancid	4	2	1
Sweet	8	7	6
Unclean	6	3	1
Whey	8	7	5
Body/texture			
Firm/rubbery	4	2	1
Mealy/grainy	4	2	1
Overstabilized	4	3	2
Pasty	4	3	2
Weak/soft	4	3	2
Appearance			
Free cream	4	2	1
Free whey	4	2	1
Lacks cream	4	3	2
Matted	4	2	1
Shattered curd	4	3	2

the Cornell Grit Test was developed. This method uses four sieve sizes as a separation process to more objectively assess the range of curd size and shape variations (Tong et al., 1994; Kosikowski & Mistry, 1997).

Creamed (or dressed) cheese should exhibit a moderate degree of gloss or sheen, and the cream dressing should definitely cling or adhere to individual curd particles. Clumping of curd particles in large masses is considered a potentially serious defect, since whey may be readily trapped and sealed inside the congealed curd pieces – subsequently rendering the product to more likely exhibit "high-acid," bitter, and/or "whey" off-flavors.

Lacks cream is an uncommon defect in creamed cottage cheese. Creamed cottage cheese with this defect lacks the "blanket" of cream dressing and may appear dull and dry.

Free cream (or dressing) can appear when the cottage cheese curd has been "dressed" with too high a level of cottage cheese dressing. When the dressing-to-curd ratio is too high, the finished cottage cheese in the retail container can appear "wet." Free cream can also occur when the curd texture is not correct. If the curd has been cooked to too firm of a texture it will not absorb the creamed dressing and will also appear wet. Also when the cottage cheese dressing viscosity is too thin (not enough stabilizer added), the dressing can easily run off of the curd (therefore no cling), and the finished cottage cheese will appear wet in the retail cup.

Free whey occurs when there is a clear or slightly yellow liquid that separates from the curd and dressing in the retail package. It will be observed on top or along the sides of the retail container. It can also occur when the creamed dressing lacks enough milk solids not fat (or total solids) in the dressing formulation. Free whey can then run away from the curd and dressing mixture. Finally, free whey can occur when the cottage cheese curd piece retains too much whey and/or rinse water on the inside of the curd piece and does not get squeezed out sufficiently during draining in the vat or through a mechanized piece of curd-draining equipment.

7.5.2.2 Body and Texture

The body and texture of cottage cheese can be well assessed by placing a half-spoonful of curd in the mouth and pressing the curd to the roof of the mouth with the tongue. The body should have a "meat-like" (meaty) consistency, but not be overly firm, rubbery, or tough when it is first chewed or masticated (placed against the teeth and gently, carefully masticated). The product texture should seem relatively smooth (meaty, silky) across or throughout the curd pieces that are chewed gently (Bodyfelt et al., 1988). The evaluator should be able to feel (as well as see) distinct curd particles. The curd particles are expected to be relatively uniform in both size and configuration for the given type of curd being considered. Ideally, creamed cottage cheese should demonstrate a relatively firm but tender body and exhibit a silky-smooth and meaty-like texture (Connolly et al., 1984; Bodyfelt et al., 1988).

Understandably, the size of curd particles and the relative degree of firmness of cottage cheese curd in the USA has not been fully and objectively standardized (Kosikowski & Brown, 1973; Rosenberg et al., 1994a, b). Body and texture characteristics are guided primarily by consumer preferences within a given market area of the country. Many manufacturers market two distinct types of cottage cheese: "small curd" and "large curd." Although large curd is usually firmer and tends to exhibit a somewhat more acidic taste (due to more entrapped lactic acid), both product types are of comparable flavor character (Bodyfelt et al., 1988).

The most desirable body for cottage cheese is presumably one that is apparently neither too firm nor too soft and should have uniform consistency across the curd particle (Connolly et al., 1984). The curd should be sufficiently firm to hold its general shape and maintain its individual identity (vs. matting), yet simultaneously be soft enough to yield a silky, "tacky" smear between the tongue and hard palate (also observed when washed curd pieces are pressed lightly between the thumb and forefinger). Curd that is too firm tends to resist such pressing (i.e., there is a tendency for the curd to "spring back" or retain its original shape when the pressure is released).

In 1963, a skilled Pacific Northwest cottage cheesemaker, Willi Sprenger of Sunshine Dairy, Portland, devised the following simple, practical test for determining the appropriate curd firmness "end point" during the curd cooking stage. Typically, when a thoroughly washed curd particle was dropped onto the plant floor from waist level, an "appropriate-bodied" curd particle would exhibit a perceptible bounce (2.5–7.6 cm (1–3 in.)). A too-soft-bodied curd, by contrast, would "splatter" and break apart when it struck the floor, while a too-firm (tough, rubbery) curd generally "bounced" upward in excess of 7.6 cm (3 in.) when dropped from waist level (Sprenger, 1963; Bodyfelt et al., 1988). Scientific, mechanical methods using a penetrometer or a texture analyzer are now being evaluated to objectively determine curd firmness during the manufacturing process (Potter, 2007). The key to achieving consistent curd body is to employ a device that can be used in a cottage cheese production environment that provides immediate results, versus after the fact discovery.

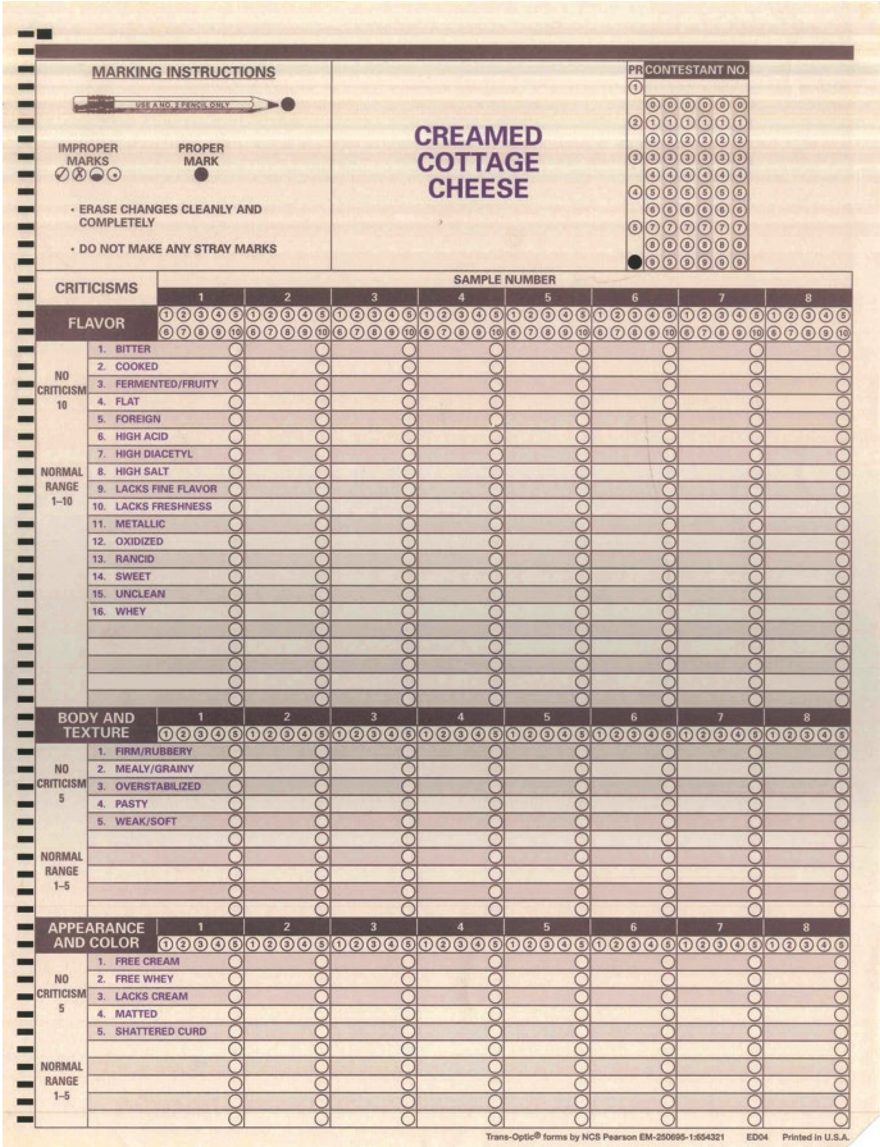
The appropriate body and texture properties of cottage cheese should be associated with consumer acceptance in the particular market area that it is sold, but it should not be too firm or too soft. In a laboratory, an evaluator can "wash" creamed cottage cheese with the aid of a fine-mesh sieve to void the dressing. This can serve to present a truer picture of curd uniformity. By tearing apart curd particles, the evaluator can readily perceive the extent of the so-called meatiness and overall consistency of a cross-section of the curd (from the outer surface to the center). Curd particles that are smooth, meaty, and tender tend to exhibit distinct striations of protein fiber when the particle is torn apart and closely examined. Such curd texture has been reported to exhibit good liquid capillarity, and thus this feature facilitates more complete adsorption of added cream dressing. Conversely, curd that is undercooked with soft centers will not absorb the creamed dressing very readily and also appear wet.

7.5.2.2.1 Body and Texture Defects of Creamed Cottage Cheese

The more common body and texture defects of cottage cheese are the following:

Firm/rubbery (tough)	Overstabilized ("slick" mouthfeel)
Gelatinous (not on Collegiate contest scorecard)	Pasty (sticky, doughy) Weak/soft (mushy)
Mealy/grainy (gritty)	

Brief descriptions of the characteristics that are indicative of the above-listed body and texture defects of creamed cottage cheese are detailed in the following paragraphs. The intensities of various body and texture defects are usually scored according to the guide for scoring creamed cottage cheese shown in Figs. 7.2 and 7.3. Various causes and methods for controlling body and texture defects of cottage cheese are summarized in Table 7.2.



MARKING INSTRUCTIONS

USE A NO. 2 PENCIL ONLY

IMPROPER MARKS

PROPER MARK

• ERASE CHANGES CLEANLY AND COMPLETELY

• DO NOT MAKE ANY STRAY MARKS

CREAMED COTTAGE CHEESE

PR CONTESTANT NO.

CRITICISMS — SAMPLE NUMBER 1 2 3 4 5 6 7 8

FLAVOR

NO CRITICISM 10

NORMAL RANGE 1–10

1. BITTER
2. COOKED
3. FERMENTED/FRUITY
4. FLAT
5. FOREIGN
6. HIGH ACID
7. HIGH DIACETYL
8. HIGH SALT
9. LACKS FINE FLAVOR
10. LACKS FRESHNESS
11. METALLIC
12. OXIDIZED
13. RANCID
14. SWEET
15. UNCLEAN
16. WHEY

BODY AND TEXTURE

NO CRITICISM 5

NORMAL RANGE 1–5

1. FIRM/RUBBERY
2. MEALY/GRAINY
3. OVERSTABILIZED
4. PASTY
5. WEAK/SOFT

APPEARANCE AND COLOR

NO CRITICISM 5

NORMAL RANGE 1–5

1. FREE CREAM
2. FREE WHEY
3. LACKS CREAM
4. MATTED
5. SHATTERED CURD

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Fig. 7.2 Collegiate Dairy Products Evaluation Contest scorecard for creamed cottage cheese (used through 2017)

Creamed Cottage Cheese

SAMPLE 1

FLAVOR SCORE: 1 2 3 4 5 6 7 8 9 10 NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Bitter	___ 7. High Diacetyl	___ 13. Rancid
___ 2. Cooked	___ 8. High Salt	___ 14. Sweet
___ 3. Fermented / Fruity	___ 9. Lacks Fine Flavor	___ 15. Unclean
___ 4. Flat	___ 10. Lacks Freshness	___ 16. Whey
___ 5. Foreign	___ 11. Metallic	
___ 6. High Acid	___ 12. Oxidized	

BODY AND TEXTURE SCORE: 1 2 3 4 5 NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Firm / Rubbery	___ 3. Overstabilized	___ 5. Weak / Soft
___ 2. Mealy / Grainy	___ 4. Pasty	

APPEARANCE AND COLOR SCORE: 1 2 3 4 5 NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Free Cream	___ 3. Lacks Cream	___ 5. Shattered Curd
___ 2. Free Whey	___ 4. Matted	

Fig. 7.3 Computerized scoresheet for the Collegiate Dairy Products Evaluation Contest

Firm/Rubbery (Tough) When the curd of overly "firm or rubbery" cottage cheese is pressed between the tongue and the roof of the mouth, a modest (but sometimes subtle) resistance to crushing or mastication can be noted by the careful observer. Further manipulation of the product in the mouth may suggest either a high solids level or low moisture content of the internal curd structure. Unless this firmness is quite pronounced and/or associated with non-adsorption of cream dressing, this defect is not considered particularly serious. Refer to Table 7.3 for additional details.

Gelatinous This is a rare defect observed in commercial cottage cheese; hence, it is no longer listed on the Collegiate Dairy Products Evaluation Contest scorecard. "Gelatinous" cottage cheese tends to have a sticky or slightly "jelly-like" character, or may resemble tapioca pudding. This body defect may have an accompanying bitter off-taste and a translucent curd appearance. A gelatinous defect is generally due to proliferation of psychrotrophic bacteria in the product and, hence, an indication of product spoilage; such a product is often unpalatable and, hence, unsalable cheese.

Mealy/Grainy (Gritty) Unfortunately, this is a quite prevalent defect in US cottage cheese. The "mealy/grainy" (the term used generally depends on primary particle size) defect can be detected by briefly pressing (with the tongue) masticated curd against the roof of the mouth and carefully attempting to perceive the presence or absence of a gritty or corn meal-like sensation (just prior to expectorating or swallowing the sample). Excessive tiny particles remaining in the teeth crevices after swallowing or expectoration also indicates the mealy/grainy defect. Another way of detecting curd graininess is to "wash" away the cream dressing, carefully knead the

Table 7.2 Common body and texture defects of creamed cottage cheese, their probable causes, and remedial measures

Body and texture defects	Probable causes	Remedial measures
Firm/rubbery	1. Cutting pH of curd too high	1. Cut curd at pH of 4.65–4.70
	2. Excessive cooking time or temperature	2. Carefully determine the optimum cooking endpoint
Mealy/grainy	1. Cooking rate too rapid, especially during initial stages of cooking	1. Slow, gradual cook temperature increments, accelerate at midpoint of cook
	2. Excess acidity developed	2. Cut curd at pH of 4.65–4.70
	3. Inadequate vat agitation	3. Controlled, steady agitation
	4. Too much curd in direct contact with hot vat surfaces	4. Minimize temperature gradient
Pasty	An extreme case of weak/soft	
	(see below)	
Overstabilized	Excessive use of stabilizer in dressing	Decrease amount of stabilizer in dressing
Weak/soft	1. Excessive heat treatment of skim milk	1. Use minimum pasteurization conditions
	2. Excessive acidity (low pH) at cut and during cook	2. Cut curd at pH of 4.65–4.70
	3. Inadequate cook-out temperature	3. Carefully determine optimum cook-out
	4. Overdressing the curd	4. Calculate and blend curd and dressing at appropriate ration (typical ~4/3 ratio)

Source: Adapted from Connolly et al. (1984). *Courtesy* American Cultured Dairy Products Institute

washed curd, and then smear it between the fingers. Instead of a silky, smooth smear (which is characteristic of an "ideal" curd texture), the evaluator often will find a somewhat dry, rough, serrated curd mass instead. The uncreamed curd of "gritty" cottage cheese is similar to the curd formed in the manufacture of casein.

The mealy/grainy defect of cottage cheese may be caused by too-low moisture and/or overdevelopment of acid during coagulum and/or curd formation (Connolly et al., 1984). To minimize this curd defect, more moisture can be incorporated by cooking the curd more gradually and by using lower cooking temperatures. Curd cutting should only be undertaken when the coagulum reaches the isoelectric point of casein (pH 4.65–4.70). Mealiness/graininess may also be caused by (1) nonuniform cutting of the curd; (2) uneven heating (cooking) of portions of the curd; (3) too-rapid cooking of the curd/whey mixture; (4) inadequate agitation during the cooking phase; and (5) allowing curd particles to contact extremely hot surfaces during cooking. The major techniques for controlling the extent of graininess/mealiness are cutting the coagulum at the proper pH (to avoid excess acidity) and maintaining sufficient, but gentle, agitation throughout the cooking stage of the cheese-making process.

Pasty (Sticky, Doughy) The "pasty" defect in creamed cottage cheese is closely associated with soft, weak, high-moisture curd or curd that is excessively ground up or shattered. En masse, pasty-bodied cheese resembles cereal dough, a flour-like paste, or glue. The curd particles have a tendency to mat or stick together in soft clumps. Authorities on cottage cheese quality simply regard the pasty defect as a possible extension or advanced degree of the weak/soft criticism (discussed next).

Weak/Soft (Mushy) This defect is characteristic of a higher-moisture cottage cheese of relatively low solids content. If a less-firm- or weaker-bodied cottage cheese is preferred for certain markets or customers, the cheesemaker has the option of employing a lower cook-out temperature for designated lots of cheese; this variation favors a higher retention of whey (moisture) in the curd. Weak-bodied cottage cheeses may not meet the legal maximum of 80% moisture content. Following storage, a weak, soft-bodied cheese may often manifest a bitter taste, due to the entrapped whey (and associated peptides). According to a quality manual published by the American Cultured Dairy Products Institute (Connolly et al., 1984), probable causes of the weak/soft and/or pasty defects in creamed cottage cheese are the following:

1. Excessive heat treatment of cheese milk (above 80 °C/170 °F).
2. Excessive acidity (low whey pH less than pH 4.40) at time of the start of cooking the curd and during the cooking process (final whey pH at the end of cook that is between 4.20 and 4.30).
3. Too-low cooking temperatures.

Overstabilized (Slick) In an attempt to "thicken" dressing, minimize free whey in the final product and/or enhance adherence of the dressing to the curd, processors may occasionally overdevelop dressing viscosity through excessive use of nonfat dry milk, stabilizers, and/or emulsifiers. The ideal dressing viscosity is between 45 and 60 s when measured on a Zahn #2 cup at 4 °C/40 °F. Overstabilized dressing may exceed a draining time of 60 s when timed in a Zahn #2 cup, or not drain out of the cup at all. Using ingredients in the stabilizer such as food starch, modified food starch, or maltodextrin may tend to promote this slick texture. When this defect occurs, it is quite apparent; creamed cottage cheese may appear markedly dry, and some individual curd particles may appear to be surrounded by a thick, pasty coating. Overstabilized dressing is not considered a serious defect unless it is so severe as to impart an off-flavor or unfavorable mouthfeel (slippery or slick) to the cottage cheese. The overuse of guar gum in the dressing may give a slick or slippery feel in the mouth when evaluated organoleptically. Decreasing the quantity or changing the source of stabilizer can effectively eliminate the so-called slick or overstabilized defect.

In addition to stabilizer, the use of fresh cottage cheese whey protein concentrate (WPC) has resulted in an overstabilized defect as well (Potter, 2007). In most cases, it is necessary to reduce the level of stabilizer to compensate for the moisture bonding and thickening action of the whey proteins. Also, the use of elevated levels of WPC can result in either pasty body and texture or possible off-flavor.

7.5.2.3 Flavor

Pertinent information about cottage cheese may be gained from a focused aroma check of the opened package after stirring of the curd and dressing just prior to tasting. Creamed cottage cheese of high quality should have a fresh, pleasant, clean, delicate acid, and mild diacetyl (buttery) flavor (Elliker, 1949; Connolly et al., 1984; Bodyfelt et al., 1988; Kosikowski & Mistry, 1997) that imparts no aftertaste when the sample has been expectorated or swallowed. There should be no particular aftertaste and only a sufficient salty taste (Bodyfelt, 1982; Wyatt, 1983) to “bring out” the desired flavor. There are conceivable regional differences across the USA, wherein variations of the intensity of the acidity taste and the diacetyl flavor note are either more or less preferred (Mather & Babel, 1959; Connolly et al., 1984; Bodyfelt et al., 1988; Rosenberg et al., 1994a; Kosikowski & Mistry, 1997).

7.5.2.3.1 Evaluation of Flavor

Cottage cheese flavor attributes are a “composite” of curd acidity, volatile compounds formed by the lactic culture fermentation, and/or from addition of aroma-producing microorganisms or added diacetyl compounds to the cream dressing. The composition of the cream dressing and the added salt also serve to greatly enhance the flavor of creamed cottage cheese. Salt is a flavor potentiator. Cream dressing should be added in such quantities that the curd can readily absorb it within a reasonable time period before marketing (2–3 days). The evaluator should recognize the possibility of two types of cream dressing, often depending on the US region: (1) a dressing virtually devoid of much aroma, but seems clean, sweet, and pleasantly acidic and (2) the other type with either a detectable (or definite), diacetyl (buttery-like), or cultured aroma with an acidic character. Both types of flavor characteristics generally are considered equally appropriate in the discretion of experienced dairy product judges, as well as most consumers.

7.5.2.3.2 Flavor Defects of Creamed Cottage Cheese

As a rule, creamed cottage cheese is a highly perishable product, even with rigorous sanitation and product-handling precautions (Bodyfelt, 1981b) that are usually practiced in manufacturing.

The specific flavor defects of creamed cottage cheese are as follows:

Bitter	Malty (not on Collegiate Contest scorecard)
Cooked	Metallic
Fermented/fruity	Musty (not on Collegiate contest scorecard)
Flat (lacks flavor)	Oxidized
Foreign, chemical, and medicinal	Rancid

High acid (sour)	Unclean (dirty aftertaste)
High diacetyl	Whey
High salt	Yeasty (vinegar-like; not on Collegiate contest scorecard)
Lacks fine flavor (acetaldehyde, plain yogurt-like)	
Lacks freshness (stale, storage)	

A brief description of the characteristic features of each of the off-flavors listed above is helpful in trying to identify them; some flavor defects are distinctive and unique to cottage cheese (refer to Table 7.3). Most cottage cheese produced today is usually flat, lacks fine flavor, high acid, high diacetyl, or has a whey flavor. One brand has a cooked flavor due to packaging the product "hot" to get extended shelf-life.

Bitter A "bitter" off-taste in cottage cheese is characterized by its (1) relatively slow reaction time and delayed perception; (2) detection at or near the back of the tongue; and (3) persistence after sample expectoration. Pronounced bitterness is not unlike the sensation imparted by quinine or caffeine. This defect is frequently encountered in older samples of cottage cheese or in cheese stored at favorable growth temperatures for psychrotrophic organisms (which are the principal causative agents). In the past, a bitter off-taste in cottage cheese may have resulted from the consumption of certain weeds by cows; however, bitter cottage cheese from this source would be extremely infrequent today.

Cooked Cottage cheese that is slightly cooked need not be faulted or critiqued. However, excessive heating of the cream dressing typically imparts sulfur notes that are considered detrimental to the desired delicate flavor of creamed cottage cheese. Presumably, the cooked flavor note derives from a definite intensity of cooked flavor of the cream dressing, rather than from the curd cooking process, which by necessity must be limited in order to control curd firmness within the finished product.

Fermented/Fruity Surprisingly, a "fruity" or "fermented" defect may have a pleasant, aromatic quality (to some individuals), suggestive of pineapple, apples, bananas, or strawberries (Morgan, 1970b). Fermented cream cottage cheese is more reminiscent of vinegar. A mere "whiff" of the just-opened package usually confirms the presence of this serious defect. Follow-up tasting usually suffices to substantiate the already-noted aroma and may also reveal an associated unpleasant, distinctive lingering aftertaste. The given cottage cheese may be near its "sell-by" date and/or have been stored at elevated and favorable temperatures for psychrotrophic bacterial growth. The product may soon reach a point of unpalatability. Complete spoilage is often imminent.

Flat (Lacks Flavor) A "flat" flavor in cottage cheese may be noted by an absence or lack of the characteristic flavor and aroma. Identification is that simple and direct.

A dry, unsalted, washed, “rennet curd” yields a distinctly flat taste, unlike that of pure casein. A creamed cottage cheese may also tend to yield a flat taste and aroma during an early or intermediate stage of the development of an oxidized off-flavor. In this case, the initial “flatness” may lead to a delayed flavor perception that suggests a metallic off-flavor; the evaluator should be alert to this possible follow-up off-flavor. Even when pronounced, a flat flavor defect is not considered serious enough to classify the cottage cheese as a poor product (unless an associated and more objectionable off-flavor accompanies the flatness). Reduced fat and nonfat cottage cheese products obviously exhibit lower flavor intensities, due to the reduction or absence of added cream dressing and its related richness and overall “flavor-rounding” effects. The relative freshness and flavor quality of the skim or low-fat milk sources for curd formation are important to the flavor attributes of the resultant cottage cheese products. In today’s marketplace, due to the manufacturer wanting to reduce the sodium content per serving of cottage cheese, the cottage cheese may be judged as “flat” merely due to a reduced level or lack of salt in the cream dressing.

Foreign (Chemical/Medicinal) A “foreign” off-flavor, though only occasionally noted in creamed cottage cheese, distinguishes itself by being entirely unlike any off-flavor that might be anticipated in the product – it seems “atypical” or most unusual. Sometimes, the actual nature of the off-flavor betrays its identity. The persistent, atypical, or “out-of-place” off-flavor may suggest possible contamination either by cleaning compounds, chlorine, iodine, phenol, or various other chemical substances that may have accidentally or unfortunately gained entry to the product.

High Acid (Sour) The terms “high acid” or “sour” basically designate various intensities of the same defect. They generally reflect an excess of lactic acid, a level of acidity beyond that which is generally considered desirable or highly acceptable to taste. However, it should be emphasized that this particular intensity is generally clean and sharp (with no particular aftertaste). The so-called sour taste can be pronounced, and it may sometimes be associated with other bacterial defects, such as bitter or fruity/fermented.

The development of lactic acid by the culture inoculated into skim milk in making cottage cheese is essential for curd formation, unless the cheese milk is chemically acidified (direct set). Also, the formed lactic acid or added acidulant helps contribute to cheese flavor. However, if too much acid is developed in the course of curd formation or curd cooking, it usually results in a high-acid (sour) curd. A high-acid curd tends to mask some of the more delicate, volatile, organic compounds responsible for the desirable flavor of cottage cheese. Insufficient washing(s) of the curd prior to dressing may result in too much whey retention in curds and hence cause or lead to high-acid flavor. A cottage cheese, such as just described, may sometimes merit another related flavor criticism – “whey taint.”

The specific types of lactic culture(s) used in dressings for enhancing flavor and/or product shelf life may become somewhat active within their shelf life period, and hence produce additional levels of lactic acid, which can “announce” itself with either definite or pronounced high-acid or sour flavors.

High Diacetyl This flavor defect is generally noted by an overall lack of aroma balance, or a too distinct intense aroma of diacetyl, plus the possible masking of other important or delicate flavor notes. It is often characterized by the presence of a harsh buttery flavor and/or excess aroma, which seems "out of balance" for cottage cheese. Additionally, some evaluators suggest the terms of "coarse" or "too harsh" to help define the flavor character. Some product manufacturers appear tempted to "over-flavor" reduced fat and nonfat cottage cheeses with either flavor concentrates or whey distillates, and this approach may lead to products that may seem "too high in diacetyl," harsh and/or coarse in flavor character.

High Salt "High salt" manifests itself as an unwanted, sharp, piercing, biting taste sensation that detracts from the pleasant delicate flavor of high-quality cottage cheese. Addition the proper amount of salt (approximately 1% or less) enhances cottage cheese flavor; however, oversalting defeats the purpose of this product ingredient. Both the reaction and adaptation times of the taste buds are of short duration for the salty taste sensation. The initial sensation encountered upon tasting high-salt cottage cheese is soon dissipated and relieved by an induced copious flow of saliva. Experienced evaluators of cottage cheese commonly recognize that 0.6–1.0% added salt is generally required to help enhance the flavor of cottage cheese. However, a distinct or obvious "salty taste" in creamed cottage cheese should not be consciously perceived by the product evaluator (Bodyfelt, 1982; Wyatt, 1983).

Lacks Fine Flavor (Acetaldehyde, Plain Yogurt-Like) When a given lactic culture that has been added to the cream dressing produces acetaldehyde as a principal volatile component, a "green-apple" or yogurt-like off-flavor often occurs in the final product. Such cottage cheese is said to "lack fine flavor," due to formation of substantial levels of acetaldehyde. The lacks fine flavor critique of cottage cheese also suggests a note of "coarseness" or "harshness" off-flavor. The term may also be used to describe cottage cheese that is clean, but lacks some flavor such as added diacetyl or one that doesn't use cultures in the dressing.

Lacks Freshness (Stale, Storage) These three off-flavors have been grouped together because they have much in common. The relative age of the product or ingredients seem to be the underlying factors for this group of flavor defects. A difference in defect intensity exists between "lacks freshness" and "stale." The latter is more obvious or intense, whereas the former defect tends to almost shield its true identity; it is simply a general lack of refreshingness in the product. Staleness may also be imparted by old ingredients (e.g., dry skim milk, cream, and stabilizer).

Cottage cheese flavor is usually at its best or "peak" within 1–5 days after manufacture. When properly made and adequately refrigerated, cottage cheese should retain its "typical flavor" for a reasonable period of time (2–3 weeks). Frequently during storage and distribution, even under adequate refrigeration (<4.4 °C (<40 °F)), cottage cheese progressively deteriorates in flavor quality. This is undoubtedly due to the simultaneous occurrence of microbiological and chemical changes. This resulting flavor deterioration can be referred to as "lacks freshness," since the cottage cheese seems to lack the refreshing flavor characteristics of a more recently made product. A storage off-flavor can develop in cottage cheese that is packaged and subsequently exposed to "volatiles" within the refrigerator or cold storage space. Hence, the "storage" off-flavor, if and when it does occur, is appropriately classified as an absorbed flavor defect.

Malty A "malty" off-flavor defect in cottage cheese is rather specific or distinctive; maltiness tends to predominate over most flavor defects that may be present. This off-flavor, which resembles "Grape Nuts®" or malted milk, is quite easy to identify due to its uniqueness. It generally has a quick reaction time; the aftertaste is not prolonged. Since a malty off-flavor is the result of contamination by an outgrowth of *S. lactis* var. *maltigenes*, additional developed acidity (a sourness taste) may accompany a malty aroma defect (Morgan, 1970a).

Metallic and Oxidized Fortunately, these two more serious off-flavors are infrequently encountered in cottage cheese. If they do occur, improper selection and/or handling of the cream for preparation of the curd dressing is usually indicated. "Metallic" has a slightly astringent, "rusty nail-like" taste, while "oxidized" is an off-flavor more reminiscent of wet cardboard or paper. Smelling the sample usually gives little indication of a metallic defect, but a weak off-odor may sometimes suggest the characteristic or "generic oxidized" off-flavor. Some research indicates that these two defects may be different intensities of the same basic defect (e.g., lipid autoxidation) resulting from light exposure or copper or iron contamination of susceptible milk or cream used.

Musty "Musty" cottage cheese exhibits an aroma that resembles that of a damp, poorly ventilated cellar. This serious, but seldom encountered, defect in cottage cheese is due to the outgrowth of various microbial contaminants, primarily molds, in cottage cheese. Cheese curd may sometimes become contaminated with certain psychrotrophic bacteria (*Pseudomonas taetrolens*) as the result of faulty plant sanitation (Foster et al., 1957). When this development is coupled with inadequate refrigeration and processing methods, the musty defect may occur; it usually intensifies as cottage cheese is held in storage. The product would soon become unpalatable, if such is not already the case. This defect may be noted more frequently during late fall, winter, or early spring, when cows are more apt to be on dry feed for extended periods (Bodyfelt et al., 1988). Also, if a milk supply that is susceptible to milk fat autoxidation is used to produce cottage cheese curd, this potential off-flavor could likely be retained by the curd. An oxidized flavor defect will generally intensify during storage and may occasionally develop into a distinct, "tallowy" off-flavor. Any copper contamination, especially of the cream or milk used in preparing the dressing, can easily catalyze development of an oxidized off-flavor.

Sweet The term "sweet" was recently added to the Collegiate Dairy Products Evaluation Contest scorecard to account for an atypical (for the product) sweet off-flavor that has become more notable since the advent of the use of lactose and/or maltodextrin in custom blends of certain stabilizers that are used in the cottage cheese industry. As new sources of ingredients continue to be utilized in the manufacture of creamed cottage cheese, novel and somewhat unfamiliar flavor notes associated with this product are observed. Hence, new flavor descriptors may continue to be identified with the progress of innovations and time. Application of the term "sweet" in conjunction with the acid-coagulated type of cheese seems contradictive, but in the instance just cited, this descriptor is appropriate.

Rancid "Rancidity," in cottage cheese, as in milk, may be noted by an astringent, puckery feeling at the base of the tongue and throat, as well as an associated bitter aftertaste, following sample expectoration. The objectionable rancid off-flavor tends to persist as an unpleasant aftertaste for a considerable period of time. Short-chain fatty acids (C_4–C_{10}) are readily formed by the hydrolysis of milk fat under certain adverse physical conditions or improper processing protocols. Subsequently, the free fatty acids react with the salts of milk, leading to formation of aromatic compounds (i.e., soaps), thus leading to hydrolytic rancidity. Rancidity is variously described as "soapy," Romano cheese-like, with a delayed "bitter" aftertaste.

If rancid milk or cream is used to manufacture cottage cheese curd and/or dressing, this serious off-flavor will carry over into the finished product. Since rancidity is due to the action of the enzyme lipase on milk fat, this flavor defect is derived from the added cream, not from the curd. This defect may intensify as the cheese becomes older, particularly if the homogenized dressing was not adequately heat treated. Proper pasteurization of all milk products used in making cottage cheese prevents rancidity, providing the raw milk and cream supplies were free of this defect.

Unclean The designation for this serious defect is self-explanatory. The off-flavor "unclean" cannot be easily expressed in other descriptor terms. Some judges have dared to use the term "dirty" to describe the unpleasant, objectionable, unclean-like off-flavor that sometimes proliferates as an undesirable aftertaste in cottage cheese that has commenced to spoil or exhibit microbial deterioration. This unpleasant flavor note, often accompanied by a distinct bitter off-taste, generally remains for some time after sample expectoration; product palatability is at stake. Skim milk used to make cottage cheese that might have a "barn-like or cowy-type" of flavor could be also judged as "unclean."

Whey The so-called whey off-flavor in cottage cheese manifests itself as either a "sweet brothy-like" flavor (due to the presence of residual lactose), or an acidic whey flavor (due to residual fermented whey), which results from insufficient chill water rinsing of the curd prior to addition of the dressing. Added whey protein concentrate or added sweet or acid whey in the cottage cheese dressing as an economical solids source can also contribute to this flavor criticism. A processor strategy that utilizes cottage cheese acid whey permeate as a solids source in cream dressing formulation in order to help minimize whey disposal costs may contribute to the "acidic whey" off-flavor defect. The whey flavor defect of cottage cheese may or may not be associated with the visible “free whey” appearance defect as observed within the product package upon opening the closure, inasmuch as product stabilizers and emulsifiers may aid in masking the visual defect.

Yeasty (Vinegar-Like) “Yeasty” and “vinegar-like” defects in cottage cheese have a peculiar aromatic quality in addition to a possible associated high-acid note. While this defect may be caused by growth of yeasts and tends to exhibit a yeasty or earthy off-odor, the often-associated sharp, pungent taste may be suggestive of vinegar (possibly due to bacterial fermentation). Various microbial contaminants, including certain kinds of psychrotrophic bacteria, are generally responsible for this objectionable off-flavor. Usually, serious sanitation shortcomings in manufacture and/or packaging are at fault and in need of elimination to correct this serious off-flavor problem in cottage cheese. The shelf life of this relatively perishable product is significantly reduced by poor sanitation and lack of temperature control throughout the distribution chain (Bodyfelt, 1981a, b; Morgan, 1970a, b).

7.6 Historical Development of the Cottage Cheese Industry

7.6.1 Improvements in Product Quality

Obviously, research conducted since the 1930s on lactic cultures and specialized equipment at US and Canadian universities, as well as commercial suppliers (Olsen, 1980), has played a major role in solving many of the manufacturing, sensory quality, and shelf life challenges posed by delicate properties of creamed cottage cheese over the decades. Research efforts focused on this fresh cheese category were quite limited, if nonexistent, prior to 1930. At about this time, dairy technologists, scientists, and microbiologists recognized that cottage cheese was gradually becoming a significant product category for the North American dairy industry. Several forms of technology transfer were implemented to bring new knowledge and sanitation protocols to the budding North American cottage cheese industry. The most common and effective methods of product quality maintenance and improvement involved the in-plant presence of trained personnel from lactic cultures and specialized ingredients suppliers and cottage cheese-making equipment providers, who visited plants and transferred their technical knowledge and scientific advances related to lactic cultures selection, bacteriophage (an infectious virus) control, and reduction of cheese culture/milk agglutinin interactions (i.e., curd sludge formation). Basic and applied research at university experiment stations focused on modified, improved cottage cheese manufacturing procedures (i.e., short and intermediate set protocols), more specific sanitation and curd cooling/handling methods, and product shelf life extension (Angevine, 1964; Olsen, 1980), which had been a limiting factor in marketing cottage cheese beyond local market areas (<100 mi).

Traditionally, cottage cheese was only made with lactic acid producing mesophilic culture based strains. Now, most of it is made with direct set cultures which contain a blend of lactic-acid-producing mesophilic *and* thermophilic lactic acid bacteria strains. This gives additional bacteriophage control and makes for a shorter incubation time . With an elevated set temperature of the skim milk in the vat, thermophilic lactic-acid-producing bacteria strains produce lactic acid faster and to a greater degree over time than mesophilic lactic acid bacteria strains do. Whey pH after cut needs to be monitored so a soft-textured cheese curd is not obtained. This means adding less cooking acid or no cooking acid to the whey before cooking is started. Additionally, higher cook temperatures need to be utilized in order to drive the whey from the curd piece during cooking, since more acid produced from the culture itself usually means softer cheese when cooked out to the same temperature endpoint.

7.6.2 Cottage Cheese Industry Pioneers

Mr. Neil Angevine, who commenced his cottage cheese work in the early 1920s, was saluted by Olsen (1980) as the one person (self-developed in requisite skill sets, technical applications, and applied sciences) who more than any other individual advanced the US and Canadian cottage cheese industries for over four decades. Mr. Angevine did not benefit from the possession of a college degree. He learned his lessons from personal contacts with several persons within the mid-western small cottage cheese plants he worked in through the 1920s. By the 1930s, Mr. Angevine had earned a reputation as being a superior "technologist" on lactic cultures, cultured products, and creamed cottage cheese. He was soon employed by a cultures supply company to visit plants all over the USA and Canada for demonstrating the best preparation and use of cultures, with emphasis on his relatively new "short-set method" for cottage cheese making. Thus, this was the beginning of a dedicated career of over 40 years of service to the lactic cultures and cottage cheese industry, which culminated in Mr. Angevine being appointed as the lead product judge when cottage cheese was added to the National Collegiate Dairy Products Evaluation Contest in 1962. Angevine's enthusiasm for demonstrations of "best techniques" soon drew in other processor and supplier personnel involved with lactic cultures, cottage cheese, and other cultured product processing. This "passion for more perfection" eventually evolved into regularly scheduled and conducted "Cultured Dairy Products Training Schools," which were subsequently transferred to the responsibility of the Cultured Dairy Products Institute, and eventually called the "Kurds and Kultures Klinics."

Another recognized "giant" of the cottage cheese and cultured products industry in the USA was Erik Lundstedt, an immigrant in 1929 from Denmark, who earned a degree in dairy chemistry from Iowa State College. After working several years in US butter and cheese plants, he next became affiliated with H.P. Hood and Sons Inc. of Boston, as the manager of Hood's cottage cheese operations for 15 years, before retiring as a worldwide consultant on cultures and cultured products and author of numerous articles in his areas of expertise (Angevine, 1964; Olsen, 1980).

Lundstedt continually looked for better methods and better quality control in cottage cheese and related products. Some of the significant achievements of Lundstedt's research were as follows:

1. Several new cultured products processing methodologies that were patented.
2. A device for more precisely determining the firmness of cottage cheese curd was created.
3. The use of citrated whey for lactic culture propagation was begun.
4. A method for enhancing the aroma of various cultured products was developed.
5. A high-protein, low-fat, unripened cheese was developed.
6. A process for drying acid whey with subsequent applications was developed.

Erik Lundstedt continued in retirement as a prolific writer of practical and scientific articles. Lundstedt, along with Dr. Frank Kosikowski and David Bandler of Cornell University, founded the American Cottage Cheese Institute in 1959–1960, with Lundstedt serving as the first president, and Angevine as the second. This organization later was re-named as the American Cultured Dairy Products Institute, which commenced publishing a well-received journal by 1961.

A mid-western leader in developing what was generally recognized as the most precise protocol for manufacturing consistent, high-quality cheese was Al Shock, who developed the Nordica System process (Potter, 2007) of cottage cheese manufacture in South Dakota in the 1950s. The Nordica System process developed and provided its own lactic cultures and manufacturing protocols, and formally licensed plants in the USA and Canada to use the specific and detailed manufacturing protocols (eventually extending the manufacturing system to England and Australia). By the late 1960s, there were over 100 cottage cheese producers licensed under the Nordica process.

7.7 Conclusion

US cottage cheese per capita consumption has continued to decline throughout the past 20 years as reported by the USDA. It can be speculated that the primary reason for little or no real growth in cottage cheese sales has been due to inconsistent product quality and lack of market focus and promotion, as compared to the dairy industry's experience and successes with yogurt. Cottage cheese manufacturers have reformulated their products over recent decades to maintain profitability in cottage cheese production by increasing the ratio of dressing to curd and using less costly or more functional ingredients. With each such change or innovation, new challenges are encountered to maintain or assure consistent flavor, texture, and appearance attributes.

A prime example of an innovation that has not necessarily enhanced product quality has been the introduction of automated curd washing and draining equipment. The increase in particle fines and broken curds retention has led to the vast majority of cottage cheese exhibiting markedly higher levels of less appealing shattered curd. In turn, this results in inconsistent dressing absorption and more visual defects in final product appearance and texture. The additional use of functional ingredients – such as cottage cheese acid whey permeate to help with minimizing cottage cheese whey disposal, improve dressing adsorption, and reduction of stabilizer costs – also leads to additional flavor defects. By contrast, the benefits of producing cottage cheese with longer shelf life periods (especially with CO_2 incorporation into dressing) and extension of yields through solids (fines) retention have helped the industry in several ways.

The future success of the cottage cheese industry will require continued development of better manufacturing methods to make this product more consistent and economical, while maintaining optimal flavor, texture, and appearance. The ability of cottage cheese industry personnel to recognize and identify the resulting defects and apply possible remedial measures will be more important than ever to expand the cottage cheese market.

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Chapter 8
Yogurt

Don Tribby and Vanessa Teter

8.1 A Brief History of Yogurt

Yogurt has been consumed since recorded time. It is not exactly known how yogurt was discovered, but it is assumed that it was by accident, perhaps by Mesopotamians in about 5000 BC (Kosikowski & Mistry, 1997). During this time, herdsman would milk goats and sheep and carry the milk with them in pouches made from an animal's stomach. These stomachs contained a natural enzyme, called chymosin, which forms a gel or coagulum when added to milk. Given (1) the warm climate in this part of the world, (2) the storage conditions available at the time, and (3) "natural starter culture" in the milk, either yogurt or cheese was made. Fermentation probably began within a few hours. Most likely, these people noted that this soured milk product tended to keep longer and they grew to prefer the flavor of yogurt to that of fresh milk. These people also eventually realized the health benefits of eating yogurt, and much later, some observers wrote about living a longer and healthier life as a direct result of frequent consumption of the fermented products (Andrews, 2000).

Yogurt also traces its roots to the Caucasus Mountain region of Russia. The people of this rugged region were commonly nomadic – and as subsistence used both the milk and meat of cows, sheep, goats, and yaks. The fermented milk product traditional to this region, kefir, is a liquid cultured product whose name translates to "good feeling." It also earned the reputation as being a healing drink and was considered a "gift of the gods." Kefir was widely consumed by all families, and the bacteria culture that was used to ferment this product was prized and guarded most closely.

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Yogurt also appears in many ancient writings, including the Indian Ayurvedic scripts, the Bible, and historical literature by Pliny, Herodotus, Homer, and Galen. In Genesis 18:8 Abraham may have served yogurt and milk to his guests, "Then he (Abraham) took curds and milk and the calf that he had prepared, and set it before them. And he stood by them under the tree while they ate."

Cultured dairy products' history also reports that Genghis Khan loved the taste of cultured products and mandated that all of his soldiers consume them on a regular basis. By the year 1215, Genghis Khan had conquered Mongolia, and Khan personally believed that part of his military success could be attributed to the fact that his army stayed strong and healthy by consuming the nutritious product kumiss. Reportedly, his official orders required that his entire army, from the top generals to the lowly slaves, were to eat this particular form of yogurt.

In 1542, a Jewish physician introduced yogurt into France from Constantinople. The King of France, Francois I, suffered from acute depression and had undergone every possible therapy known at that time. The "Ambassador to the Sublime Porte" told him about this doctor from a distant land who made a concoction derived from soured sheep milk. This particular fermented milk drink had been reported to possess therapeutic properties. The king sent for this doctor, who traveled with his sheep from Constantinople to Paris, France. The king, after drinking this fermented elixir, was reported to be healed. However, the sheep were not so fortunate – they all died from the long trek and the cold climate. This doctor ultimately returned home without surrendering his "formulation secret" to the king.

The broad popularity of kefir in Russia dates back to the early 1900s, when the All-Russian Physicians Society contacted two brothers who owned a cheese plant for help in obtaining some kefir starter culture. The society was looking to popularize this product for its reputed health and aging benefits. The royal Caucasus family closely guarded the culture used to produce kefir. According to legend, two brothers hired a beautiful young lady to help obtain the prized culture (Mariani, 1999). She failed in her attempt to gain the culture, but did win the prince's love. He proposed to the lovely lady, but she declined his hand in marriage, and left for home. The prince became so angered with her refusal that he had her kidnapped, but she was ultimately rescued. The lady and the Physicians Society sued the prince in the Czar's courts and won a legal settlement. The prince offered her gold and other valuables, but she finally agreed upon gaining possession of some of the valuable kefir culture, and thus, the case was finally settled. In September 1908, this successful legal litigant took some of the kefir culture to Moscow, where it was used for many years as the kefir culture strain, and was incorporated into many different medicines. Thus, this beautiful lady was ultimately responsible for both the spread and the popularity of kefir across Russia, and eventually to many parts of the rest of the world.

Yogurt gained global attention in the early 1900s when the Russian bacteriologist Ilya Metchnikov conducted research on the extended life spans of certain Bulgarians. He noticed that these people had longer life spans than those of the surrounding countries. His studies emphasized that Bulgarian people consumed large amounts of yogurt and related cultured milk products. His papers were widely published and valued; he received a Nobel Prize and the popularity of yogurt significantly increased.

As early as 1784, Turkish immigrants are credited with bringing yogurt to the USA. However, yogurt popularity commenced in the late 1930s and 1940s when Columbo and Danone (later renamed Dannon in the USA) began yogurt businesses on the east coast in the USA (General Mills, 2007; Dannon, 2007). In 1947, Dannon started adding strawberry preserves to the bottom of the cup, and thus made the first "sundae"-style yogurt.

The global popularity of yogurt spread quickly in the USA after WWII. Many soldiers tasted it for the first time in Europe; afterward, they brought the idea and the interest to the US market.

Greek yogurt was introduced to the US market in 2007 by the Chobani Company. Greek yogurt has a thicker consistency and higher protein and solids content compared with yogurt products that were typical of the US market at the time, labeled as stirred (Swiss) or cup-set. Greek yogurt is a cultured milk product made by the addition of milk solids (referred to as Greek style) or by whey removal through straining or centrifugation (referred to as Greek yogurt). This approach has been used to manufacture many different, but similar, types of cultured products throughout the world for thousands of years. Some products in this category, like Quark and Skyr, are becoming more popular in the US market.

Similarly, thinner-cultured milk products, more commonly known as drinkable yogurts, have also been made and consumed around the world since the beginning of time. First natural cultures were used, and now the strains used were those that evolved to give the best flavor and texture.

8.2 Yogurt Defined

The Code of Federal Regulations (CFR 131.200 (USFDA, 2020)) definition of yogurt is "Yogurt is the food produced by culturing one or more optional dairy ingredients with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (Olsen, 2002; USFDA, 2020)". One or more other optional ingredients may be added, but must be added prior to culturing. Yogurt, before the addition of bulky flavors, contains not less than 3.25% milk fat and not less than 8.25% milk solids not fat, and a titratable acidity of not less than 0.9%, expressed as lactic acid. The food (base) may be homogenized and shall be pasteurized or ultra-pasteurized prior to the addition of the bacterial culture. Flavoring ingredients may be added after pasteurization or ultra-pasteurization. To extend the shelf life of the food, yogurt may be heat treated after culturing is completed, to destroy viable microorganisms.

Optional dairy ingredients are described as cream, milk, partially skimmed milk, or skim milk, used alone or in combination. Other optional ingredients include concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, and/or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat milk solids content of the food, provided that the ratio of protein to total nonfat solids of the food and the protein efficiency ratio (PER) of all proteins present shall not be decreased as a result of adding such ingredients.

Nutritive carbohydrate sweeteners such as sugar (sucrose), beet, or cane; invert sugar (in paste or syrup form); brown sugar; refiner's syrup; molasses (other than blackstrap); high-fructose corn syrup; fructose; fructose syrup; maltose; maltose syrup and dried maltose syrup; malt extract and dried malt extract; malt syrup and dried malt syrup; honey; and/or maple sugar may be used (USFDA, 2020).

8.2.1 Greek Yogurt Defined

There are two types of Greek yogurt, and as mentioned before, none have legal definitions. They are defined by their processing techniques more than any standard definition. In the industry, there are two ways to create what consumers think of as Greek yogurt. The first is by fortification – this can be done by adding various milk protein powders (such as whey or casein into the product). This allows for two things to happen simultaneously – the first is a thicker product as the proteins react with the water in the product, and the second is the protein content itself is also higher. In the industry, this is what's referred to as a Greek-style yogurt – meaning it is thicker and is higher in protein but is created simply by formulation.

The second way Greek yogurt can be created is by mechanical separation – this can be done using ultrafiltration or centrifugation, essentially any processing technique that allows the curd to be concentrated and the acid whey removed from the curd. This in turn creates a thick product as well as concentrating the proteins in the curd itself, therefore driving up the protein content of the finished product. Because this is how Greeks make yogurt, typically this is simply called Greek yogurt to the consumer and this is how most companies.

While there are two different types of Greek yogurt, and many different ways of creating those types, there is no CFR definition for Greek yogurt or Greek-style yogurt. But the fact that the name has the fat content and the name "yogurt," it must adhere to the standard identity of each of the corresponding products, i.e., Greek nonfat yogurt and Greek low-fat yogurt.

8.2.2 Drinkable Yogurt Defined

There is no CFR definition for drinkable yogurt. But, like Greek yogurt, the fact that the name contains the fat level (nonfat, low-fat) and yogurt, it must conform to the standard of identity or definition of yogurt. To make a drinkable yogurt, most times different cultures are selected that do not create as much body and texture in the product, and additional sheer will be added to the product post fermentation to help break any bonds that are created during fermentation.

8.3 Yogurt Cultures (Microflora)

The special properties of cultured milk products begin with the unique properties of the microorganisms used in their production. Perhaps more than any other type of cultured dairy products, yogurt has enhanced the shelf life, appeal, and digestibility of fresh milk for the North American consumer. Yogurt is a fermented dairy product resulting from the symbiotic growth of *Streptococcus salivarius* subspecies *thermophilus* and *Lactobacillus delbrueckii* subspecies *bulgaricus* to produce a smooth viscous gel with a desirable cultured flavor. Various styles of yogurt are now targeted for a variety of different consumer groups from children to geriatrics, and the variety of products depends on the properties and microbiology of starter cultures used in their production. Many companies use *S. thermophilus* and *L. bulgaricus* strains for production of yogurts with distinctive nutritional or physical characteristics. In addition, *Lactobacillus acidophilus*, *Bifidobacteria* species, and other strains not required by the standard of identity are added for their purported health benefits. In the current yogurt market, culture strains are selected based on their rate of acid production, flavor profile, exopolysaccharide production, and bacteriophage resistance to produce yogurts with specific textural properties, reduced post-fermentation acidification, and milder flavor than products of the past.

8.3.1 Essential Microflora for Yogurt Production

1. *Streptococcus salivarius* subsp. *thermophilus* (*S. thermophilus*) are Gram-positive cocci in pairs to long chains, with optimum growth temperature of 40–45 °C (104–113 °F), a maximum growth temperature of 50 °C (122 °F), and are able to survive lower temperature pasteurization (63 °C/145 °F; University of Guelph Dairy Science and Technology, 2007). This organism is extremely sensitive to antibiotics (readily inhibited by 0.01 IU/ml of penicillin, with slight inhibition apparent in as little as 0.001 IU/ml of penicillin). This sensitivity to antibiotics as well as chemical cleaners underscores the need for high-quality milk supplies and sensitive antibiotic testing procedures. While bacteriophage also can be a problem for certain commercially popular strains, sensitive testing procedures and good plant sanitation can minimize the chances of production failures. *S. thermophilus* is weakly proteolytic and requires free amino acids generated by *L. bulgaricus* (below), attained from either severe milk heat treatment or exogenous sources. *S. thermophilus* produces formic acid and is responsible for reduction of oxygen levels in associative growth with *L. bulgaricus*.

2. *Lactobacillus delbrueckii* subsp. *bulgaricus* (*L. bulgaricus*) are Gram-positive rods that occur singly or in pairs in young cultures (University of Guelph Dairy Science and Technology, 2007). In older cultures, Gram-variable rods occur either in pairs or chains, with or without granules. *L. bulgaricus* is less sensitive to antibiotics than *S. thermophilus*, with 0.30 IU/ml of penicillin required for significant inhibition. A strict nutritive requirement for formic acid is satisfied by severe heating of milk (e.g., 88 °C (190 °F)) for 30 min or by associative growth with *S. thermophilus*. *L. bulgaricus* can be highly proteolytic, affecting yogurt flavor and shelf life if it dominates the cocci organism. Up to 2–3% of lactic acid is produced in pure cultures, as well as high levels of acetaldehyde. *L. bulgaricus* can be attacked by bacteriophage, though not as readily as *S. thermophilus*. Optimum growth temperatures are 40–43 °C (104–110 °F), with maximums of 53–60 °C (127–140 °F) for certain strains.

8.3.2 Optional Microflora for Yogurt

In addition to the cultures required by law for yogurt production, optional microflora may be added to yogurt for health benefits, as in the case of probiotics, or for textural reasons like the use of exopolysaccharide-producing cultures to increase the body of the yogurt.

1. *Lactobacillus acidophilus* (*L. acidophilus*) is a Gram-positive rod, very similar in morphology to *L. bulgaricus*, but it is not a major contributor to acid, flavor, or texture when used as an adjunct microorganism in most yogurts. *L. acidophilus* is able to survive in the small intestine because of its bile and phenol resistance, which *S. thermophilus* and *L. bulgaricus* do not possess (Gibson, 2001; Rahrs, 2005a, b). However, propagation and survival of *L. acidophilus* in yogurt is difficult, due to peroxides generated by *L. bulgaricus* when oxygen is present. The NCFM strain of *L. acidophilus*, which was developed at North Carolina State University, is believed to implant in the small intestine and produce antimicrobial substances against undesirable intestinal anaerobes (Gibson, 2001). It may also be beneficial in re-establishing intestinal flora in patients who have undergone antibiotic therapy. Optimum growth temperatures for *L. acidophilus* propagation are 35–38 °C (95–100 °F), with maximums of 45–48 °C (113–118 °F).
2. *Bifidobacterium infantis* and *Bifidobacteria longum* (*B. infantis and B. longum*) are small, Gram-positive irregular rods that occur singly or in pairs in milk cultures. Clinical research indicates that these strains may be the predominant organisms in the large intestine of infants and some adults. As with *L. acidophilus*, this organism is considered preferable to the normal anaerobic organisms that inhabit the intestinal tract. *B. infantis* is most common in infants and *B. longum* appears more commonly in adults. The suggested health effects of *Bifidobacteria* species include the ability to inhibit gut invasion by streptococci,

inhibition of colonization by *E. coli*, serum cholesterol reduction, and the ability to elevate immunocompetence, as measured by impact on mean corpuscular volume of red blood cells and macrophages (Gibson, 2001).

3. Several types of microorganisms produce unique polysaccharides (exopolysaccharides or EPS) that can be used to improve the viscosity of yogurt. Wise discrimination in the selection and use of these microorganisms may relieve excessive reliance on stabilizers, and a richer, creamier texture can be achieved even in low-fat or nonfat products. Some producers elect to use these microorganisms instead of hydrocolloids. The use of specialized heavy-body strains can also improve consistency and control after acidification. Polysaccharide formers are most often strains of *S. thermophilus*.

8.4 Yogurt Starter Handling and Fermentation

Commercial cultures are available as direct-set cultures or as bulk starter. Proper handling and propagation of yogurt starters is critical for maintaining optimal strain balance, flavor development, and shelf life. The choice between preparing a fresh, milk-based starter culture versus using a frozen or freeze-dried direct-set entails a trade-off between consistency and set times. Direct-set cultures take a little longer than bulk starter and tend to be used in Swiss-style yogurt more than cup-set. With the vast range of freeze-dried and frozen direct-set and bulk starter cultures, processing plants can now select strains and propagation techniques that are most amenable to different yogurt styles and production processes.

1. *Starters.* Most plants in the USA use frozen and freeze-dried direct-set types of cultures that perform the basic functions of acid and flavor development. Freeze-dried direct-set cultures are more stable than frozen cultures at storage temperatures of up to 0 °C and tend to involve less risk in shipping, storage, and handling. Fermentation times for freeze-dried cultures last from 5 to 7 h at 41–42 °C (106–108 °F) until vat set, whereas frozen cultures take 5–6 h, depending on the freshness of the culture. Propagation of bulk starter cultures is still used at some plants that desire a faster product set time of 3–4 h. Good consistency with bulk starter depends on keeping bacteriophage out of the milk-based starter, testing starter milk for low-level antibiotics, and ripening to a consistent end-point pH. The optimum ratio of either a bulk starter or direct-set culture depends on the type of product – a traditional yogurt should be in the ratio range of 1:1 to 4:1 *cocci*:rods (*S. thermophilus*:*L. bulgaricus*); however, for mild-flavored yogurt, the *cocci*:rods ratio may be as high as 15:1.
2. *Fermentation*. A properly conducted fermentation will promote balanced growth of the essential yogurt microflora. Normally, *L. bulgaricus* stimulates early growth of the *cocci* by enzymatically liberating essential amino acids from the milk protein. This is one reason why sufficient inoculum levels are critical for rapid fermentations. As a result of this early stimulation, the *streptococci* typi-

cally outnumber the *lactobacilli* by three or four to one within 1–2 h. The rods begin to develop rapidly once the pH drops below the 4.8–5.0 range, and it is only at or below a pH of 4.5–4.6 that the characteristic yogurt flavor begins to be expressed. Most yogurts are considered "ripe" somewhere in the pH range of 4.0–4.5, depending on how strong or mild a product is preferred. A pH lower than 4.0 is undesirable, since *L. bulgaricus* tends to produce excessive lactic acid, acetaldehyde, and proteolytic by-products in this pH range. This culture can help maintain a product pH of 4.1–4.3 throughout shelf life, thereby maintaining a mild flavor and a pleasant product appearance. Such cultures can also eliminate the graininess that commonly develops during breaking and cooling of vat-set yogurts. Reducing yogurt temperature to 21–24 °C (70–75 °F) is usually sufficient to stop culture activity and allow packaging without setting up the stabilizer portion of the product. When fermentation is stopped at too high a pH (above pH 4.7), the yogurt will often have a weak body and/or stringy texture; hence the use of a pH meter for determining the break point is essential.

8.5 Yogurt Manufacturing

Yogurt process and formulation variations are as numerous as the number of manufacturers. The finished yogurt will vary regarding body and texture depending upon the type of ingredients, processing, starter cultures, and flavor and in the packaging that is used.

The processing of yogurt can be broken down into the following steps: batching, pasteurization, homogenization, culturing and fermenting, fruit and flavor addition, packaging and cooling, and storage.

Each step is extremely important in the process, and strict attention to detail must be taken.

8.5.1 Batching of Yogurt Mixes

There are a number of different types of batching equipment used by yogurt manufacturers to blend the raw material ingredients together. Each blender has its own advantages and disadvantages, but all are used to standardize the mix and blend ingredients. At this point, any additional ingredients are added to the milk blend, such as nonfat dry milk, whey or whey protein, sugars, and/or stabilizers. It is important to add the dry ingredients to the milk at a point of highest agitation, but at the same time, to avoid air incorporation or foam. Foam tends to hold large amounts of milk solids, and if the foam is left behind in the mixing vat after pasteurization, those solids are not incorporated into the base, and therefore the final product may be low in total solids and have a weak body.

Many of the ingredients added to the yogurt base are very hygroscopic. When these ingredients come into contact with milk, they will absorb liquid quickly and can form lumps, "fish eyes," or in extreme cases can clog a line. Therefore, it is extremely important that the dry ingredients are added at a rate that they become incorporated into the mix without agglomerating. "Fish eyes" are described as a mass of dry material that has a layer of partially hydrated material on the surface, but dry in the center. If the "fish eye" is made up of stabilizer material, this product might not hydrate fully, regardless of the amount of heating and agitation that ensues. These ingredients will not have their full functionality in the yogurt, and thus the body and texture may be lacking. These lumps may be noticed floating on the surface, in in-line filters, or remaining in the tank after emptying.

The most important aspect of ingredient blending is to incorporate as little air as possible and to completely add the dry ingredients to the base without forming lumps. After the blending process, it is common to hold the yogurt mix, with agitation, for a short time prior to pasteurization to allow the stabilizers to hydrate and become fully functional.

8.5.2 Pasteurization of Yogurt Mixes

Pasteurization of yogurt mixes can be accomplished by several different methods. As with any other dairy product, the purpose for pasteurization is to heat treat milk to eliminate pathogenic bacteria. Pasteurization also aids in the hydration of the stabilizers and dry ingredients that were added during blending, as well as adding a pleasant cooked flavor. Heat treatments beyond pasteurization are used to denature the proteins and attain the highest level of functionality from the milk proteins, which are important for product texture.

The three main types of pasteurization are (1) vat method (low temperature long time (LTLT), 80 °C (175 °F) for 30 min), (2) high temperature short time ((HTST), 80–88 °C (175–190 °F) for 18–50 s depending upon the length of the holding tube), and (3) ultrahigh temperature ((UHT), 138 °C (280 °F) for 2–4 s). The latter method is not as common, but it is starting to gain application. Some manufacturers who pasteurize using methods 2 and 3 hold their yogurt mixes in holding tubes for an additional 5–20 min at the pasteurization temperature in order to denature whey proteins and improve product viscosity.

It is common to pasteurize Greek-style yogurt mix at temperatures of 88–93 °C (190–200 °F) with a hold time of 5–7 min.

8.5.3 Homogenization of Yogurt Mixes

Yogurt mix homogenization, though not essential, aids in hydration of stabilizers and the interaction of stabilizers with milk proteins. In the manufacture of yogurt and other dairy products, it is common to homogenize mixes at approximately

63 °C (145 °F), with a total pressure of between 7 and 10 MPa (1000 and 1500 psi) in the first stage and 3 MPa (500 psi) in the second stage or alternatively, 7 MPa (1000 psi) in the first stage and 3 MPa (500 psi) in the second stage. Different types of homogenizers may be used (such as a microgap type), but the same pressure conditions are applied. Some manufacturers homogenize after the regeneration section of the pasteurizer and some homogenize after the cooling section. In all cases, homogenization should never be conducted on raw milk, or hydrolytic rancidity will be induced.

The composition of the yogurt stabilizer can influence the homogenization pressure and temperature that is used. Some gums and starches require heat and shear to activate or "bloom." There are also certain types of starches that will be ineffective if they are homogenized after they have become fully hydrated or bloomed. If this happens, the entire functionality of the starch will most likely be lost, and many body and texture defects in the finished yogurt may be noticed, such as weak body, syneresis, or wheying-off. Processing recommendations from stabilizer supplier representatives are advised for material sources and utilization strategies.

8.5.4 Culturing and Fermenting the Yogurt Mix

The sequence of the steps of culturing, fermenting, smoothing (when used), cooling, flavor addition, and packaging are dependent on whether a stirred (Swiss) style or a cup-set-style yogurt is made, regardless of formulation variables.

8.5.4.1 Culturing and Fermenting Stirred (Swiss) Style Yogurt

After pasteurization and homogenization, the yogurt mix is cooled to the optimum setting temperature. Depending upon the bacteria used in the yogurt culture, normal set temperatures range between 32 and 46 °C (90 and 115 °F), with a normal incubation (set) more than 8 h. These incubation conditions are dependent upon the type of cultures used and the type of yogurt produced.

After the yogurt mix has reached its "set" temperature, the culture is added. Extreme care should be taken in the inoculation process of the vat. If contamination occurs in the yogurt-making process, this is usually where it occurs. All containers and equipment used in the inoculation process such as pails, buckets, hand agitators, and culture packages and cans must be sanitized with an approved sanitizer.

After addition of the culture, the agitator must be left on low speed for a minimum of 15 min to ensure adequate dispersion. Improper agitation may result in pockets in the yogurt vat that have a higher-than-normal concentration of bacteria, or hot spots, and will develop much faster than the rest of the vat. Also, there may be pockets that have very little bacteria, and therefore will have little to no acid development. When the main body of the vat is ready to be broken and cooled, this portion may affect the finished body, texture, and flavor of the finished product.

Upon adequate agitation of the yogurt, the agitator must be shut off and the culture allowed to grow in the yogurt base and develop acid. During this process, it is extremely important to not disturb the knit or mesh of the product. The agitator must not be turned on for any reason – to do so would cause a weak body and mouthfeel and/or a lumpy, watery, or wheyed-off final product. In extreme cases where an agitator has been left on during the entire fermentation, the casein will precipitate, and there will be no gel and no possibility to save the batch.

After the prescribed set time, the product should be checked for either % acidity, by titratable acidity, or pH. It is advisable to take samples from several different places around the top of the vat. When using a sanitary straw, the straw should be inserted into the yogurt approximately 46 cm (18 in.). Aliquots obtained from the different locations should be commingled and tested. If possible, it is also advisable to take a sample from the bottom of the vat. Since it is common to have a temperature difference from the top to the bottom of the vat, differing acid levels or pH may be seen.

After achieving the proper pH, the agitator may be turned on to the lowest speed and the cooling process initiated. Depending upon the efficiency of the vat, or the method of cooling, this should take anywhere from 2 to 4 h. It is common to cool the yogurt base to between 10 and 20 °C (50 and 70 °F). When cooling, it is also important to not over-agitate. Setting the agitator at higher than the slowest speed may cause shear of some of the proteins and disturb the "knit process" that has taken place during culture incubation.

Upon reaching the desired cool-down temperature, the agitator(s) should be shut off and the product allowed to remain quiescent until the fruit is added.

As the product is pumped to either the flavor tank or the filler, it is a common and advisable practice to pass the yogurt through an in-line "smoothing" device. This may vary from a simple mesh-screen to a more elaborate bell-valve, or gum-drop-type device. The purpose of any smoothing device is to simply smooth out or break up any remaining yogurt lumps or curds that may have not been broken up during the combined agitation and cooling process. Seek the advice of your stabilizer consultant to ascertain if the selected smoothing device may affect any of the stabilizer components. Some types of smoothing devices need to match up with the process and the temperature that the yogurt is being pumped, blended, and handled.

8.5.4.2 Culturing and Fermenting Greek Yogurt

Greek yogurt culture temperatures range between 32 and 46 °C (90 and 115 °F) depending upon what culture strains are being used. Because many Greek yogurts do not contain stabilizer, it has become common for manufacturers to use a culture that contains EPS-producing strains. These cultures produce a ropy texture that also builds a heavy body. Normal break pH is 4.70.

After the culturing of Greek yogurt is completed, the product is agitated, and the white mass is concentrated with approximately 30% of the volume removed as whey. Larger production facilities use a separator or other mechanical methods of separation, where some smaller operations may use either a cheese cloth or a semi-porous bag or container. If using a separator, the white mass is pumped through the separator at the culture temperature or slightly below. If using a cheese cloth, the white mass is placed into the bag or cloth and hung on a rack for a specific amount of time until sufficient whey drains through the pores and the desired total solids is obtained. Whey and some lactose are removed during the concentration process. If the whey removal is conducted in the culture temperature range, care and consideration should be given to the culture type and strains used. The cultures will continue to grow and produce acid that could affect the finished product quality. A final pH of 4.4 is common for Greek yogurt. When considering the cultures used, the culture supplier can assist in the selection of a yogurt culture that will slow its acid production at the desired pH.

The product is then passed through a smoothing device on the way to the flavoring tank. This device is either a stainless plate with small holes or slats cut into it or a type of a modified sheer pump that will smooth the yogurt and break up any lumps that may exist.

8.5.4.3 Culturing and Fermenting Cup Set Yogurt

After pasteurization and homogenization, the yogurt mix is cooled and inoculated at a temperature slightly higher than the optimal setting temperature. The inoculated yogurt mix is then pumped and filled into retail cups prior to incubation. During the pumping and filling, it is common for the mix to cool several degrees. Therefore, it is important that the processor adjust the inoculation temperature so that the product is at the optimal incubation temperature upon reaching the incubation room. Depending upon the bacteria used in the yogurt culture, normal set temperatures range between 32 and 46 °C (90 and 115 °F), with a normal incubation (set) time of 5–6 h. These incubation conditions are dependent upon the type of cultures used and the type of yogurt produced.

Many manufacturers add the culture “in line” after the mix has exited the regenerator section of the pasteurization unit. If contamination occurs in the yogurt-making process, this is usually at this point, so caution must be taken to avoid any possible contamination. All containers and equipment used in the inoculation process such as pails, buckets, hand agitators, culture packages, and cans must be sanitized with an approved sanitizer.

Because the inoculated yogurt mix is placed into a cup prior to culturing, fruit and flavor are also added to the bottom of the retail cup prior to packaging as well. Addition of the fruit-flavor system is commonly completed in line. Some possible concerns with the fruit are floating fruits. This can be rectified by adjusting the amount of sugar or total solids in the white mass, and in the fruit-flavor systems. It is recommended that the processor discusses these issues with the approved fruit supplier.

After addition of the culture, the cup-set yogurt is moved to the incubation room where it will be left until the pH reaches 4.4–4.6. This usually takes between 5 and 6 h depending upon regional differences and variations in solids levels, and heat treatments. The product should be checked for pH after 3 h of ripening.

Upon reaching a desired pH, the ripened yogurt should be gently moved to a cooler with a high amount of air movement, and cooled to stop the bacteria growth as quickly as possible. A common practice is to put the pallets of finished yogurt in front of a forced air cooler, open the cardboard boxes to allow adequate air movement. Another common practice is the use of a blast cooler. The cases of yogurt are placed on a conveyer through the blast cooler. If the yogurt is palletized, it is important to place the cases of yogurt in a way that the product will allow for adequate air flow throughout the pallet. This will speed up the cooling process and slow down the acid development. Upon cooling the yogurt, the pallets should be carefully moved to a refrigerated storage facility and not disturbed for 12–24 h. During this time, the product firmness and whey retention is enhanced.

In the process of making cup-set yogurt, variability in culturing, incubating, and cooling steps makes it common to have slight differences in product quality and consistency from pallet to pallet.

8.5.5 Flavor and Fruit Addition

Fruit flavoring may be added in several different ways, either by means of a flavor tank or by the use of a mixing pump. The flavor tank method involves pumping yogurt into a tank and adding the yogurt fruit preparation on top. With this method, an adequate agitator is necessary to properly blend the yogurt and the yogurt fruit. After the product has been thoroughly blended, the yogurt is then pumped to the filler.

With the mixing pump method, fruit flavoring material and yogurt are each pumped separately and then mixed together as they both move toward the filler.

As with any fruit addition, keep in mind that the fruit needs to be completely blended prior to reaching the filler, but over-agitation and excessive shear must be avoided.

In many cases in Greek yogurt, 2–3% cream may be added back to the concentrated yogurt prior to adding flavor and fruit, dependent on the desired fat. This added cream helps improve the mouthfeel to eliminate and reduce the “drying out” of the tongue that is common with high-protein yogurts. It also helps with creamy consistency, as well as flavor.

Drinkable yogurt, after breaking the white mass, is passed through a smoothing device, cooled, and mixed with fruit and flavor. Many fruit preparations have a combination of fruit, flavor, sweetener, and color added in as one blend. Amounts of fruit/flavor with yogurt will depend upon the fruit flavor companies and the final product requirements.

8.5.6 Packaging and Cooling

After the product smoothing and filling steps, the filled yogurt cups may be placed into either a corrugated box or a tray, and then overwrapped with plastic film. These packaged units will then be placed onto a pallet, which will soon be placed into the cooler. Pallets with freshly filled yogurt should be positioned into a designated section of the cooler, or specified pallet space where it will not be moved or disturbed for a minimum of 18–24 h. After filling, the yogurt begins to re-knit and forms the unique delicate texture that is important for the final body conformation or tactile properties of the yogurt. If the yogurt is physically disturbed during this knitting process, the end result(s) may be a weak body, syneresis on either the sides and/or surface of the yogurt, and/or a nonhomogeneous appearance of the yogurt.

8.6 Yogurt Flavors

The preferred or top-selling yogurt flavors have not changed much in the past several decades, especially with fruited, flavored, and yogurt drinks. Most of the yogurt sold in the USA is packaged in 113-g (4 oz), 150-g (5.3 oz), 170-g (6 oz), and 910-g (32 oz) containers. Some of the larger containers have changed in regard to the top flavors, with strawberry usually at or near the top of the list. In the larger containers sold (1815 g, 64 oz), vanilla or plain are the top sellers, followed by strawberry. Most products are used for home culinary usage and in various food service areas. The top flavors do not seem to change, regardless of the sweetener used.

The top ten flavors for stirred (Swiss) and fruit-on-the-bottom (FOB) yogurt, ranked from most to least popular, are typically as follows:

Strawberry
Unflavored/plain
Vanilla
Blueberry
Peach, mixed berry/berry, raspberry, cherry, strawberry/banana, and coconut

Many additional yogurt flavors have been developed but are either a version of the top ten or a combination of one of the above-listed flavors. It has also been a trend to expand with indulgent flavors, such as honey, caramel, chocolate, and additional inclusions such as granola, nuts, and certain unique or heavier flavors to be added to the yogurt. An interesting observation is that the top five flavors constitute approximately 80% of all flavored yogurt sales.

The top flavors for drinkable yogurt are as follows:

Strawberry
Unflavored/plain
Strawberry banana
Berry, blueberry, mango, vanilla, piña colada, peach, and cotton candy

The top ten selling Greek yogurt flavors are as follows:

Unflavored/plain
Strawberry
Vanilla
Blueberry, peach, raspberry, berry, cherry, honey, and coconut

8.7 Yogurt Stabilizers

Stabilizer is a term commonly applied to describe an ingredient used to perform a multitude of functions. Stabilizers generally serve to bind water, build viscosity, contribute to creaminess, and protect against temperature abuse. Ingredients that are normally used as components in yogurt stabilizers are starch, gelatin, guar gum, locust bean gum, carrageenan, pectin, and xanthan gum. The particular makeup of the stabilizer blend will depend on several of the following criteria: desired function, eating characteristics of the finished product, processing parameters, cost, storage conditions and desired shelf life. Greek yogurt generally does not have stabilizer added due to the protein level, smoothing process, and increased solids.

Starch Starch is the major carbohydrate reserve in plant tubers and seed endosperm, where it is found as granules, each typically containing several million amylopectin molecules accompanied by a much larger number of smaller amylose molecules. The largest source of starch in the USA is corn (maize) with other commonly used sources being wheat, potato, tapioca, and rice. Amylopectin (without amylose) can be isolated from "waxy" varieties of grains. Genetic modification of starch crops has recently led to the development of starches with improved and targeted functionality. Starch is versatile and inexpensive and has many uses as a thickener, water binder, emulsion stabilizer, and gelling agent.

Gelatin Gelatin is one of the most versatile ingredients to be used as a yogurt stabilizer. It is a protein that is derived from the partial hydrolysis of the skin, bones, and connective tissue from cattle, pigs, and selective fish. The unique attribute of gelatin is its ability to form a clear thermo-reversible gel with a melting point close to the human body temperature. For this reason, it works very well in pre-stirred yogurt. Gelatin will contribute to water-holding capacity in pre-stirred yogurt. If it used excessively, products will develop a short texture and have the potential for syneresis. It is extremely important to heat the product to 60 °C (140 °F) for complete hydration. Gelatin will start to solidify and become a solid mass at a temperature of ~29 °C (85 °F).

Guar Gum (From Cyamopsis Tetragonolobus) Guar gum is a complex carbohydrate obtained from a legume. The guar plant is grown in the geographic regions of India and Pakistan. The seedpod is harvested, and the seed coat and endosperm are removed. The usable product component is then milled and sifted. The gum is readily dispersible in cold solutions, has excellent water-holding capacity, and provides good mouthfeel. Guar gum is relatively inexpensive. Excessive amounts of guar can cause a slimy texture and a mouthfeel that is slick-like. Additionally, a distinctive "beany" flavor may be attributed to high-usage levels. Guar gum that has not been thoroughly cleaned in preparation stages can add undesirable dark-colored specks to finished products.

Locust Bean Gum (Ceratonia siliqua) Locust bean gum (also called Carob bean gum) is a galactomannan extracted from the seeds of the Carob tree (*Ceratonia siliqua*). These trees are grown around the Mediterranean region, having a history that predates Christ. It was used by the early Egyptians in the mummification process and was also used as a standard weight measurement for gold and precious gems. The term "carat" is derived from the Latin name Ceratonia. Locust bean gum is an excellent stabilizer ingredient and, used at low levels, will impart a clean flavor and creamy mouthfeel. Fluctuating prices and high demand are issues when considering this ingredient. Locust bean gum must be heated to 79 °C (175 °F) to properly hydrate the gum prior to its use.

Pectin Pectin is a structural element in plant tissues. It is most commonly obtained from the peels of citrus fruits such as lemon, lime, grapefruit, and orange. Pectin can also be extracted from apple pomace and pressed sugar beet pulp. Pectin is derived from the original source by initially being ground, then exposed to water and acid extraction processes, followed by an alcohol-precipitation process. The pectin is then dried, milled, and standardized. Pectin is considered by many as all natural (though no standard of identity for "natural" exists as of the publication date of this book) and is a popular ingredient in yogurt stabilizer. The use of pectin as an ingredient in yogurt typically provides nice pudding-type consistency. The price is dependent upon the particular weather patterns in the citrus-growing regions of the world, especially in hurricane regions.

Xanthan Gum Xanthan gum is a high-molecular-weight polysaccharide gum, produced by a pure culture fermentation of a carbohydrate, by a bacterium called *Xanthomonas campestris*. After fermentation, a sterilization step follows and the sought-after component is precipitated with isopropyl alcohol, followed by centrifugation, drying, and milling. Xanthan gum is soluble in cold water and is both thixotropic and thermo-reversible. It is relatively shear and acid resistant, as well as being freeze/thaw stable. It is used sparingly as an ingredient in yogurt stabilizers since it has a tendency to cause graininess. It has a synergistic affect with other gums such as guar and locust bean gums (Rahrs, 2005b).

Carrageenan Carrageenan is a natural product obtained from the pressing and extraction of red or brown seaweed. The three main types of carrageenan are kappa, iota, and lambda. During the extraction process, the seaweed is washed, filtered, concentrated, precipitated with either potassium chloride or alcohol, then dried, ground, and blended. Each of the three types of carrageenan produces different structures. Kappa produces a rigid high-strength gel that is thermal reversible. Kappa has the highest degree of milk reactivity. Iota carrageenans produce an elastic gel that is also thermal reversible, have a high salt tolerance, and are thixotropic. Iota carrageenan in the presence of calcium tends to gel and has low milk reactivity. Lambda carrageenans are non-gelling, enhance viscosity, and have little to no milk reactivity.

8.8 Procedures for Sensory Evaluation of Yogurt

The preparation for evaluating yogurt samples may be as critical as evaluating the samples themselves.

8.8.1 The Space for Sensory Evaluation

Selecting the proper facility or location has an important effect in the way the samples are viewed. Make sure that proper attention is given to this objective.

It is important to select a room or area that has adequate natural lighting. The enhancement of product colors and the range of color and appearance defects, when using natural lighting without any shadows, is invaluable. It is also important to select a location that is free of off-odors. Odors such as lab extraction smells, petrochemicals, ammonia, cleaning compounds such as chlorine, or sewer gas will affect the evaluation.

8.8.2 Selecting Samples for Sensory Evaluation

Ongoing product review in yogurt plants occurs on a regular basis and should be scheduled at a consistent time and location. Samples may be evaluated daily to review the prior days production, and possibly end of shelf life or accelerated storage products.

When determining who should attend the product review, it is suggested that anyone who has direct contact with the process or product essentially resides in a "pool" of potential participants, who have some level of interest and concern. The processors who do the blending, processing, yogurt batch break, adding fruit, and filling all should or need to be involved, as well as QA, R&D, and plant management. In addition, sales and marketing representatives may want to be involved if they reside in the general area. By reviewing the products, these people have a direct responsibility and ownership in the product's success. They will be able to see both the good job that they are doing and areas or opportunities for improvement.

When setting up an evaluation process, it is important to decide if the purpose is to evaluate the previous days' production in order to determine whether the product meets the requirements. Alternatively, the objective may be to review retained product for the purpose of observing how the product holds up during shelf-life studies. Regardless, samples need to be selected and placed in a safe location that is representative of the conditions of the cooler or distribution process. Many processing plants have a section of the cooler that is dedicated to samples only. This potentially eliminates any issues with product being removed. Throughout the processing day, samples need to be pulled routinely and labeled for time and date. These samples then may be pulled in a series of different dates to review shelf life. It is common that for each day of product review, samples from the previous day are reviewed as well. Products in the middle of shelf life and at the end of shelf life should also be reviewed. This process provides a good indication of how the product holds up during a normal shelf life and will warn of possible issues that are noticed. Issues such as flavor, color, or the beginning of a yeast or mold problem may be addressed before the problem progresses to an "advanced stage."

It is important to look at the product that has been retained in the cooler and the product that has been through the distribution/marketing process. These samples may be obtained by simply purchasing them at a local grocery store. These samples are more representative of what the consumer will be purchasing, because they have been subjected to temperature changes and handling issues. Many times there are defects that show up when the product is shipped to a warehouse that are not noticed in the samples kept in the plant cooler.

8.8.3 The Sensory Evaluation Process

When judging yogurt, it does not matter what type of yogurt is being reviewed – Greek, stirred or Swiss style, or drinkable, yogurts are all evaluated under the same criteria in regard to appearance and color, body and texture, and flavor.

When setting up the samples for review, examiners look first at the outside of the container. They notice any smudges on the package, and whether the code date is easy to read and in the proper place. The next step is to open the container without disturbing the yogurt and view the top of the cup, particularly noticing any possible mold or yeast growth, discoloration, or whey or watery liquid exudates. The observers also look around the sides of the cup for possible indications that the product may have shrunken. Finally, the cup is tipped upside down on a plate and the cup bottom is punctured. The cup is lifted off and the yogurt "mound" left on the plate. Notice is made of any unusual aromas. A spatula or a knife is used to scrape out the remainder of any yogurt in the cup bottom.

The precise time that the product is placed on the plate is noted. This is important because yogurt will change in appearance as it warms up. Most visual changes occur after it has been left at room temperature for more than 15 min. After the yogurt has been placed on the plate, observers first notice the yogurt appearance on the plate. For most yogurts, it should resemble a thick pudding with little to no running.

Next, notice if there are color streaks or "color leaching," or any unusual color of the coagulum or fruit. There is a wide range of colors for yogurt, but generally, it is most acceptable to have a color that is "true to the natural fruit." If a blueberry yogurt is being made, then the color should be similar to the color of a fresh blueberry, if a strawberry, then that of a fresh strawberry. If the yogurt color is very pale or extremely dark, the product is characterized as "atypical color." Otherwise, the color variable is very wide.

A spoonful of yogurt is placed in the mouth, and notice of how the yogurt clings or sticks to the tongue and sides of the mouth is made. Also, how fast the yogurt dissipates off the tongue as it is being moved around the mouth determines if the product is judged to be weak. If the yogurt is low in total solids, the yogurt and flavor will dissipate; thus it is perceived to be weak. When the yogurt is rubbed on the roof of the mouth, the desirable texture is smooth and not gritty. After noticing the texture and mouthfeel, the first flavors and sensations perceived and where in the mouth they are observed are recognized. One of the first sensations is the acidity of the yogurt. The sensation is on the sides of the tongue. Sweetness is also one of the first flavors perceived. It is noticed in the front and middle of the tongue. Sensing too high an amount of acid and sweetness can cause these flavor notes to be overpowering. Also noticed at the beginning of the tasting cycle may be strong off-flavors like oxidized, atypical (foreign), old ingredient, unclean, and yeasty.

It is advisable to not swallow the yogurt but expectorate it (spit it out). Therefore, the flavor will not stay in the mouth for a long time afterward. After the acid and sweet sensations, the next flavors that are noticed are cooked, too high flavoring, low flavoring, and some of the stabilizer flavors. Also noticed at this time are the high-intensity sweeteners and different types of sweeteners such as acesulfame potassium, aspartame, and sucralose.

Finally, at the end of the tasting cycle (after expectorating), some flavors that are not associated with being the most pleasant are noticed. These include rancid, bitter, old ingredient, lacks freshness, unnatural flavors, and acetaldehyde. Also noticed at the end are some of the preservatives such as potassium sorbate and sodium benzoate. These are noticed after spitting out the yogurt, and a burn is typically perceived in the middle and back of the tongue.

8.8.4 Scorecards

Sensory evaluation is an invaluable tool that should be made a part of any quality assurance program. The attributes chosen for routine evaluation and the scoring system will vary based on the situation.

Swiss Style Yogurt

SAMPLE 1

FLAVOR SCORE: 1 2 3 4 5 6 7 8 9 10 NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Bitter	___ 8. High Sweetness	___ 15. Oxidized
___ 2. Cooked	___ 9. Lacks Fine Flavor	___ 16. Rancid
___ 3. Foreign	___ 10. Lacks Freshness	___ 17. Unclean
___ 4. High Acetaldehyde	___ 11. Low Acid	___ 18. Unnatural Flavor
___ 5. High Acid	___ 12. Low Flavoring	___ 19. Yeasty
___ 6. High Flavoring	___ 13. Low Sweetness	
___ 7. High Intensity Sweeteners	___ 14. Old Ingredient	

BODY AND TEXTURE SCORE: 1 2 3 4 5 NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Gel-Like	___ 3. Ropy	___ 5. Weak
___ 2. Grainy	___ 4. Too Firm	

APPEARANCE AND COLOR SCORE: 1 2 3 4 5 NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Atypical Color	___ 4. Free Whey	___ 7. Shrunken
___ 2. Color Leaching	___ 5. Lacks Fruit	
___ 3. Excess Fruit	___ 6. Lumpy	

Fig. 8.1 Collegiate Dairy Products Evaluation Contest Swiss Style Yogurt scorecard. (Collegiate Dairy Products Evaluation Contest, 2022)

One example of a scorecard (Fig. 8.1) and scoring system (Table 8.1) is the Collegiate Dairy Products Evaluation Content scorecard for yogurt (Collegiate Dairy Products Evaluation Contest, 2022). This example assigns a perfect score of 10 for flavor, 5 for body and texture, and 5 for color and appearance. Defects arising from egregious manufacturing errors, such as rancid, old ingredient, or oxidized, or from spoilage issues, such as unclean or yeasty, are assigned greater penalties than less serious defects, such as low acid.

8.9 Sensory Defects in Yogurt

8.9.1 Appearance and Color Defects

Atypical Color Atypical color is when the color of the yogurt does not represent the flavor of the named or labeled yogurt. For instance, a strawberry-flavored yogurt should be a creamy-light red to pleasant pink color. If this color is either too dark, or too light, or possibly the given yogurt has a different color all together, the observed color is considered "atypical" for that flavor of yogurt (Figs. 8.2 and 8.3). Atypical color is usually observed in those products that are labeled "all-natural," or

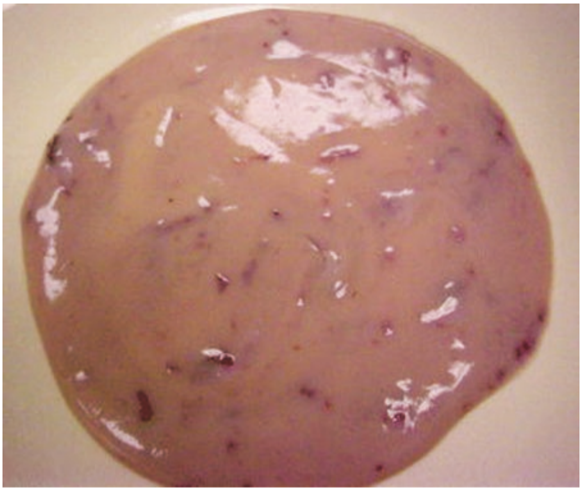
Table 8.1 Proposed scores for strawberry yogurt

Flavor	S	D	P
Bitter	9	7	5
Cooked	9	8	6
Foreign	8	7	6
High Acetaldehyde	9	7	5
High Acid	9	7	5
High Flavoring	9	8	7
High Intensity Sweeteners	9	7	5
High Sweetness	9	8	7
Lacks Fine Flavor	9	8	7
Lacks Freshness	8	7	6
Low Acid	9	8	6
Low Flavoring	9	8	7
Low Sweetness	9	8	7
Old Ingredient	7	5	3
Oxidized	6	4	1
Rancid	4	2	*
Unclean	6	4	1
Unnatural Flavor	8	6	4
Yeasty	6	4	2
Body/Texture			
Gel-like	4	3	2
Grainy	4	3	2
Ropy	3	2	1
Too Firm	4	3	2
Weak	4	3	2
Appearance			
Atypical Color	4	3	2
Color Leaching	4	3	2
Excess Fruit	4	3	2
Free Whey	4	3	2
Lacks Fruit	4	3	2
Lumpy	4	3	2
Shrunken	4	3	2

use lower quality fruits or flavorings, or colorants that are not stable under low-acid conditions. It has also been observed that yogurts and yogurt fruit flavorings that have been stored at improper temperatures may lose some of their sensitive pigments. This is typically caused by an oxidation reaction of the fruit. At the 2023 National College Diary Product Judging Contest, The Coaches Committee met and it was decided that the atypical color would no longer be judged or scored and the term Atypical Color will be removed from the Appearance and Color section of the

Fig. 8.2 Strawberry yogurt exhibiting slight (left) and pronounced (right) atypical color (*light*). The image on the right also lacks fruit (pronounced).

Fig. 8.3 Strawberry yogurt exhibiting atypical color (*dark*)



scorecard. The reason for the removal is that the colors that are used in in yogurt have changed significantly over the years as the industry moves to a more natural sources of colors. Determinining the difference between what yogurt color was atypical and what was an acceptable strawberry color has become more difficult for not only the judges but also the coaches.

Problem corrections involve the utilization of only high-quality fruit and fruit-based materials that have acid-stable color, plus storage of yogurt and fruit flavorings under proper temperature conditions.

Fig. 8.4 Color leaching in strawberry yogurt

Color Leaching This defect reflects a difference in color between the yogurt mass and the added fruit. Color leaching commonly shows up as a ring or a halo effect around pieces of fruit or berry (Fig. 8.4), which is caused by a difference in osmotic pressure between the fruit piece and the yogurt mass. This pressure difference may be the result of different sweeteners used: (1) in the fruit and (2) in the yogurt mass. Color leaching can also be caused by using yogurt fruit that has an added color that is not acid-stable, fruit that has had excessive color added, or by using a fruit source that has not been properly stabilized.

Correction, or better control of the color-leaching issue, may be realized by communication with fruit suppliers, confirming the final use of various fruit-based products, and confirmation that these flavor sources are properly stabilized for the purpose of using them in cultured yogurt. Another option would be to substitute some of the fructose used in the yogurt. This could possibly reduce osmotic pressure differentials between the yogurt and the added fruit pieces.

Lacks Fruit This visual defect is either the result of an insufficient amount of fruit added or usage of a poor-quality fruit that when a minimal amount of agitation is applied to blend the fruit and yogurt mass together, the fruit simply breaks apart and seems to disappear and leads to the impression of being insufficient (Fig. 8.5).

To best prevent or control the frequency of this defect, one needs to confirm that the proper amount of fruit has been added. The use of higher-quality fruit that can withstand minimum or typical amounts of agitation and avoidance of excessive pumping and agitation can go a long way to minimize the “lacks fruit” defect in yogurt.

Excess Fruit This yogurt appearance defect is usually provoked by excessive quantities of fruit being added and mixed into the yogurt mass (Fig. 8.6), presumably via improper calibration of metering devices. This costly situation and less-than-optimal yogurt ingredient balance can usually be rectified by checking and re-checking product-to-product formulation and calibration of pumps and metering devices.

Fig. 8.5 Strawberry yogurt exhibiting lacks fruit defect

Fig. 8.6 Strawberry yogurt exhibiting excess fruit defect

Free Whey This is most noticeable by the translucent, greenish-yellow liquid on the surface and around the sides of the cup of yogurt. It has many different causes, such as (1) excessive agitation, especially above pH 4.7; (2) too low a pH because of fast acid development; (3) disruption of the in-vat coagulum before the yogurt was set; (4) heat shock of the yogurt; (5) subjecting the yogurt to extreme temperature conditions; and (6) freezing/thawing of the yogurt. Other possible causes for wheying-off are improper pasteurization, homogenization, inadequate stabilization (either too little or excessive), and rough handling of yogurt cups (Bodyfelt et al., 1988; Lyck, 2004).

In determining a corrective action, it is a good idea to check all processing procedures to ensure correct methods, times, and temperatures. Checking homogenization efficiency is quick and accurate. Ascertain whether the homogenizer is working properly and whether maintenance is necessary. Confirm thermometer accuracy, and check pasteurization records to confirm that the yogurt base was treated to the proper temperature to denature proteins. It is also advisable to check temperatures in cooling areas as well as refrigerated transit trucks and trailers to confirm proper temperatures are achieved and maintained. Finally, a critical point must be emphasized to not disturb the curd while it is knitting together after the containers have been filled.

Lumpy This unpleasant appearance defect causes the yogurt mass to appear rough, uneven, and nonhomogeneous (Fig. 8.7). It somewhat resembles the surface of cauliflower. Lumpy yogurt is unattractive although it may not affect the eating quality of the yogurt. It is noticed after it has set-up and knit together as a smooth and uniform coagulum or custard-like light pudding. The subsequent development of the lumpiness may be caused by (1) improper stabilization, (2) the use of too much gelatin as a stabilizer, (3) inadequate agitation at the time the product is broken, (4) not passing the product through a smoothing- device prior to adding the fruit flavoring, (5) filling the yogurt at too high of a temperature (therefore the culture continues to grow), or (6) filling the cups of yogurt at an improper pH value or at too high pH (incomplete, weak fermentation attained).

To minimize and eliminate the lumpy defect, determine that the proper amount of stabilizer has been added to each yogurt mix. Consultation with stabilizer technical representatives may be advisable if yogurt lumpiness prevails. Cooling all yogurt batches to 21 °C (70 °F) prior to packaging, allowing the finished yogurt adequate time to agitate prior to filling, and the using a smoothing-device help eliminate this issue.

Fig. 8.7 Slight (left) and pronounced (right) lumpy strawberry yogurt examples

Fig. 8.8 Strawberry yogurt samples with shrunken defect; the sample on the left does not exhibit free whey, whereas the sample on the right has free whey in the gap between the yogurt and the cup

Shrunken This defect is characterized by the yogurt itself pulling away from the side of the cup and leaving a gap, which usually fills in with free whey (Fig. 8.8). Defect causes include heat shock (temperature abuse), too high acid production, too high stabilizer usage or incorrect stabilizer used, or disruption of the yogurt mass after filling and while the yogurt is knitting together.

8.9.2 Body and Texture Defects

Body and texture defects in yogurt are caused by many different factors, but quite often, they may be prevented and/or minimized by following proper and recommended yogurt manufacturing processes. Many of the defects are the result of improper protocols and mishandling of ingredients and finished product. When looking to correct any given defect, it is important to first identify the cause of the defect and then apply the corrective action(s).

Following is a list of the most commonly found body and texture defects in yogurt, their causes, and possible corrective action steps to eliminate or reduce the problem. Some of the corrective actions are most obvious, while some may be more difficult and complex. Many shortcomings may be corrected before they cause problems in the yogurt. It is always important to screen all ingredients prior to processing that are used in the yogurt. Firstly, tasting and smelling all the milk and cream ingredients used is obviously the first critical step. Secondly, all dry ingredients such as whey, nonfat dry milk, stabilizers, and sugar should periodically be smelled and tasted by making a 1:9 solution in either milk or water. Potentially serious flavor defects may be detected if regularly scheduled tasting sessions occur. The sugar storage tanks should be inspected for yeast and mold growth on a regular basis. This is always a potential source of contamination to the finished yogurt and/ or potential off-flavors. At the 2023 National Collegiate Dairy Products Judging Contest, the Coaches Committee met and agreed to add the term High Astringency to the Body and Texture section of the scorecard. The scores will range from Slight-4, Definate-3 and Pronounced-2. The need for adding High Astringency is due to the large number of high protein or Greek yogurts that have entered the market. This attribute is described as a mouth drying effect, similar to that of high tannin wine. It also has gives a sensation of chalky mouth feeling and is caused by the acid / protein of the yogurt.

Gel Like/Too Firm This attribute has the appearance of formed gelatin in the cup (or on the plate) and a very firm set (Fig. 8.9). It can also be noticed by pushing the yogurt to the roof of one's mouth and observing the extent of resistance. Yogurt with the more ideal body characteristics (Fig. 8.10) should have little or moderate resistance and should melt away very smoothly. Gel like or too firm can be caused by too high stabilizer usage, or the wrong choice of stabilizer. It can also be caused by an excessively high amount of milk or whey solids in the product base. To correct, simply reduce the use of a specific stabilizer, the amount of total solids, or alternatively contact the stabilizer technical representative to confirm proper usage and incorporation of the best or correct stabilizer for the given yogurt mix formulation (Lyck, 2004).

Weak This characteristic is observed within a finished product that appears "runny" or too liquid-like or has little or no residence time on the tongue. When a spoonful of yogurt is placed into the mouth, it should, for a short time, cling to or reside on the tongue. If it does not, and the flavor dissipates rather rapidly, it is considered to be a weak-bodied product. This defect is quite common with "no-fat- and/or no-sugar-added" yogurts in which a nonnutritive sweetener has been used. It is simply caused by a rather low amount of total solids in the formulation, but it can also be caused by excessive heat treatment or types of agitation that breaks down the gel

Fig. 8.9 Strawberry yogurt that has a gel-like or too firm body and appearance (to be confirmed in the mouth)

Fig. 8.10 Strawberry yogurt exhibiting an ideal body and appearance

structure that was created by the stabilizer, culture and proteins, or combinations thereof (Bodyfelt et al., 1988).

Correcting this obvious defect requires adding more milk solids, which can add to ingredient costs, or the manufacturer may need to consider an alternative stabilizer (Lyck, 2004).

To correct this defect, first, try to identify and confirm what is causing the issue, then implement heightened control to prevent this from happening. Make sure that after the product is cup-filled and placed into the cooler, it is not moved until the yogurt has a chance to knit together. Check thermometers to determine proper calibration, and review batch sheets to confirm that proper formulation occurred (Lyck, 2004).

Grainy This defect is associated with detection of small particles on the tongue surface. It is an objectionable texture shortcoming that is quite noticeable and unappealing. The defect causes are harder to determine because the occurrence of this defect is typically an inconsistent event. Some of defect causes are heating the base milk at too high a temperature, or increasing the temperature at a too rapid rate, such that the protein precipitates out. Another cause is from too high and too rapid acid development due to high fermentation temperature, agitation during acid development, or improper mixing of the starter culture. Graininess may be reduced by routing the yogurt through a screening device prior to cup filling, since this eliminates the small lumps of the coagulum (Lyck, 2004).

Ropy Ropy yogurt texture is detected by placing a spoon into a yogurt mass and lifting the spoon for 5–13 cm (2–5 in.). If the observer readily views a trailing stream (or stringiness) of yogurt between the spoon edge and the product container, the product is considered “ropy” (Fig. 8.11). Ropy yogurt normally has a “slick” mouthfeel. Such yogurt body is also often defined as slimy. Ropy-like body in yogurt is usually the result of five different causes: (1) improper stabilizer or gums, (2) microbial contamination, (3) use of yogurt cultures that contain polysaccharide-

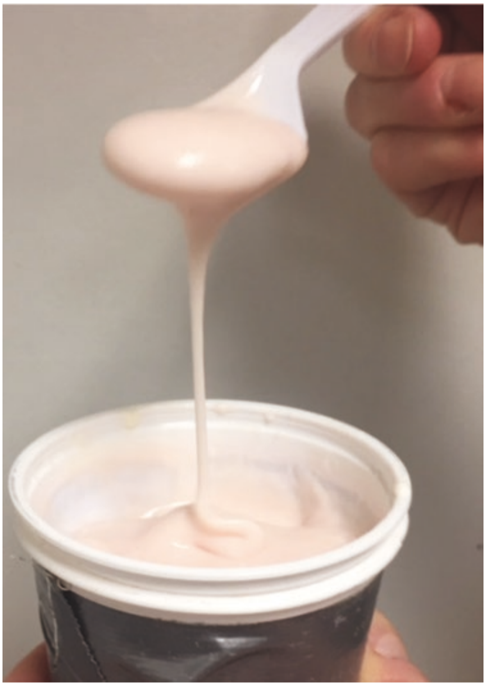


Fig. 8.11 Yogurt exhibiting a ropy defect

producing bacteria, (4) improper setting temperatures, and (5) too high sugar content in the product base (mix). If the "long texture" is being caused by contamination, there is sometimes an associated offensive odor with the off-body incident.

To correct the negative attributes associated with ropy body/texture, one should first check the calibration of the thermometers on the setting vat. Next confirm the product formulation to ensure that proper amounts of each ingredient have been added. Also check that any in-line filters or shearing devices designed to smooth the texture are present and working properly. If these parameters seem acceptable, then contact the stabilizer technical representative and the culture supplier to determine future options or corrective actions. Also check the CIP-cleaning charts to determine that vats, lines, and all equipment are being cleaned and sanitized properly (Lyck, 2004).

8.9.3 Flavor Defects

High Acetaldehyde Acetaldehyde is the chemical compound responsible for the traditional green apple flavor produced by yogurt bacteria. This flavor note is a natural, always present flavor common to yogurts. It is noticed at the end or near the end of the tasting sequence and typically lingers for some time. This flavor note is quite similar to a green apple hard candy. A problem exists if a given yogurt exhibits too high an amount of the acetaldehyde note for many consumers or "would-be" consumers of yogurt. If the green apple flavor is clearly distinguished in combination with other acidic flavors, it is presumed to be at too high a level.

There are quite a number of reasons for high levels of acetaldehyde in yogurt, particularly in plain (non-flavored) yogurts. Some of these reasons are (1) improper culture, (2) incorrect set temperature, (3) insufficiently low storage temperature, and (4) the yogurt was broken at too high a pH (Tribby, 2001).

Bitter This yogurt defect is characterized by an offensive aftertaste that is sensed at the back of the throat and at the end of the tasting sequence (i.e., delayed detection). This defect is caused by the use of poor-quality or old milk that has been contaminated with psychrotrophic or spoilage bacteria or with certain starter cultures with proteolytic activity. Bitterness can also be caused by poor-quality yogurt ingredients, such as NFDM powder, dry whey, and fruit flavorings, or by using starter culture that is either old or contaminated. Another potential reason for bitter flavor development is finished products being stored at too high a temperature (Bodyfelt et al., 1988).

Using fresh, high-quality yogurt ingredients and milk suffices to eliminate many potential points of contamination. A prime safeguard is to screen all incoming ingredients and fruit, use a regular rotation of starter cultures, and to assure that proper techniques are used when transferring cultures from the bulk tank, or transferring from the culture freezer to the culture tank.

Cooked A slight to moderate intensity of cooked flavor is considered a desirable attribute by many yogurt producers, depending upon the relative intensity or severity. Cooked is typically perceived nearer the end of the tasting cycle at the top and the back of the throat. Cooked may have an aroma like that of caramelized sugar, or butterscotch; others are reminded of an eggy-like flavor sensation. Cooked notes are usually caused by higher than optimum pasteurization temperatures and/or holding times. Other dairy ingredients that have undergone severe heat treatments, such as nonfat dry milk, condensed milk, or whey, may also be a cause of this type of flavor note in yogurt. If large amounts of high-fructose corn syrup have been used as a product sweetener, this may also provoke this defect. Fruit preparations that have a jammy consistency and flavor, and are added at high levels, can also give the product a cooked flavor. If the cooked flavor is at a level that is particularly noticeable or overpowers the given yogurt flavor, then it is considered a defect.

Close monitoring of the pasteurization system can suffice to minimize or eliminate the cooked defect; and careful screening of all incoming raw materials against severely "heated" off-flavors is also most helpful.

Atypical (Foreign) An atypical, or foreign, flavor defect in most dairy products is usually caused by the presence of an out-of-place aroma and/or an off-taste, reminiscent of residual cleaner, sanitizer, lubricant, or some other out-of-place material within the processing system. Also, the use of excessive amounts of potassium sorbate as a mold inhibitor causes a foreign off-flavor. Many such atypical and objectionable flavor off-notes are generally detected on the middle-backside of the tongue recognized as either an off-taste or as an off-aroma or, in the case of potassium sorbate, a burn on the middle of the tongue.

The serious aspect of the atypical (foreign) off-flavor is that QA and production staff must prevent it from happening in the first place. All plant personnel have to be absolutely sure that all tanks and lines have been properly rinsed and drained prior to use.

Potassium sorbate is used to control yeast and mold in yogurt thereby extending shelf life. Ways to eliminate this particular defect include (1) adding sorbate to yogurt base directly, (2) requesting that the fruit supplier add potassium sorbate to the fruit, (3) reducing or eliminating potassium sorbate, (4) switching to a different mold inhibitor, or (5) using hepa-filtered fillers to eliminate spore contamination.

High Acid A certain amount of acid needs to be present in yogurt in order to coagulate the proteins and form the coagulum typical of this product. If the acid level becomes too high, the acid taste becomes too sharp, harsh, and/or offensive to a majority of consumers. In addition, the intense acid taste masks the other flavor notes of the yogurt. If the acid flavor is too low, the product will become flat tasting and will seem too sweet and candy-like. It is important to have the correct balance between sweet and sour. The defect of high acid is caused by many factors, such as (1) improper set temperature, (2) too low a break pH, and (3) insufficient or slow cooling after the yogurt, has been broken. It is noticed as a severe acid intensity on the front and sides of the tongue, ranging from the beginning to the middle of the tasting cycle. Certain yogurt cultures are also more acid tolerant and capable of acid production during the first weeks of storage of the finished product.

In order to best control against development of the high-acid defect, first, it is important to first check the calibration of the involved thermometers. Second, it is important to monitor the cooling process and determine if the product is being cooled properly. Other control strategies for limiting the high-acid off-flavor of yogurt are as follows: (1) make certain that the yogurt is being broken at the proper pH, (2) make certain that the correct yogurt cultures are being used or changed to milder cultures, (3) check the formulation to confirm that the correct acid/sweetness balance is achieved through the formulation, and (4) assure that the proper amount of sugar is added either in the base or through the added fruit (Tribby, 2001).

Low Flavoring This is not necessarily a product defect, but may cause the given yogurt to be perceived as not being of the highest quality. In some instances, the low-flavoring defect is the result of poor-quality flavorings, or an improper amount of flavor being added to the fruit or yogurt base. Checking to insure that the specified amounts of flavoring are being added and blended or changing the flavoring system should solve the problem.

Lacks Fine Flavor This comment is used to describe yogurt that is generally a good yogurt but is missing a key attribute that makes it a very good yogurt. It could be product that may be to the end of the shelf life or product that may have had some older fruit used to flavor the yogurt. When “lacks fine flavoring” is used, it usually is given to yogurt that may have some other defects that are not advanced enough to impart a negative flavor, but contribute slightly to bring down the overall quality of the yogurt.

Lacks Freshness “Lacks freshness” describes product that has either a stale off-flavor, a storage off-flavor, or is at or near the end of its shelf life. This unfavorable flavor defect of yogurt is usually noticed at or near the end of the tasting sequence, perhaps even after swallowing the product. Lacks freshness of yogurt may also be the result of using old fruit, or some ingredient that has not been stored under proper temperatures or conditions. Ingredients such as NFDM, whey, or stabilizers can and will contribute to this off-flavor, if they have been subjected to high storage temperatures and/or offensive smelling storage or transportation conditions.

It is important to screen all incoming ingredients for potential off-flavors prior to their use in product formulation. The implementation of an aggressive ingredient stock rotation program (with documentation) and adherence to ingredient shelf life recommendations is an important prerequisite for consistently high-quality yogurt.

Low Sweetness This yogurt attribute (or defect) is generally associated with improper formulation, and the result greatly impacts the eating quality of the yogurt. It may also be caused by overheating the mix prior to inoculation or by use of an improper blend of sweeteners. Several of the non-nutritive sweeteners are not as heat-stable as sucrose or high-fructose corn sweetener, and therefore they may have had some of their sweetening potency reduced during pasteurization. Also contributing to sweetness is the balance with the pH (or acidity level) of the final product. If the acidity level of the finished product is too high, it will detract from or take away the perception of sweetness in the finished yogurt.

Low Acid Inasmuch as yogurt is considered to be a cultured dairy product, and hence should exhibit an acid taste, it is quite noticeable to the taster or consumer when it lacks an “acid” profile. In yogurt manufacture, there are a number of causes for a finished product to not have a sufficient amount of acid. Typically, low acid is attributed to either too low a setting temperature, a poor-quality or inactive culture, or breaking the fermentation prematurely. Yogurt culture “inactivity” can be caused by the presence of inhibitor substances such as (1) residual cleaning compound or sanitizers, (2) an antibiotic in the milk supply, or (3) it may be the result of bacteriophage attack on the starter culture. All of the aforementioned “inhibition incidents” adversely affect the growth of the yogurt bacteria and prevent them from developing the proper pH of the finished product.

For yogurt manufacturing plants, appropriate culture handling programs include (1) comprehensive sanitation programs, (2) personnel training to maintain proper GMPs, (3) a rotation program for the culture strains (established to neutralize bacteriophage lysis of cultures), and (4) routine calibration check of thermometers (to assure that the proper culture incubation protocols are achieved). If slow vat sets occur frequently, it is important to monitor culture freezer temperatures to ensure that cultures are maintained at proper temperatures in order to assure culture activity.

Metallic The metallic defect has decreased in the last several decades due to the elimination of metals other than stainless steel in dairy plant piping and equipment. The earlier generation of softer and copper-bearing dairy metals triggered serious and objectionable metallic off-flavors frequently. With the universal use of stainless steel, metallic-type off-flavors are nearly a "defect of the past."

Elimination or good control against the development of any metallic off-flavors in yogurt milk and/or finished yogurt products requires the use of all stainless steel equipment and utensils within all milk handling and transport throughout the plant. Water supplies are another place to be on constant guard against the presence of even moderate concentrations of divalent cations (Cu, Fe, and Mn). Depending upon the given region of the country, many areas have hard water, which increases the likelihood of having some unwanted minerals in the water. The presence of these minerals can be controlled or eliminated by the use of either water treatment and/or sanitary filters. Mineral additions to yogurt for nutrition reasons can be a source of metallic flavors. Sensory screening of mineral fortifiers and dairy ingredients should suffice to identify any possible metallic off-flavors. In hard water areas, regular scheduled checks of scale build-up on boiler pipes are an appropriate precaution against metal ions being incorporated into the finished products through steam.

Old Ingredient This defect may be one of the most offensive in yogurt or any dairy product. It is described as a "dirty sock" or "dish rag" flavor, and usually is noticed at the end of the tasting sequence. The flavor hangs around quite long after the product is expectorated or swallowed and does not clean up very well. Either old or outdated product or contamination from dirty equipment or ingredients frequently causes this off-flavor. Processing milk that is older than 48 h (uncommon today) can cause the old ingredient flavor defect. Using a yogurt starter culture that produces only rather low amounts of acidity may also be a cause.

To prevent the old ingredient defect from occurring, all incoming ingredients need to be flavor-screened prior to acceptance. Also, an ingredient rotation system should prevent product from becoming old and out-of-code. Periodic inspections of the CIP system to confirm that it is working properly is most helpful, as well as conduct of examinations of equipment for cleanliness and sanitation.

Oxidized (Light-Activated) Oxidized yogurt is recognized by a distinctive "cardboardy" or "burnt hair/burn feathers" odor and off-flavor that is caused by the products or ingredients being exposed to either ultraviolet light or direct sunlight. Severe cases make the product unsaleable. This objectionable off-flavor usually is noticed at the middle of the tasting cycle. Added vitamins, particularly vitamin C, can cause a cardboard-like off-flavor when they oxidize in the product due to light oxidation.

Rancid This defect, if observed, may lead to the decision that the given yogurt is unsaleable. It is noticed either by the characteristic aroma of hydrolytic rancidity or by its unique off-taste, with bitter taste at the end of the tasting cycle in the back of the throat. It also has an off-smell that resembles feta cheese. The mixing of pasteurized and unpasteurized milk and cream causes hydrolytic rancidity. It may also be caused by excessive mechanical agitation or freezing of raw milk. Holding raw bases after ingredient-blending operations for extended periods of time prior to pasteurization (and inactivation of native milk lipase) will also cause this defect.

To prevent rancidity from occurring, it is extremely important to pasteurize all milk and cream to inactivate the lipase enzyme and prevent all mixing of unpasteurized milk and cream with product that has been homogenized. Eliminate as much mechanical mixing of the product prior to pasteurization as possible.

High Flavoring This defect is the overwhelming flavor that is caused by the addition of too much of the individual fruit flavor base, or adding too much flavor itself. It usually is picked up in the middle of the tasting experience and remains on the tongue for an extended time after the yogurt has either been swallowed or expectorated.

This defect can easily be remedied by either reducing the amount of fruit flavor that is added or by asking the fruit supplier to reduce the amount of flavor that is in the fruit. It is also a good idea to check and calibrate the pumps that are used to add the fruit to the base to determine that they are in proper calibration.

High Sweetness This defect is usually the result of an unbalanced formulation that contains either higher than normal amount of sweetener or a wrong acid sweetness profile. It is noticed at the first start of the tasting process in the middle of the tongue, and lasts until the tasting sequence is over.

The first remedy is to review the formulation to determine if the recipe was followed properly. Second, if a blend of sugars is used, either high fructose or sucrose, review should be done to make sure the proper ratio has been followed. Finally, if there is not sufficient acid produced by the cultures, or by the fruit, the acid/sweetness balance will not be proportional and the product will taste sweeter than normal. A simple pH measurement will determine if the product pH meets the specifications.

Unnatural Flavor An unnatural flavor defect refers to any detected flavor that is not the listed flavor on the packaging label. An example would be if a product was labeled "strawberry-flavored yogurt" and when the product was tasted, it instead had a flavor more typical of raspberry, than of strawberry. This defect may also be caused by the excessive use of flavor concentrates, poor-quality flavor concentrates, or the use of poor-quality fruit that has been fortified with other flavors either natural or artificial that are not typical of the named flavor. Sometimes if the acid/sweetness profile is not balanced, the product may have a different flavor profile than the yogurt processor intended. Even human error may be involved in the cause for this flavor defect. It is a common practice to push out the proceeding flavor on a production line with the next flavor to be packaged. An example would be if the processor is filling strawberry-flavored yogurt and the next flavor is raspberry. There will be some mixing of products in the line, and it is up to the operators to ensure that this mixed product is not packaged. If a miscalculation is made, there may be some product that was filled under a different flavor.

Unclean This defect is characterized by a “dirty sock” flavor, and the mouth simply does not “clean-up” (the lingering unpleasant aftertaste remains). It is noticed at the end of the tasting cycle and lingers in the mouth for an extended time. The defect cause is usually the result of microbial contamination of the raw materials, the yogurt cultures, or processing equipment. It is generally presumed that the causative microbial agents are psychrotrophic bacteria (low temperature growing, Gram-negative, spoilage bacteria).

The unclean defect may be an important indication that processing equipment is not being cleaned and/or sanitized properly. Thorough inspection of the yogurt making and filling equipment should be conducted. Proper screening of all incoming ingredients should be conducted to determine if the problem may be caused by product that is being added such as milk, cream, nonfat dry milk, whey, fruit, etc. An inspection of how the starter culture is added to the yogurt vat should be conducted to determine if any contamination occurs at this point due to poor aseptic inoculation technique.

8.10 Conclusion

The ability to analyze dairy products is an invaluable tool that can have lasting benefits to the dairy industry. To correct negative attributes in yogurt, the first step is to identify the problem in order to understand the root cause. To look at the appearance, feel the body of the yogurt in the mouth, and be able to identify the flavor attributes, both positive and negative, is the best means to remedying the problem. To become proficient in sensory evaluation can save a business time and money; it is a valuable tool for anyone associated with yogurt manufacturing. With training, patience, and practice, it can be mastered.

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Chapter 9
Cheddar and Cheddar-Type Cheeses

Stephanie Clark

9.1 Introduction to Cheddar Cheese

Cheddar cheese is generally classified as a hard, internally ripened cheese and is the most widely recognized and produced member of a group of cheeses often called "Cheddar-type." Until 2002, Cheddar was the most plentifully available cheese in the USA. Commodity data from the US Department of Agriculture Economic Research Service show that per capita consumption of Cheddar cheese increased from 5.8 pounds in 1970 to 10.6 in 1987, fluctuated between 9.0 and 10.4 through 2019. Per capita consumption topped out in 2017, at 11.1, and dropped back to 10.1 in 2019 (USDA ERS, 2020). The burgeoning pizza market has led to the emergence of mozzarella cheese as a contender for the honor of most available cheese. During that same period, the per capita consumption of mozzarella has steadily risen from 1.2 pounds in 1970 to 10.0 in 2005 and 12.5 papc in 2019. However, the rapid rise of mozzarella does not diminish the importance of Cheddar cheese, which continues to be strong as a stand-alone product and as an important ingredient for the food industry.

The variations in processes and techniques involved in making cheeses within the Cheddar-type group result in relatively small differences in cheese characteristics when placed in the context of all cheeses. Therefore, Cheddar cheese grading is the primary focal point for discussion in this chapter. An outline of the proper

This chapter is the result of careful work by previous authors of *Judging Dairy Products* (Nelson & Trout, 1934, 1948, 1951, 1964) and *The Sensory Evaluation of Dairy Products* (Bodyfelt et al., 1988; Partridge, 2009), with addition of new materials, deletion of redundancies, and a rearrangement of content.

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sequence of procedures for grading will be followed by a section defining defects and attributes in detail. The use of the Collegiate Dairy Products Evaluation Contest (CDPEC) Cheddar cheese scorecard for the training of students to evaluate body and texture and flavor characteristics will be woven into the general topic of grading.

9.2 Essential Steps of Cheddar Cheese Making

The US government Code of Federal Regulations (CFR Title 21, Part 133.113; US FDA, 2022) defines Cheddar cheese as cheese made by the Cheddar process or by another procedure that produces a finished cheese having the same physical and chemical properties as that produced by the previously described Cheddar process. This cheese is generally made from cow's milk (but milk from goats, sheep or mixed milk is common), with or without the addition of coloring matter (usually annatto bean extract). Common salt (NaCl) is typically added.

The traditional method of converting of milk into Cheddar cheese can be divided into nine essential steps:

1. *Preparation of milk*. Although raw milk may be used if the cheese is aged at >1.7 °C (35 °F) for >60 days prior to sale, cheese milk preparation generally includes pasteurization or thermization. Thermization is a sub-pasteurization heat treatment that reduces bacterial numbers yet retains some indigenous enzyme activity and requires >60 days of cheese aging at >1.7 °C (35 °F) because it is classified as a raw milk cheese. Following heat treatment, the milk is adjusted to the setting temperature of 30–31.1 °C (86–88 °F).
2. *Ripening of milk*. The first addition to the tempered milk in the vat is the appropriate starter culture, followed by the addition of colorant, if used. The starter culture produces the required lactic acid as well as a variety of metabolic enzymes. Often times, adjunct cultures are added along with the primary lactic starter culture to provide unique flavor characteristics and/or to accelerate ripening.
3. *Setting and cutting the curd*. Following 30–60 min of ripening, rennet or another coagulating enzyme is added to induce the formation of the milk gel within 25–35 min. The milk gel (coagulum) is then cut into individual curds using appropriate cheese knives (harps), with wires placed approximately 0.65 to 1 cm (1/4 to 1/2 in) apart.
4. *Cooking the curds*. The curds are allowed to heal for 5–15 min, followed by gentle agitation as the whey syneresis begins, and the individual curds develop a cohesive body and texture. The milk temperature is simultaneously raised with constant agitation to the final cooking (scalding) temperature of 37.8–40.0 °C (100–104 °F) within 30 min, followed by an agitated cooking time that varies with the target characteristics of the cheese.
5. *Cheddaring*. In the traditional Cheddaring stage, whey is drained from the curds, which are allowed to bind together, thus forming mats of curd. The mats are subsequently cut into loaves. Loaves are typically flipped and stacked, approxi-

mately every 15 min and maintained at appropriate temperatures to allow production of additional lactic acid for modification of curd body and texture. The Cheddaring stage is also an important process step for control of the final moisture content of the finished cheese.

6. *Milling*. When the appropriate body and texture and a target acidity have developed, the curd mats are milled into approximately 2 × 2 × 5-cm (¾ × ¾ × 2 in)-sized curds. *Optional substitution for steps 5 and 6*. The make procedures may be modified to eliminate the Cheddaring step (for a stirred curd process) and/or to add a wash step (water is added to the vat after partial whey removal, to reduce the lactose available for fermentation).
7. *Salting*. Salt is added to the properly acidified curd to slow cultures and to help with moisture control, as well as flavor, body, and texture development of the finished cheese.
8. *Molding*. After mixing of the salt and curd, the curd is placed in the mold, which gives the cheese the desired shape. Traditionally, curd is pressed in the mold for about 18 h; however, modern, continuous pressing systems shorten the time required. Proper handling of the curd in the molding process will help provide the desired close-knit texture characteristic of Cheddar cheese.
9. *Packaging and curing*. After extraction of the cheese from the mold, one of several types of coating or packaging materials may be applied to the block as a barrier to oxygen and water, including the option for a natural rind (bandaging, larding, cave aging; Fig. 9.1). Such barriers (except natural rind) have the potential for growth of molds and prevent drying. The Cheddar cheeses are then placed in the aging facility for development of flavor and body and texture. The enzyme activity from rennet and cultures is responsible for the catabolism of cheese curd components resulting in the development of flavor components and body and texture changes.

Fig. 9.1 Vacuum-sealed, rindless Cheddar cheese (left) and muslin bandage-wrapped Cheddar cheese (right). (S. Clark images)

Table 9.1 Code of Federal Regulations for Cheddar-type cheeses (US FDA, 2022)

Cheese variety	CFR, Title 21, Paragraph
Cheddar/Cheddar for manufacturing/low-sodium Cheddar cheese	133.113/114/116
Colby/Colby cheese for manufacturing/low-sodium Colby cheese	133.118/119/121
Washed curd and soaked curd cheese/washed curd cheese for manufacturing	133.136/137
Granular and stirred curd/granular cheese for manufacturing	133.144/145
Monterey and Monterey Jack/high-moisture Jack cheese	133.153/154

Numerous variations and subroutines within each of these general steps make possible the varieties included in the Cheddar-type cheese family. Definitions for Cheddar and similar cheese types may be found in the Code of Federal Regulations (CFR), Title 21, Part 133 (US FDA, 2022) (Table 9.1).

All of the varieties listed in Table 9.1 require a minimum milk fat content of at least 50% by weight of the solids. Given a constant milk fat-to-casein ratio, the hardness of a given cheese is a function of moisture content. The maximum moisture content on a weight basis is 39% for Cheddar and granular/stirred; 40% for Colby; 42% for washed/soaked; and 44% for Monterey/Monterey Jack cheeses.

Moisture content and acidity are regarded as the two most important factors in the control of cheese properties. Generally, a firm, low-moisture cheese will result in a slower rate of ripening, more selective microflora activity, milder flavor, longer product keeping quality, and a cheese more suited for additional aging or maturing.

The salt content, the relative amounts of milkfat above the minimum requirement, and chemical changes that result from the controlled growth of starter and adjunct microorganisms and associated enzymatic activity during manufacturing and ripening processes will also help determine the sensory characteristics of the cheeses between and within varieties. The addition of proteolytic and lipolytic enzymes to the cheese milk before pressing can also modify the sensory characteristics of the cheese. Hence, a combination of factors is responsible for yielding the variety within the Cheddar-type classification.

9.3 Composition and Nutritive Value

In cheesemaking, marked changes in composition of the original cheese milk occur at two distinct stages: (1) during separation of the curd from whey and (2) during cheese ripening. Nearly all water-insoluble and some water-soluble components are retained in the curd. For Cheddar-type cheese, protein, fat, calcium, phosphorus, and vitamin A are concentrated approximately eight- to tenfold compared to the amounts of these constituents found in milk. Most of the water-soluble components, including the water-dispersible whey proteins, are "lost" to the whey. As a result, lactose, whey proteins, and water-soluble salts are not appreciably retained by the curd, and thus, are present only in small quantities associated with the relatively small amount of moisture (whey) retained in the cheese curd. When using cheese milk concentrated by membrane processing, more of the whey proteins are incorporated into the cheese curd, improving the nutrient profile and yield (Iyer & Lelievre, 1987).

Cheese curd retains the most important nutrients of milk. Most notable are the nutritionally complete protein, casein, calcium, phosphorus, and vitamin A. Cheese is considered to be one of nature's most versatile foods, being simultaneously nutritious and readily digested (Miller et al., 2000).

Some Cheddar cheese is referred to as "full-cream cheese" because it is made from whole milk (~4.0% fat). However, most Cheddar cheese is manufactured from standardized milk, wherein the relative fat and casein proportions are adjusted, usually by adjusting the milk fat content of the cheese milk to approximately 3.8%, thus maintaining a constant casein:milk fat ratio. To produce 1 lb (0.45 kg) of Cheddar cheese requires approximately 10 lb (4.54 kg) of whole milk (almost 5 qt). Nearly one-half of the total solids of whole milk remain in the cheese curd, including about 75% of the milk protein. The milk fat content of Cheddar cheese is about 31–35% of the total weight (>50% of dry matter). Cheddar cheeses meeting the labeling requirements of reduced (25% reduction in fat), low-fat (3 g of fat or less in a reference serving of 28 g), or nonfat (0.5 g of fat or less in a reference serving of 28 g) are available and present many challenges to the cheesemaker due to toughening of the cheese structure and reduction in flavor development.

Cheddar-type cheeses may be made from milk of other sources, such as goats or sheep, and will have different sensory characteristics as a consequence of differences in milk fat and protein composition for each lactating species (refer to Chap. 18).

9.4 Degree of Ripening

Much of the Cheddar cheese made from pasteurized milk is marketed shortly after manufacture (≤ 90 days) as a mild cheese or for use in producing processed cheese (Chap. 12). Historically, the ripening or curing of Cheddar cheese to develop characteristic Cheddar cheese flavor is a slow, complex, bacteriological, chemical, and enzymatic process that requires months, and sometimes years, for extra-sharp cheese flavor. Consequently, Cheddar may be found on the market in various stages of ripeness, or aging. For best results, cheese ripening requires carefully controlled temperature and humidity.

Although not legally defined, unripened Cheddar cheese is often referred to as "fresh," "current," or "green" cheese. Cheese at this stage is characterized as having a flat or weak flavor (compared to a medium or sharp cheese) and a relatively tough, curdy, or corky body. Good-quality Cheddar cheese that has been properly cured for at least 3 months or longer has a moderate, slightly nutty, "Cheddar" flavor and is generally referred to as a "young" or "mild" cheese. At 6–8 months of age, more of

Table 9.2 General[a] Cheddar cheese classifications based on the extent of ripening

Classification	Aging time
Mild	2–3 months
Medium or mellow	4–7 months
Sharp or aged	8–12 months
Extra-sharp	Over 1 year

[a]These are typical aging times for traditionally manufactured Cheddar and may vary slightly among cheese manufacturers. Modern accelerated ripening techniques significantly shorten this timetable

the distinct, aromatic Cheddar flavor should be evident; such cheese is considered as "semi-" or "medium-aged." Generally, a year or longer is required to develop the fully aromatic or robust Cheddar cheese flavor desired in an "aged," "sharp," or "matured" cheese. "Extra-sharp" Cheddar cheese is usually aged in excess of 1.5–2 years (Table 9.2).

The grading of cheese and assignment of extent of ripening designation for labeling is dependent on the organization doing the grading. If the USDA is the contracted grading entity, the grader will designate the cheeses as either fresh/current, medium, or cured/aged. However, outside of USDA grading practices, the assignment of extent of ripening designations is entirely up to the organization with the final approval on the label. Graders may be employed by the manufacturer, formulators, brokers, or the wholesale buyers.

Whether the flavor of Cheddar cheese is mild or pronounced does not depend exclusively on the aging process. The quality of the milk, the bacteriological and chemical control in manufacture, moisture, salt content, and the temperature and method of curing have much to do with the nature and intensity of flavor in the final product. The development of typical Cheddar cheese flavor is highly dependent on age, and it is generally advisable not to evaluate cheeses of various ages within the same class. In educational cheese clinics, exhibits, and/or contests where Cheddar cheese is to compete for awards, the cheese should be entered into different age classes or categories. Young (mild) cheese (under 4 months old), semi-aged (medium) cheese (from 4 to 8 months old), and aged (sharp) cheese (over 8 (or 12) months old) are logical age classifications. Rindless and natural rinded cheeses may also be judged in separate classes.

The use of "accelerated" ripening techniques such as added enzymes, adjunct cultures, and elevated temperature has resulted in many if not most cheeses meeting the sensory equivalent of "sharp" flavor in as little as 6 months. Cheeses that are the product of accelerated ripening are not good candidates for the traditional timeline displayed in Table 9.2, but should be judged by the same set of standards as any Cheddar cheese. The acceleration of ripening will accelerate the development of sensory defects as well as proper character; therefore, milk quality, make procedures, and ripening regime must be followed with great care.

9.5 Form and Style

As market demands are identified, Cheddar cheese may be made in several sizes, forms, or shapes, which are generally called styles. Usually, a judge will not be concerned with cheese style, except to remember that large-sized cheeses are not as prone to drying out as smaller ones; this may slightly affect the texture and flavor of cured cheese.

The Cheddar cheese industry has developed a multiplicity of small sizes and shapes (Fig. 9.2), but it has also recently produced larger, more utilitarian sizes of cheese, as well. The rindless 40-lb block, 640-lb (291 kg) block, and 500-pound (227 kg) barrel cheeses have evolved as the predominant forms and sizes in contemporary cheese manufacture for reasons of economy, ease of handling, and warehousing.

A "mammoth" is a large, oversized, attention-arresting Cheddar cheese. Such cheeses are formed for the express purpose of display, advertising, and a focus of interest for special occasions, such as the opening of a new supermarket or advent of a festival that features cheese or dairy products. The size of a mammoth cheese generally varies from 300 to 13,000 lbs. For many years, the largest cheese on record was the 22,000-pounder made in Ontario, Canada, and exhibited at the Columbian Exposition, Chicago, 1893. However, this one was exceeded by the 34,591-pound Wisconsin Cheese Foundation giant displayed at the 1964 New York World's Fair, followed in 1988 by a 40,060-pound Cheddar named "Belle of Wisconsin," and finally in 1996 by a 57,518-pound turned out by Agropur of Granby, Quebec. Usually, these mammoths have excellent flavor and body and texture quality since the curd tends to cure quite well in a large cheese. In fact, since so much value is at stake, every precaution must be taken, from the selection of milk and curd handling to careful control of curing for such a cheese to be acceptable.

CHEESE HOOP SPECIFICATIONS

HOOP NUMBER	NAME	Weight of Cheese Pounds	Size of Cheese*	Height of Hoop Less Bandager
1	Longhorn, with one handle only	12	6" x 13"	15 5/16"
2	Favorite or ½ Young American	5½	7" x 3½"	5 5/8"
3	Young American	10	7" x 7"	9 1/16"
5	Daisy	22	13½" x 4¼"	6 5/16"
27	Midget	11	9 5/8" x 5"	6 5/8"
28	Gem	2½	5 1/8" x 3¼"	5 1/8"
14	20-pound Square Wilson-Style	20	14 3/16" x 11 3/16" x 3¼"	2 5/8"
44	40-pound Square Wilson-Style	40	14 3/16" x 11 3/16" x 6½"	4¼"
46	60-pound Square Wilson-Style	60	14 3/16" x 11 3/16" x 9¾"	6"

*First dimension listed for round hoops is diameter, second dimension is height.

Fig. 9.2 Examples of some of the hoops or molds used to form various shapes and sizes of Cheddar and related cheeses. (Bodyfelt et al., 1988)

9.6 Grading of Cheddar Cheese

The practice of “grading” is used to evaluate the potential use and relative value of a cheese as it enters the channels of commerce leading to the consumer. Grading may tell the manufacturer that the cheese in question is suitable for extended ripening or must be moved quickly as young cheese for further processing. The term “judging” is generally reserved for competitions, but the judge uses the same criterion as the grader as appropriate to the contest.

Much can be learned about the quality of a given cheese by its appearance. By careful observation of the external appearance, and the internal body, texture, and color characteristics of a cheese, an experienced judge can often place a given cheese into a quality classification without actually tasting it.

The “ideal” Cheddar cheese should have (1) a clean, delicate, pleasing aroma and, when cured, a nutty flavor; (2) a firm and springy body, showing smoothness and waxiness (if cured) when worked between the thumb and fingers, and slight curdiness if fresh; (3) a texture that reveals a smoothbore or closed appearance (few or no openings); (4) uniform, translucent color, whether colored or uncolored (when fresh, it may be slightly seamy); and (5) a smooth finish that is clean, well-shaped, uniform in dimensions and overall size, with a complete, airtight package, and mold free.

9.6.1 Federal Grading of Cheddar Cheese

The US Cheddar cheese sold in central markets, or on contract, is usually sold on the basis of government grade. If sold on contract, the cheese age and style of package are generally specified. Such cheese is generally graded according to Federal standards by a USDA grader; the cheese price is determined primarily on the “basis of sensory quality.” Generally, a college student who has mastered the evaluation of Cheddar cheese by the scorecard system can, after a short apprenticeship with a Federal grader, become proficient in grading cheese according to Federal standards.

The Dairy Grading Branch of the Dairy Programs Division, Agricultural Marketing Service of the USDA, recognizes four grades of Cheddar cheese. The nomenclature for these grades is as follows: (1) US Grade AA; (2) US Grade A; (3) US Grade B; and (4) US Grade C. Cheeses within Grades are also assigned one of three degrees of curing: (1) fresh or current, (2) medium, or (3) cured or aged. Detailed descriptions of the quality grades and US Standards for grades of Cheddar cheese as well as Colby, Monterey (Monterey Jack), and bulk American cheese may be found on the USDA AMS website (USDA AMS, 2022).

9.7 Sequence of Cheddar Cheese Grading Procedures

Following a logical and repeatable set of procedures for the grading of Cheddar and Cheddar-type cheeses will allow the grader/judge to become more proficient and efficient. This section provides a summary of the appropriate procedures for grading and introduces the several example scorecards. The following section describes the defects/attributes of Cheddar cheese in more detail.

9.7.1 Preparation for Evaluation

Appropriate facilities for cheese tempering, sampling, proper disposal of waste cheese, and cleaning of sampling equipment should be provided for evaluators. The facility should be well lit and air conditioned (approximately 65–68 °F) to ensure cheese is neither too warm nor too cold during evaluation. Evaluators should dress in layers, prioritizing cheese quality over comfort. Prior to sampling, one's hands should be washed and dried, since they directly contact exposed cheese surfaces. As soon as the cheese samples to be evaluated are arranged in order and numbered or coded for proper identification, the sensory evaluation process may begin.

Before evaluation, cheese samples should be tempered at l0–15.5 °C (50–60 °F) for a sufficient length of time to ensure a uniform temperature throughout the cheese. This usually requires 1–2 h for the smaller styles (≤5 lb) and 3–5 h for larger ones. Generally, a cheese plug taken from a warm (over tempered) cheese appears weak bodied; by contrast, a cold plug may appear short or corky. Actual body and texture characteristics cannot be determined readily unless cheese samples are properly tempered before evaluation. Flavor and flavor defects can also be more readily assessed at a warmer temperature.

9.7.2 Evaluation of Surface Appearance

The first procedure in grading Cheddar cheese is visual examination of surface finish or packaging material. The judge should note whether the sample appearance is generally clean, neat, attractive, and symmetrical, or whether the surfaces might be uneven, nonparallel, or rounded. Next, the evaluator should look more closely at the surfaces and observe whether the coating of plastic film (or paraffin) or wax or bandage is smooth and free from holes, tears, or wrinkles. Finally, the judge should undertake a close examination of the surface for mold growth; a mental record of all observations of the sample appearance should be made.

Obviously, this technique of evaluating appearance cannot be followed entirely when cheese is encased in opaque wrappers. Laminated paper-Pliofilm or foil wrappers serve to obscure the cheese from the critical eye of the judge. About the only recourse the evaluator has in noting the appearance of such cheese is to note the cleanliness of the wrapper, the evenness and tightness of adherence, and freedom from breaks and tears.

9.7.3 Sampling

Cheese samples are usually obtained with a double-edged, curved-blade instrument known as a cheese trier (Fig. 9.3). For best service, the edges of a cheese trier need to be sharp. A trier that cuts a larger plug has an advantage over one of a smaller diameter since the extent of "openness" and possible color defects are easier to detect with a larger plug. A cheese trier with a 127-mm (5-in) cutting edge, 15.8 mm (5/8 in) diameter at the base (top), and 14.3 mm (9/16 in) diameter at the tip is recommended.

The trier should be inserted into the top surface of the cheese, preferably about halfway between the center and the outer edge of the cheese sample. After insertion, the trier should be turned one-half way around to cut a sample core. The plug is withdrawn, by twisting and lifting, simultaneously. The process produces a long tapered cylinder of cheese (Fig. 9.4). The back (warm) surface of the cheese trier, with the freshly drawn plug in place, should immediately be smelled to detect any volatile aroma components while at their strongest concentration. The upper 2.54 cm (1 in) of the cheese plug may be broken off and replaced, flush with the surface of the original hole, though this practice is not always followed (Fig. 9.5). This partially protects the cheese from developing mold contamination and retards drying and cracking of the cheese surface surrounding the hole. Various wax-like polymers of plastic or gels have been developed to seal trier holes to restrict the access of oxygen to the center of the cheese.

Fig. 9.3 Cheese triers of various sizes

Fig. 9.4 Removing a cheese plug from a 5-lb block of Cheddar with a 127-mm (5-in) trier. (Stephanie Clark images)

Fig. 9.5 Students in the Collegiate Dairy Products Evaluation Contest try samples of Cheddar cheese. (S. Clark image)

The evaluator should carefully examine the cheese plug and note whether the plug has a clean-cut surface (with no loose particles) or whether it is rough (with a feather-like edge as though the cheese had been cut with a dull knife). The evaluator should make a mental note of these observations as anything less than a clean waxy cut may be an indicator of defects such as short body and acid flavor. To remove the plug from the trier while maintaining its shape, apply moderate pressure to the top of the plug with the thumb of the hand holding the handle. Then, from the top, loosen the plug from the trier by gently grasping and twisting with the thumb and fingers of the free hand.

9.7.4 Evaluation of Color

The evaluator should observe the color of the cheese and determine whether the appearance is bright and clear or dull and lifeless. The cheese should be free from mottled or light and dark portions, curd seams, or faded areas surrounding any mechanical openings. The cheese judge should re-examine the plug and observe whether the cheese appears to be (1) translucent, which is desirable, or (2) opaque (difficult for the eyes to observe beyond the surface), which is undesirable. The evaluator should especially note whether the color is uniform throughout the sample. In quality evaluation, color uniformity is generally more important than the shade of color. Some cheese consumers prefer an uncolored product (no added annatto coloring). Uncolored (or lightly colored cheese) generally results in a light cream shade (sample 7 in Fig. 9.6); this depends on the milk fat and/or carotene content of the cheese milk. Other groups of consumers seem to prefer an intense deep-orange color for Cheddar cheese (sample 5 in Fig. 9.6). A good judge will note any defects in color that may be an indicator of defects in flavor or body and texture.

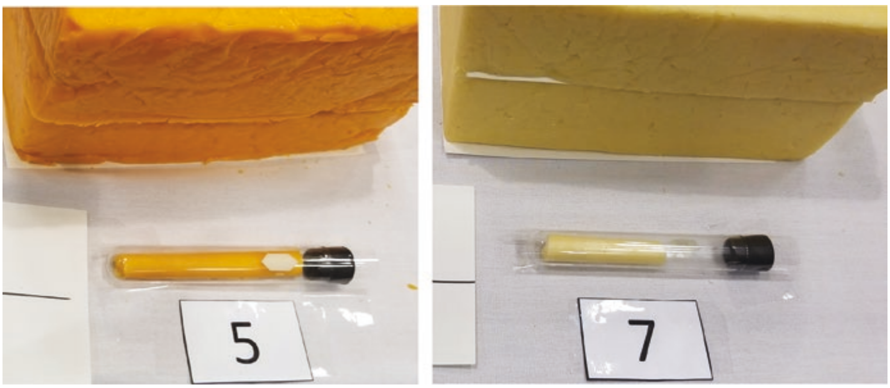

Fig. 9.6 Plugs of Cheddar cheese are placed in glass test tubes for evaluation by student contestants in the CDPEC. (S. Clark images)

9.7.5 Evaluation of Body and Texture

The judge should observe the nature and extent of the mechanical (open) or gassy defects in the cheese plug. Although visual, these defects are considered body and texture defects. In the CDPEC, a single plug is drawn by the lead judge and is placed in a glass test tube, capped, and taped to the table, so all student contestants may observe the same plug (Fig. 9.6). The shape or configuration of openings or gas holes should be examined closely to see whether they are regular, angular, rounded, large, and/or small. For the purposes of the CDPEC, the defects variously identified by USDA graders as either “pinny, sweet holes, gassy and slitty” are all scored as the “gassy” defect. The luster or sheen of the inner surfaces of these openings and whether the surfaces appear dry (preferable) or wet are helpful observations. Free moisture within these openings is sometimes indicative of certain flavor defects (i.e., whey taint, unclean) or potential quality shortcomings. See Fig. 9.7 for examples of gassy and open defects.

After the visual assessment, evaluators should take the ends of the cheese plug by the forefingers and thumbs of both hands and bend the plug slowly into a semicircle, while carefully observing when the sample breaks, as well as the nature of the break. A cheese plug that bends into approximately one-third to one-half of a full circle before breaking apart demonstrates the preferred plasticity. Generally, if the plug shows a definite resistance toward any bending and finally breaks abruptly, a “short” defect is noted (Fig. 9.8); if the plug bends until the plug ends nearly touch (if it breaks apart at all), a “weak” defect is noted.

Next, the judge should take one of the broken pieces of cheese between the thumb and the forefingers and attempt to manipulate it into a uniform mass. The relative resistance (or lack of resistance) offered by the cheese to applied pressure from the thumb and fingers should be ascertained. A common procedure is to work

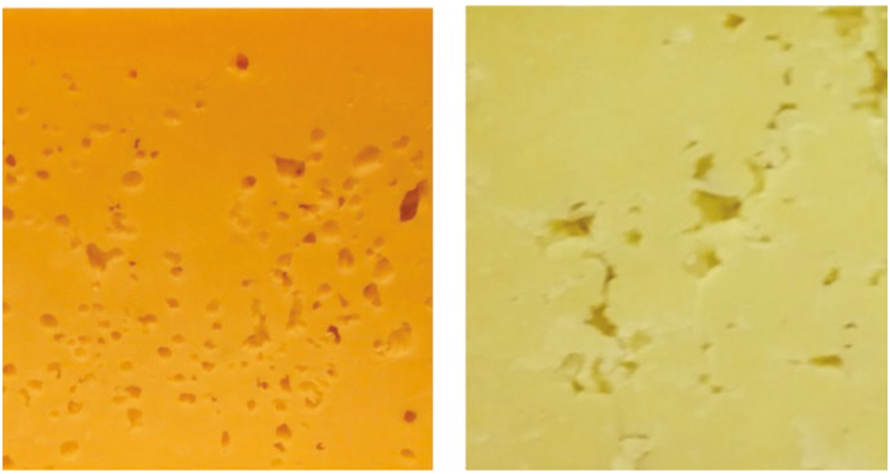

Fig. 9.7 Gassy (left) and open (right) defects evident in sliced cheese. (S. Clark images)

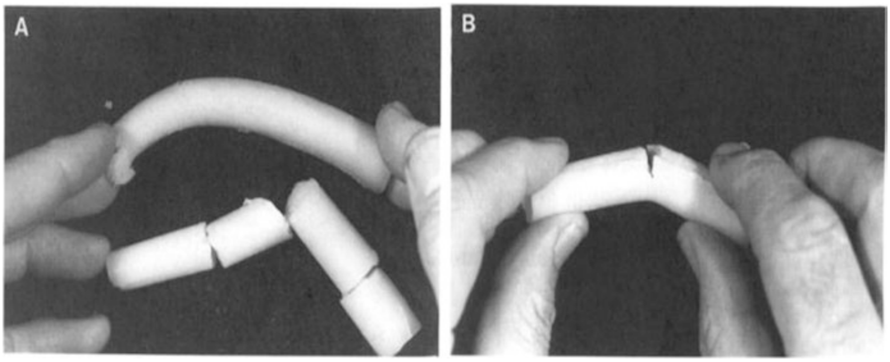

Fig. 9.8 A comparison of a “ideal”-bodied (**a**) and a “short”-bodied (**b**) Cheddar cheese. (Bodyfelt et al., 1988)

the piece of cheese by compressing to about half its original diameter, twisting and pressing the elongated portion to about half of its diameter, and repeating this process 12–15 times. Consistency in piece size and working method allows the evaluator to more objectively compare pieces of worked curd. The evaluator should try to form a small ball or marble of the softened product. Formation of a cohesive sphere of cheese is generally indicative of an appropriate degree of waxiness and elasticity for a typical Cheddar cheese of any age.

Next, the formed “ball” of cheese should be placed into the depression between the tips of the first two fingers, and with gentle to moderate pressure, the evaluator should push the thumb (of the same hand) into the manipulated cheese. Then the thumb should be slowly pulled from the slightly depressed “cheese ball.” If the cheese sample adheres or sticks to the thumb or feels tacky or wet to the thumb’s touch, the cheese sample is considered to demonstrate the pasty (sticky) defect. In stark contrast, if the cheese sample tends to fall apart in response to thumb pressure, either a curdy or crumbly defect is suggested, respectively, depending on the advancing age of the cheese. The “worked cheese” should remain smooth, waxy, and somewhat pliable for an “ideal” Cheddar cheese. The tempered sample should exhibit a tendency to remain as a solid mass upon gentle finger manipulation.

An optional approach is to spread the cheese mass over the palm of the hand (with the thumb of the opposite hand) and determine whether the thin smear of cheese feels smooth, silky, waxy, and/or fine or whether the sample variously appears to be sticky, pasty, mealy/grainy, or crumbly. The judge should then reassemble (or attempt to reassemble) the cheese particles and try to compress them into a compact “ball” and note the response of the cheese to this form of manipulation. Mealy/grainy may be better determined in the mouth than in the hands.

9.7.6 Evaluation of Flavor

By the time the sample has been worked into a semi-soft ball, the temperature of the cheese mass should have increased from combined pressure and hand warmth and thus enable easier detection of any aroma. The evaluator should place the tempered cheese sample directly under the nose and observe the aroma a second time. The judge should compare the aroma with that noted when the sample first was removed from the cheese. For tasting, the evaluator should place a small portion of an "unworked" plug into the mouth and chew until a semi-liquid stage is reached. The judge should roll the macerated sample about within the mouth for sufficient time to determine both taste and aroma, then expectorate the sample and determine the overall flavor judgment(s). The evaluator should avoid using the previously worked cheese sample due to the possibility of carryover from fingers from previous samples and loss of some volatile flavor components.

As a rule, too many samples tends to dull the sense of taste and smell; ideally, no more than 15–20 samples should be tasted at one scoring, as they may eventually all tend to taste alike. For beginners, about ten samples can be tasted successively with some assurance that the taste sensing nerves are functioning normally or are not overtaxed.

Rinsing the mouth occasionally with tepid water will allow appropriate reconditioning of the mouth for subsequent sampling. After experiencing a particularly poor-quality sample (i.e., rancid, garlic/onion, or intense sulfide/bitter), in a non-contest environment, rinsing with a lukewarm saline solution to cleanse the mouth of previous cheese flavors may be helpful. A pinch of common table salt placed into the mouth and rinsed out with tepid water can be equally effective. Apple slices or grapes are also useful for cleansing the mouth between intense-flavored cheese samples. After any cleansing procedure, a final rinse of water is recommended. Experienced judges find it most helpful to "go back to the best sample in the lot" after evaluating a poor-quality sample.

9.7.7 Scoring

All sensory observations should be recorded on a designated cheese scorecard or a tablet/computer provided for this purpose. The quality score of cheese is determined by comparing the properties or characteristics of each cheese with their accepted standards of perfection or "ideal." These standards of perfection, when assembled, form what is known as a scorecard for Cheddar cheese. The less-experienced judge should strive to follow the aforementioned procedure quite closely. Deployment of a scorecard enhances accuracy when more than two or three samples are evaluated. The judge should strive to keep a mental image of each sample's deviations from the standard. Once this ability is attained, continual re-examination of the various samples becomes unnecessary. The practice of re-examining, reworking, and retasting cheese is not typically conducive to the best evaluation performance. Such a practice leads to vacillating judgment, which is just as apt to be wrong as to be correct. A confident judgment should be made following the initial sampling, if possible.

9.7.7.1 The Collegiate Dairy Products Evaluation Contest Scorecard

One example of a Cheddar cheese scorecard is the one used by the Collegiate Dairy Products Evaluation Contest (CDPEC). Initially created by the Coaches Committee of the American Dairy Science Association (ADSA), a committee since disbanded, the official CDPEC scorecard was developed for use in training university students in sensory evaluation of Cheddar. The standard of perfection is somewhat arbitrary in origin, and the judge in training should realize that some characteristics listed as defects on the CDPEC scorecard may, in fact, be desirable characteristics for given market segments. The sulfide defect is an excellent example of a sensory characteristic that may also be considered an attribute. A cheese given a score of "6" for definite sulfide may be considered a top-quality cheese if classified and marketed as a New York-style Cheddar. For purposes of research, the use of the cheese lexicon and descriptive analytical techniques or appropriate consumer acceptance testing should be used. A discussion of proper sensory methods for research use is given in Chap. 17.

The scorecard lists some essential factors or items by which a cheese is evaluated; appearance and color are not a part of the scorecard. Each flavor and body and texture attribute is assigned a point weighting that reflects the relative importance of each factor in determining the overall sensory quality. For the novice cheese judge, the scorecard (Fig. 9.9) and associated scoring guide (Table 9.3) can be essential evaluation tools; as such, they should be studied in detail. The evaluator should keep

Cheddar Cheese

SAMPLE 1

FLAVOR SCORE: 1 2 3 4 5 6 7 8 9 10 NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Bitter	___ 6. Heated	___ 11. Unclean
___ 2. Feed	___ 7. High Acid	___ 12. Whey Taint
___ 3. Fermented	___ 8. Oxidized	___ 13. Yeasty
___ 4. Flat / Low Flavor	___ 9. Rancid	___ 14. Metallic
___ 5. Fruity	___ 10. Sulfide	

BODY AND TEXTURE SCORE: 1 2 3 4 5 NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Corky	___ 5. Mealy	___ 9. Weak
___ 2. Crumbly	___ 6. Open	___ 10. Crystals
___ 3. Curdy	___ 7. Pasty	
___ 4. Gassy	___ 8. Short	

Fig. 9.9 The computerized CDPEC contest Cheddar cheese scorecard for sensory defects

Table 9.3 Suggested CDPEC scoring guide for flavor and body and texture of Cheddar cheese for designated defect intensities (ideal = perfect 10 for flavor; 5 for body and texture)

Cheddar cheese			
	Slight	Definite	Pronounced
Flavor			
Bitter	9	7	4
Feed	9	8	6
Fermented	7	5	3
Flat/low flavor	9	8	7
Fruity	7	5	3
Heated	9	8	7
High acid	9	7	5
Metallic	8	6	3
Oxidized	7	5	2
Rancid	6	4	1
Sulfide	9	7	4
Unclean	8	6	3
Whey taint	8	7	5
Yeasty	6	4	1
Body and texture			
Corky	4	3	2
Crumbly	4	3	2
Crystals	4	3	1
Curdy	4	3	2
Gassy	3	2	1
Mealy	4	3	2
Open	4	3	2
Pasty	4	3	1
Short	4	3	2
Weak	4	3	2

in mind the relative values of the various scorecard items that are considered in the quality grading process. The scorecard does not address issues of finish and appearance, or color; however, these are important considerations when grading cheese for industrial or regulatory purposes and will be discussed later in this chapter. When evaluating cheese, the proper identification of an attribute(s) or a defect(s) is very important in helping the manufacturer identify strengths and weaknesses in the make procedures for the cheese in question.

In using the CDPEC scoring guide, one should keep in mind that if two or more defects are noted, the lowest scoring defect within the flavor or body and texture categories will set the category score for that product. *The defect scores are not cumulative*.

9.8 Defects/Attributes of Cheddar Cheese

9.8.1 Finish and Appearance Evaluation

Cheese should generally exhibit symmetrical, parallel ends, square, and even edges appropriate to the form in which they were made; packaging that is evenly folded, neat, close-fitting plastic film or wrapper free from wrinkles; a clean, thin, uniform, close-adhering coating of paraffin (if used) showing no blisters or scales; and freedom from pinholes, tears, breaks, cracks, undesirable mold, rot spots, or soiled areas.

The finish of the cheese is important during evaluation, as it furnishes an indication of the skill and care taken by the cheesemaker during manufacture of the cheese and of the subsequent handling of the product. An ill-shaped, poorly formed and packaged cheese indicates carelessness in manufacture, which may be correlated with undesirable sensory properties. Untidy, soiled, or moldy cheese does not present a pleasing appearance or full product utility. Defects in package finish are usually quite easy to observe and assess for their significance to maintaining product integrity.

The beginner judge should become familiar with the possible defects in cheese finish, and in turn correlate them, if possible, with other defects. The defects listed in the following paragraphs are closely associated with cheese wrapped with various types of protective coverings. (Common appearance defects, probable causes, and remedies may be found in Table 9.4).

9.8.1.1 Rindless, Flexible-Wrapped, or Non-paraffined Cheese

Modern processing and merchandising has led to the introduction of new styles and packaging materials for Cheddar cheese. Twenty-pound (9.1 kg) and 40-pound (18.2 kg) blocks and 500-pound barrels and 640-pound blocks have displaced the time-honored round "daisy" and "Cheddar," which were covered with a cotton bandage (cheese cloth) and paraffin. Taking the place of cotton and paraffin are a wide variety of flexible wrappers constructed of multiple polymer, laminated films that provide better oxygen and vapor barriers, greater tensile strength and bonding properties. In Cheddar cheese operations, these packaging materials are generally applied directly to the pressed "wet curd" immediately after de-hooping, with vacuum treatment, followed by heat sealing of the wrapper. The film-packed cheese may be placed in a fitted fiberboard box with a veneer reinforcement liner or other suitable container for storing and shipping. The cheese judge should be alert to possible flexible-wrapper defects listed in the following paragraphs.

Damaged Coverings Torn or punctured wrappers readily permit air access and microbial contamination of bulk cheese and thus must be prevented. Careless handling contributes to the "damaged" package defect. Hopefully, for economic reasons, damaged wrappers occur infrequently, but all wrapped bulk cheese warrants close inspection in this respect.

Table 9.4 Common color and appearance, body and texture, flavor defects of Cheddar cheese, their probable causes, and remedial measures

Appearance and color defects	Probable causes	Remedial measures
Acid-cut: bleached or faded, or dull looking (portions or entire cheese surface)	1. Excessive acid developing in the whey or at packaging stage 2. Nonuniform moisture distribution in the cheese	1. Monitor acid development carefully 2. Take precautions to insure consistent and uniform moisture retention in curd
Crystals or white specks: Granules or small hard mineral or protein deposits	1. If young cheese, results from calcium lactate complex formation (not desired) 2. If in aged cheese, derived from proteolysis and crystallization of tyrosine	1. Use make procedures that limit the levels of lactic acid and calcium in the serum of the cheese 2. Limit the fermentation of lactose through selection of appropriate cultures (pasteurized milk cheese only) 3. Reduce the level of lactose available in cheese milk by using ultrafiltration/diafiltration 4. Minimize post-packaging acid development
Mottled appearance: Irregularly shaped light and dark areas on cheese surface	1. Combining curds of different colors, batches, or moisture content 2. Uneven acid development in curd 3. Unwanted microbial growth: (a) H_2O_2 production, and/or (b) fruity off-flavor and (c) pasty body	1. Avoid adding starter culture after color incorporation 2. Attempt to cut the curd into uniform-sized particles 3. Handle all curd carefully to avoid drying during matting, Cheddaring, or “holdovers”
Pinking: Develops a pink color on the surface	Oxidation of annatto color	1. Avoid storing cheese under fluorescent lighting 2. Allow proper development of acid to develop during cheesemaking 3. Package the cheese using a good oxygen barrier
Seamy: Shows light colored lines around curd pieces	1. Exudation of milkfat from curd pieces due to excessive forking, too-warm temperatures, and lack of salt dissolution 2. Over-stirred set	1. Wash “greasy” curd at 32 °C (90 °F) and thoroughly drain 2. Avoid over-forking of the curd 3. Allow all of the salt to dissolve completely 4. Press curd at 30–32 °C (86–90 °F)
Moldy appearance	Growth of mold on cheese surface	1. Insure airtight seals on cheese packages 2. Avoid O_2 in the packages by vacuum or CO_2 or N_2 gas flushing

(continued)

Table 9.4 (continued)

Body and texture defects	**Probable causes**	**Remedial measures**
Corky, dry and hard	1. Lack of acid development 2. High salt in moisture phase 3. Not enough coagulant 4. Use of too much calcium chloride	Follow standard or recommended procedures for cheesemaking
Crumbly, mealy/grainy	Excessive acid production and low moisture retention in cheese	1. Avoid ripening at higher temperatures 2. Control acid development and moisture level in curd
Curdy or rubbery	Inadequate curing conditions	Optimize ripening temperature and time
Pasty, sticky or wet	1. High moisture retained by curd 2. Excessive acid development	Control acid development in relation to time and temperature parameters
Weak or soft	1. Excessive fat content 2. High moisture in cheese 3. Failure to develop “body” in cheese during cooking 4. Low salt in moisture phase	1. Standardize fat in cheese milk 2. Cook curd to desirable firmness (higher temperature, longer time) 3. Avoid piling curd slabs too high or too soon while Cheddaring curd
Flavor defects	**Probable causes**	**Remedial measures**
Bitter	1. Excessive moisture 2. Low-salt level 3. Proteolytic starter culture strains 4. Microbial contaminants 5. Excessive acidity 6. Poor-quality milk 7. Plant sanitation problems	1. Use carefully selected cultures 2. Reduce amount of starter 3. Monitor salting levels and method of adding 4. Upgrade milk quality 5. Improve sanitation 6. Control acid and rate of development
High acid	1. Development of excessive lactic acid 2. Excessive moisture 3. Use of too much starter 4. Use of high-acid milk	1. Reduce ripening time 2. Reduce starter amount 3. Monitor milk acidity 4. Cook to slightly higher temperature 5. Follow a standardized procedure for cutting, cooking, draining, Cheddaring and salting steps
Fermented (vinegar-like)	Heterofermentative *Lactobacilli*	1. Improve cooling 2. Short wash pasteurizer every 8–12 h 3. Review milk quality

(continued)

Table 9.4 (continued)

Flat (lacks flavor)	1. Lack of acid production 2. Use of milk low in fat 3. Excessively high cooking temperature 4. Use of too low a curing temperature 5. Too short a curing period	1. Check starter activity 2. Increase starter amount 3. Increase curing temperature 4. Lengthen curing period 5. Standardize cheese milk for fat content
Fruity	1. Certain strains of *S. lactis* or *S. diacetylactis* 2. Low acidity 3. Excessive moisture 4. Low-salt level 5. Poor milk quality	1. Eliminate lactic strains that produce ethanol 2. Monitor starter activity 3. Check salting procedures 4. Upgrade milk quality
Rancid	1. Milk lipase activity 2. Microbial lipases from contaminants 3. Homogenization of raw milk 4. Late lactation or mastitic milk	1. Standardize the Cheddaring process. 2. Avoid excessive agitation, foaming, and severe temperature fluctuations. 3. Improve sanitation 4. Monitor milk quality
Unclean	1. Poor-quality, off-flavored, or old milk 2. Unwanted microbial contaminants 3. Allowing off-flavored cheese to be "aged" 4. Improper technique of Cheddaring	1. Upgrade milk quality 2. Improve sanitation 3. Market marginal quality cheese as mild 4. Standardize the Cheddaring process
Whey taint	1. Poor whey expulsion from curd 2. Improper Cheddaring techniques 3. Failure to drain whey from piles of curd slabs (especially between pieces)	1. Standardize the Cheddaring process. 2. Constantly make sure expelled whey is free to drain away from Cheddaring curd 3. Wash curd with 32 °C (90 °F) water to remove excess whey

Sources: Compiled from Blake et al. (2005), Chandan (1980a, b), Johnson (2004), Van Slyke and Price (1979), Wilson and Reinbold (1965), Wilster (1980), and Wendorf (2007)

Loosened Coverings For maximum protection against mold growth, air (oxygen) must be excluded insofar as possible from under the wrapper of cheese coverings. Some wrappers are bonded so tightly to cheese surfaces that loosening and removing of wrappers in cheese cutting and packaging operations may be difficult. All non-bonded wrappers must be pressure- or vacuum-sealed to void as much oxygen as possible. Usually, these wrappers cling to the cheese as though they were bonded. "Loosening" and "ballooning" of the wrapper is generally undesirable, as mold growth may occur within the air space provided if the integrity of the covering is lost. Loosened wrappers may be noted by sight, or by stroking the cheese surface with the hand. Cheese package edges and ends should be closely examined for any unnecessary looseness and/or air pockets.

Soiled Coverings A “soiled (or greasy) wrapper” often denotes extreme carelessness in packaging, handling, and storage. Such a condition may suggest a general lack of concern for both cleanliness and good housekeeping. This defect is even more serious when accompanied by damaged wrappers.

9.8.1.2 Pliable, Wax-Coated Cheese

Microcrystalline paraffin and a variety of polymers yield adhesive, flexible, plastic-like protective coatings when surface-dried cheeses are dipped into the melted wax. These appealing, thick coatings may be produced in a wide variety of colors and may be semi-transparent to opaque. The cheese must be handled with reasonable precautions so that the coating will not chip or flake. This type of flexible wax is often used as a cheese covering for any cheese that is subsequently cut into retail portions, or for small units cut from bulk cheese to be cured and sold as miniature-sized cheese. This coating is relatively free of defects if the proper form of wax is used.

9.8.1.3 Paraffined Cheese

Although paraffin (wax) currently finds limited use as a covering material for cheese, the cheese judge should be aware of the following defects, which may rarely appear with poorly applied pliable wax coating but are often related to the use of paraffin.

Blistered This defect manifests itself by areas of thin, loose paraffin, usually on the end of the cheese where cheesecloth may be absent. Such a condition readily lends itself to the possible entrance of mold and/or harboring cheese pests (see Cheese Mites and Skippers in Sect. 9.8.1.6); therefore, blistering is quite objectionable for paraffin-coated cheese.

Checked A “checked” or cracked paraffin is denoted by breaks or formed cracks in the cheese covering. Applying a heavier-than-necessary paraffin coating usually causes this defect. Checked paraffin offers an opportunity for mold and pests to gain entrance to the cheese.

Rough Rough paraffin is manifested by a lack of surface smoothness or paraffin finish. The paraffin surface seems to contain small hard particles; this leaves the impression that the surface of the cheese may have been covered with tiny particles of foreign matter prior to coating. Although not usually that serious, this defect is somewhat undesirable as a surface blemish for what may otherwise be a high-quality cheese. Roughness may be detected either visually or by running the hand over the surface.

Scaly Loose or scaly paraffin offers poor protection for cheese; it permits moisture to escape and mold to gain entrance; hence, this represents a serious packaging defect. In cutting cheese, particles of paraffin often become intermixed with the cheese itself, and thus produce an untidy, unappetizing cheese slice. Scaly-like paraffin should seldom occur if the cheese surface is pre-dried sufficiently, then completely dipped into hot paraffin (not lower than 104.4 °C (220 °F) for at least 10 s). The paraffin is then allowed to completely harden and solidify via allowing it to cool to near ambient temperature before subsequent handling occurs.

9.8.1.4 Workmanship

High Edges Cheese showing this defect lacks square or symmetrical edges, such as desired in well-finished cheese. Sometimes, edges of the cheese may be so long that they tend to bend over (curl under) onto the end of the cheese, and thus form a protected area for mold growth or pests. These undesirable long edges are usually dry, do not cure properly, and thus represent waste.

Lopsided, Misshapen Nonparallel ends or sides, a result of uneven distribution of curd in the hoops, possibly coupled with unequal pressure in the press, characterize a misshapen cheese. Such defects detract from a neat appearance of the cheese unit(s) under evaluation. This unwanted configuration may sometimes be correlated with weak-bodied cheese.

Uneven Edges Heavy pressure against followers or press boards that are too small for the hoop may cause the curd to squeeze out around the edges and form a narrow raised edge or rim around the outer edge of the cheese, generally up to about one-half inch thick. The presence of these raised, uneven edges not only detracts from cheese appearance but additionally results in a waste of curd. The raised edge dries out and does not cure properly. Cheese should be pressed in a manner that ensures that the bottom edge of the cheese meets evenly with the sides.

Uneven Sizes Cheese of a designated style should be well within a specified weight tolerance for that style of cheese; lack of size uniformity may result in an unattractive appearance. Carelessness in assuring even distribution of the curd among the various hoops is often correlated with other finish and/or appearance defects. An “uneven size” of cheese also may result in excess trim losses when blocks are cut subsequently into retail-sized pieces.

9.8.1.5 Surface

Bruised Slightly depressed areas over which the paraffin is broken indicate a bruised surface. Cracks may radiate from the center of the break. Obviously, a bruised surface permits mold contamination and pest infestation.

Light Spots A cheese that exhibits "light spots" has more or less irregular light- and dark-colored areas over the flat surfaces. Though this defect is quite noticeable, it is not a particularly serious one, as far as product protection is concerned.

Moldy "Mold growth" on cheese may occur on portions where the cheese covering has been penetrated by a cheese trier, or from holes or tears in the packaging material. The presence of even a slightly moldy portion not only substantially detracts from the appearance but also may jeopardize the flavor and consumer acceptance of the entire cheese. As soon as the cheese is cut, mold mycelia usually have the opportunity to disperse across the entire cheese. Moldiness is considered a serious product finish defect and is a constant problem; annually it results in considerable waste and economic losses for the US cheese industry.

Additionally, some mold contaminants can pose public health problems due to production of certain mycotoxins (carcinogenic aflatoxins). No absolutely successful method has as yet been found and applied to prevent regrowth of mold from bulk forms of cheese onto cut and rewrapped cheeses. Even cheese that has been thoroughly cleaned, scraped, and repackaged, and possibly treated with approved mold inhibitors, may develop surface mold during extended storage or distribution.

Open Short depressions on or near the surface are referred to as an "open" surface. This openness usually stems from insufficient curd pressing or a too-cold curd at the time of pressing. This open surface typically reflects an open-textured cheese; there tend to be many mechanical openings. Defects of surface openness are objectionable because these surface depressions and openings serve to (1) increase the amount of cheese trimmings and (2) provide sites for mold and/or cheese pests to establish themselves.

Rough A "rough-surfaced" cheese exhibits severe irregularities of surface finish. This defect may result occasionally from (1) the use of unclean press cloths to which particles of dried curd have adhered; (2) insufficient or improper pressing of "hooped" cheese; or (3) rough and uneven shelving. Cheese that has this defect lacks the preferred neat and attractive appearance that facilitates marketing the product.

Soiled, Unclean Most unfortunately, cheese takes on an untidy "soiled" or "unclean" appearance when dirt or soil adheres to various cheese surfaces. Usually, soiled surfaces are due to carelessness on the part of the cheesemaker and production team. This defect should not be tolerated in the manufacture of high-quality cheese.

9.8.1.6 Miscellaneous Factors

Huffed, Bloated The so-called huffed or bloated cheese results from gassy fermentation (Fig. 9.10). A cheese suffering from this defect usually becomes rounded on the sides and ends, producing a somewhat oval shape to the cheese unit. In occurrences of the huffed defect, the lower edges of the cheese may be raised slightly above the top plane of the shelf. Occasionally, a gassy condition within the cheese wrapper may develop to the extent that the general symmetry of the cheese unit is distorted and the packaging material may be ruptured. A huffed cheese usually yields a sample plug that is dominated by obvious gas holes. Plugs pulled from some bloated cheese may exhibit openings in the shape of narrow slits; these openings are commonly called "fish eyes" or "slits." Huffed cheese generally portrays poor sensory qualities; serious off-flavors frequently accompany gassy fermentations.

Ink Smears Occasional "ink smears" from careless cheese branding often detract from the appearance of cheese. Generally, this is a relatively minor defect that is not correlated with other defects, other than careless workmanship.

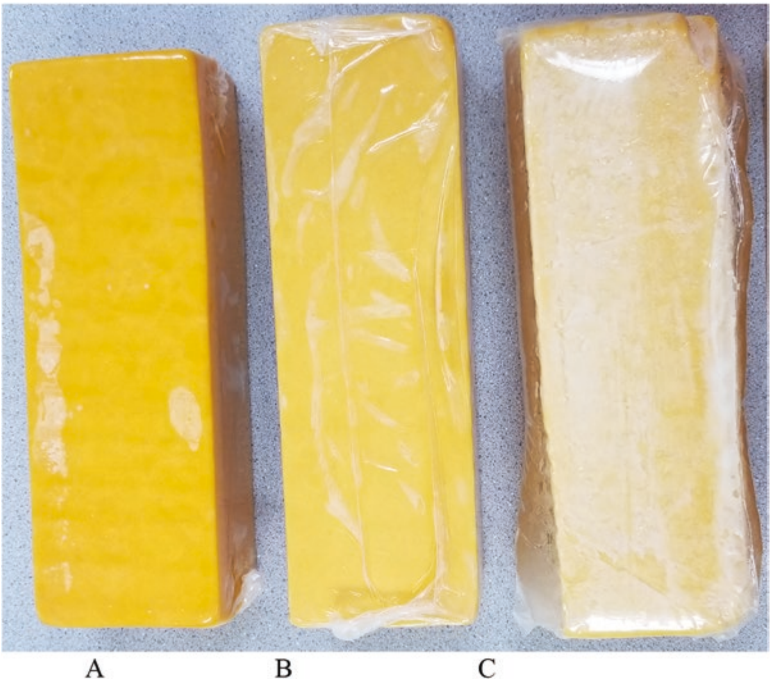

Fig. 9.10 A lineup of Cheddar cheeses exhibiting vacuum-sealed plastic ((**a**) a tight seal with no apparent defects; (**b**) loose packaging; (**c**) huffed or bloated cheese exhibiting extensive crystal formation). (S. Clark images)

Cheese Mites and Skippers Fine, loose, brown dust on the surface of aged cheese, cheese wrappers, or on the shelving usually manifests the presence of "cheese mites." Microscopic examination has revealed this brown dust to consist of live and dead mite bodies, molted skins, excreta, and minute particles of cheese. In badly infested cheese (which has not been moved for some time), the brown dust may appear over extensive areas of the cheese; however, it is more generally localized in favorable harboring places (such as cracks, under a folded edge or under loose paraffin). Evidence of mites is often found on natural rinded Cheddars. Skippers, the larvae of the cheese fly, are infrequently noted; they only occur as the result of poor sanitation practices.

9.8.2 Color

The color of Cheddar cheese, regardless of the chosen intensity, should always be uniform throughout the cheese. American Cheddar cheese may be uncolored, light to medium colored, or high in color. For uncolored cheese, the most desired color is a light cream shade; for medium-intensity-colored cheese, a deep cream color or a pleasant yellow-orange hue is acceptable. Deep, intense shades of yellow-reddish hues are generally discriminated against. Not only should the shade of color be appropriate and uniform for the given cheese, but the color should exhibit some luster. The cheese surface color should be slightly translucent – appearing as if one could actually see into the cheese interior for a short distance. The "translucent" quality of Cheddar cheese is closely associated with desirable body and texture.

Not only is cheese color one of the items capable of being most accurately evaluated, but when carefully observed and correlated, may also serve as an index to defects in body, texture, and flavor. Some color defects that may be associated with Cheddar cheese, and associated body and texture attributes, are discussed in detail below. Common color defects, probable causes, and remedies may be found in Table 9.4.

Acid-Cut (Bleached, Faded) The color of "acid-cut" cheese generally appears dull and lifeless, with an opacity that allows little light to be transmitted through even a thin slice. Quite often, a degree of bleaching may be noted more or less uniformly throughout the entire cheese (Fig. 9.11). In some cheese, acid-cut color may occur only within close proximity to mechanical openings. In such instances, the cheese may have a "mottled" appearance. Of these two defects, a uniform acid-cut color is less objectionable than a mottled one; however, neither is desirable. Evaluators should readily recognize the acid-cut color defect and be on the alert for the possible association with a given body and texture or a specific flavor defect. Generally, the faded color of acid-cut may be associated with high-moisture and high-acid development in cheese, but it also may occasionally be observed in cheese with a dry body and a crumbly texture. Cheese showing this defect nearly always has a distinctive high acid or sour flavor. The acid-cut color defect is becoming less common due

Fig. 9.11 A lineup of Cheddar-type cheeses ((**a**) Cheddar with faded appearance; (**b**) Cheddar with extensive crystals; (**c**) pepper Jack with typical appearance. (S. Clark image)).

to better control of acid development by cheesemakers, improved lactic cultures, and better monitoring and control of the manufacturing process. However, the resurgence of pasture-based feeding has resulted in the fading defect appearing in cheeses as a result of higher natural color content resulting from these feeding practices (Wendorf, 2007).

Atypical Color Specks Atypical color specks take the form of occasional white or black specks, rust spots, and/or red blotches. While there may be little or no association between foreign specks and a specific off flavor, the presence of atypical color deposits generally reflects carelessness in the manufacturing process. White specks may result if addition of color to milk is made prior to addition of starter culture due to small clumps of starter not getting colored. Other potential sources for specks may include water condensation on pipes dripping into the vat, poor filtration of milk, or lack of good environmental cleaning and sanitation procedures.

Color Too High (Unnatural) This defect is characterized by high yellow-orange color intensity, especially when precut cheese is warmed to room temperature or higher. There is generally no association between this defect and flavor, since the defect stems from the use of an excessive amount of added colorant to the cheese milk. More intensely colored Cheddar cheese may be preferred in some specific markets, but in others it is often discriminated against.

Mottled The "mottled" color defect appears as rounded, irregularly shaped areas of contrasting light and dark color, with one shade gradually blending into the other. This defect may result either from certain physical causes during cheese manufacture or be due to atypical microbiological activity during the curing process. Chief causes often ascribed to this defect are the combining of curd from two different lots of cheese or nonuniform development of acidity within the curd. When a mottled color results from unusual microbial growth, an associated yeasty, fruity, or acid off-flavor, and/or pasty body may sometimes accompany this appearance defect. However, the mottled appearance is intended with Colby-Jack cheese.

Pinking A "pink" discoloration of cheese occurs when the water-based colorant annatto is exposed to intense lighting (Fig. 9.12b) This defect is most often found in cheese packaged for retail sale and subsequently subjected to extended exposure to fluorescent lighting in display cases. The pinking reaction can be intensified if the cheese has an atypical pH around 5.4 instead of the typical range of 4.8–5.1, or if the packaging used does not present an effective barrier to oxygen (Hong et al., 1995a, b).

Seamy (Uneven or Wavy) The appearance defect "seamy" is portrayed when the cheese appears interlaced with dark- or light-colored lines around each original piece of curd (Fig. 9.12a). This is particularly noticeable when one directly examines the block or the surface appearance of freshly cut cheese. The seamy appearance defect may be seen in very young cheese, when proteolysis has not yet progressed. The slight degree of seaminess that is occasionally noted in fresh or young Cheddar cheese is not particularly objectionable, since this form of seami-

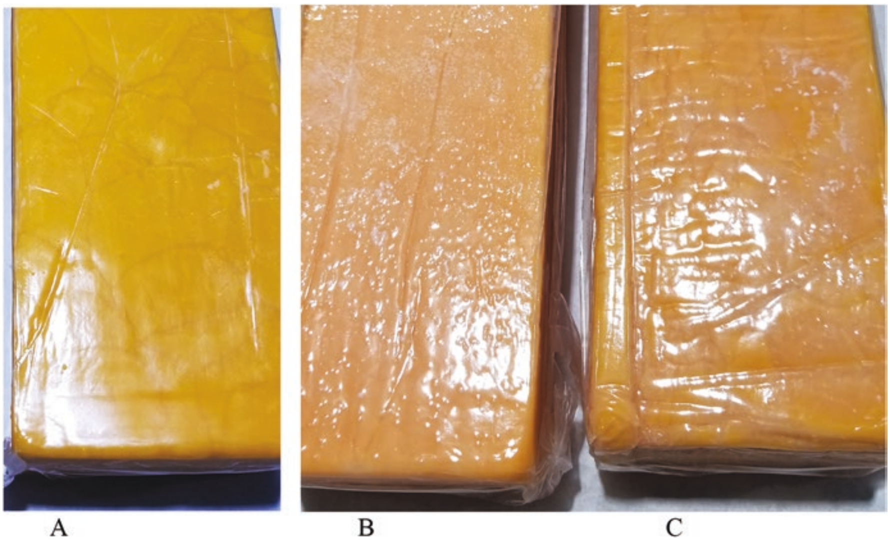

Fig. 9.12 A selection of Cheddar cheeses with appearance defects ((**a**) very slight seamy; (**b**) pinking and crystals; (**c**) seamy, pinking, and crystals). (S. Clark images)

ness generally disappears with additional aging. Seamy can result from improperly pressed cheese, or curd surfaces being physically altered by exuded or crystallized milkfat, uneven or over-salting, or moisture evaporation that probably occurred prior to curd pressing. Cheese exhibiting this color defect not only tends to lack color uniformity but may also demonstrate a short-bodied, crumbly, and/or friable texture. Occasionally, wider bands of discoloration may occur in cheese (without the seaminess lines); this condition may be described as uneven or wavy color. The wavy color character may be a result of inadequate dilution of the coagulant prior to addition or excessive agitation or vibration after setting the milk.

9.8.3 Body and Texture

Cheddar cheese with the most desirable body and texture displays a full, solid, close-knit plug (see Fig. 9.4) that is entirely free from gas holes or mechanical openings, and possesses smoothness, meatiness, waxiness, and silkiness. Cheddar cheese with the above-described quality attributes lends itself to uniform slicing into thin, intact pieces.

The term "body," as applied to cheese, usually refers to various physical attributes that primarily affect the relative firmness or softness of the cheese. By contrast, the term "texture" refers particularly to the structure and arrangement of the various parts that make up the whole cheese. Thus, texture in cheese is observed visually by the quantity, size, shape, and distribution of openings and by the sense of touch to uncover internal particles. Common body and texture defects, probable causes, and remedies may be found in Table 9.4. The more common descriptors of cheese body defects are listed below and are described in the following sections.

Body defect descriptors	Texture defect descriptors
Corky (dry, hard, tough)	Crystals
Crumbly (friable)	Fissures
Curdy (rubbery)	Gassy (holes or slits)
Greasy	Mealy/grainy
Pasty (smeary, sticky, wet)	Open (mechanical openings)
Short (flaky)	
Spongy	
Weak (soft)	

9.8.3.1 Desirable Body and Texture Characteristics

As a general rule, a "closed" (few or no openings in the cheese mass) texture is desired; however, a slightly open texture is not objectionable, providing the body possesses such properties that the open texture does not give rise to a weak-bodied, curd, or crumbly cheese. Worked plugs exhibiting various cheese body and texture characteristics are shown in Fig. 9.13.

Firm Body A plug of Cheddar with desirable "firm" body feels solid and offers some resistance to applied pressure. Firm-bodied cheese yields a clean-cut plug that generally tears apart slowly on bending, rather than breaking suddenly. The preferred texture is closed; the curd particles should be well matted or fused together in a high-quality cheese. A slice of firm-bodied cheese tends to tear apart somewhat like a thoroughly cooked chicken breast. A firm-bodied cheese should not be confused with either a dry, corky, or curdy body; the latter cheese body products often resist pressure and seem excessively springy or quite rubber-like.

Waxy Body A desirable "waxy body" is exhibited when a cheese plug responds to the combined pressure of thumb and fingers as would cold butter, tempered candle wax, or modeling clay. In "breaking down" a waxy-bodied sample by finger manipulation, little resistance is offered other than the normal force required to mold the cheese into a cohesive "cheese ball" (Fig. 9.13a). Preferably, a "malleable" cheese shows little tendency to "spring back" to the original position, but rather assumes or retains a new configuration as a result of applied finger pressure. A waxy body is generally associated with either medium-aged or aged (sharp) cheese. A pliable or waxy body is a good indicator of desired slicing properties and proper flavor development.

Silky, Smooth Body A "silky, smooth-bodied" cheese exhibits fineness of grain and a continuous, slightly oily, silky smooth film when the mass, worked between the thumb and fingers, is spread over the palm of the hand. The "worked cheese" usually spreads evenly without forming irregular patches in the hand. The spread-

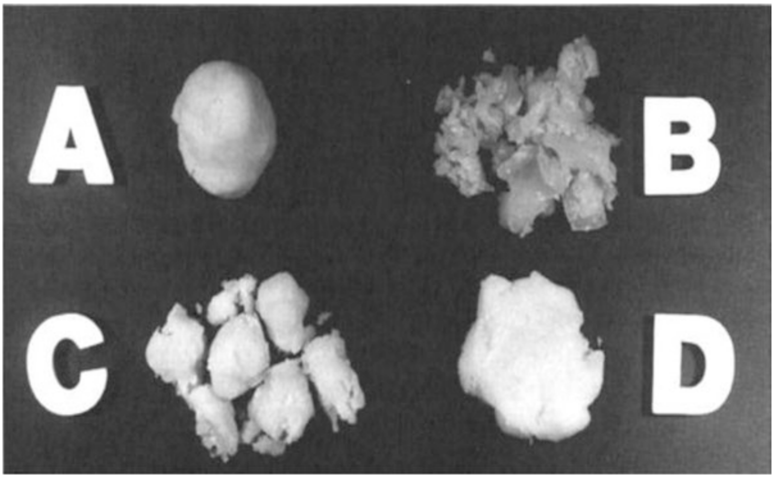

Fig. 9.13 "Worked" Cheddar cheese samples showing: (**a**) "ideal" body; (**b**) Corky; (**c**) Crumbly and possibly Curdy; (**d**) Pasty. (Bodyfelt et al., 1988)

out cheese sample should readily reassemble into a small intact ball. The smooth, silky-like property of the cheese sample is generally indicative of proper cheese breakdown, flavor development, and desired mouthfeel.

9.8.3.2 Body Defects

Corky (Dry, Hard, Tough) This defect is generally associated with a low-moisture, low-fat, and/or young cheese or a particularly dry aged cheese. Difficulty is sometimes encountered in trying to sample dry, tough cheese, due to initial resistance against the trier during penetration. The drawn plug resists any form of pressure; when sufficient finger pressure is applied, the plug may resist breaking down and/or exhibits a distinct tendency to recover its original shape. The plug is stiff or rigid upon bending; it seems to have a rubber-like consistency. When a portion of a so-called corky cheese is worked between the thumb and forefingers, the desired smooth, silky, even distribution of cheese particles is notably lacking (Fig. 9.13b). The worked mass of cheese tends to curl up under sliding pressure of the thumb over the forefingers and is usually distributed in irregular patches. This defect may be associated with other body defects of which dryness is a closely related factor. A dry-bodied cheese generally has an opaque appearance. This defect sometimes appears to be associated with curd mealiness (a texture defect). Appearance defects of seamy or acid-cut color may also be exhibited.

Crumbly (Friable) A "crumbly bodied" cheese is one that tends to fall apart when tried, sliced, and/or worked (Fig. 9.13c). A plug of such cheese may be extremely friable (Fig. 9.13c). This defect sometimes appears to be associated with curd mealiness (a texture defect) as well as with acid-cut and seamy color defects. A crumbly cheese may sometimes be quite dry, but more often will be normal in this respect. A crumbly, friable body is more likely to occur in aged cheese (~10 months of aging) than in young cheese.

Curdy (Rubbery) This body defect is quite characteristic of freshly made, "green," or uncured cheese. Such cheese usually seems firm, almost hard or rubbery, but not as dry or firm as corky. The plug resists finger pressure; when it does yield to pressure, there is a tendency for the cheese to spring back to its original shape but to less of an extent than corky. Additionally, when worked into a ball, if the cheese is curdy, the ball will commonly display curds that were not adequately warmed or broken down by body temperature to make a smooth ball (Fig. 9.13c). A cheese exhibiting a curdy, rubbery body will likely exhibit a fresh, "green," flat, or undeveloped flavor. Since curdiness is primarily a characteristic of young, uncured cheese, before the curd has had an opportunity to break down (undergo proteolysis), the defect is not usually considered objectionable in mild-aged cheese. Such cheese should eventually develop the desired body and texture characteristics upon additional aging. A curdy cheese that breaks along a seam between curds should not be confused with a short-bodied cheese (see below).

Greasy A "greasy" cheese is one that has free fat on the surface, as well as in and around openings within the cheese or surfaces of individual curds. The defect is easily recognized by an almost oil-like appearance or feel. Greasy cheese often exhibits marked seaminess or may develop it upon additional aging.

Pasty (Smeary, Sticky, Wet) Cheese showing the "pasty" defect is usually characterized by the presence of high moisture. There is often difficulty in securing a full, well-rounded plug; the cheese shape is easily distorted. Upon compression between thumb and forefingers, the cheese breaks down easily into a pasty, sticky mass that tends to adhere to the fingertips as the product is manipulated (Figs. 9.13d and 9.14b). This defect is often associated with a weak body and/or high acid, fruity, and/or fermented off-flavors.

Short (Flaky) A "short," "brittle," or "flaky" body is characterized by a lack of meatiness, waxiness, or overall homogeneity; the consistency of the cheese may appear loose-knit (it takes a "short" time to break). The plug will break easily on bending a short distance rather than tearing apart and will show a distinct lack of elasticity. The break will occur at any point along the length of the plug and should not be confused with a break occurring at the seam between curd particles, which is

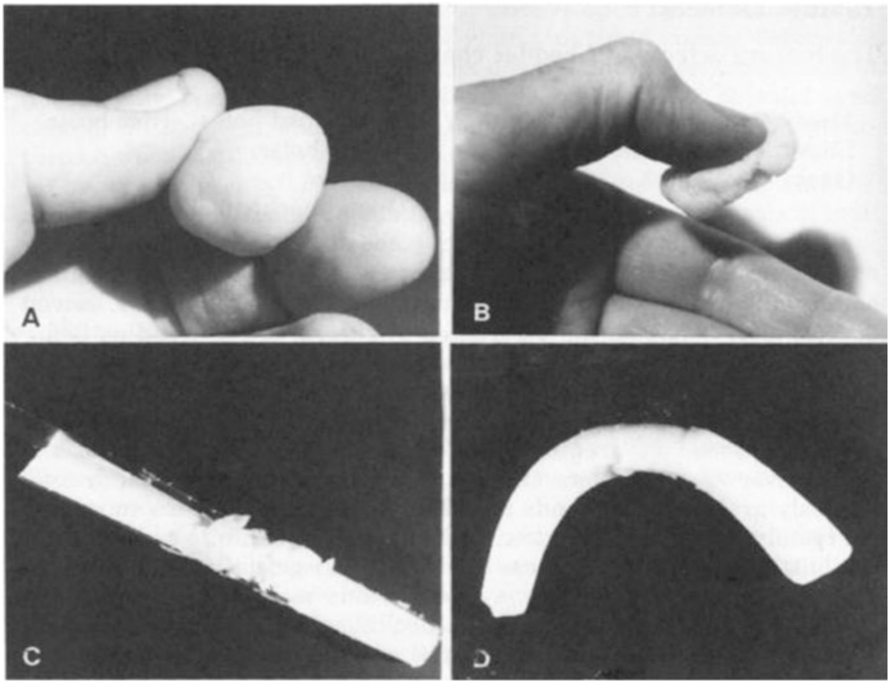

Fig. 9.14 Examples of some common body characteristics (defects) of Cheddar cheese: (**A**) An "ideal" waxy body (practically forms a marble); (**B–A**) distinctly "pasty" or "sticky" body; (**C–A**) "crumbly" plug; (**D–A**) "weak" body. (Bodyfelt et al., 1988)

more indicative of a curdy cheese. The sample piece may appear dull in color, but in many cases, may exhibit a fairly even and somewhat glistening surface. A cheese having this body defect may be too acid and/or dry to exhibit more desirable body properties. Sometimes a short-bodied cheese is inclined to be mealy when a piece of a plug is worked between the thumb and forefinger (or by mouthfeel).

Spongy A spongy bodied cheese fails to yield a full, continuous plug, due to the presence of excessive gas or mechanical openings that prevent an adequate degree of firmness in the body of the cheese. When a spongy cheese is plugged, it tends to sink immediately next to the trier. Such cheese is distinctly springy when pressure is applied to the surface. This defect is commonly associated with gassy, high-moisture, weak-bodied cheese.

Weak (Soft) A weak-bodied cheese is noted particularly by the ease of cheese trier penetration, and/or by the relatively small amount of finger pressure necessary to crush the structure. Weak-bodied cheese is soft and is closely associated with high-moisture content. An aged, weak-bodied cheese may demonstrate fruity/fermented, whey taint, and/or unclean flavor defects, enhanced presumably by relatively high whey (moisture) content. When bent between the thumbs and index fingers of opposite hands, weak-bodied cheese tends to approach touching end to end (Fig. 9.14d). However, bending end-to-end is not always indicative of weak cheese. Consider Swiss cheese, for instance; a plug can be bent end-to-end without breaking, but the body is more firm/rubber or even corky-like.

9.8.3.3 Texture Defects

A closed textured cheese should yield a solid plug with practically no visible openings (Fig. 9.4). The plug, however, may gradually break apart along a curd seamline, especially in a young cheese. Mechanical openings may be a sign of insufficient matting (Cheddaring) or pressing of the curd, or both. An "open" cheese yields a plug that may contain numerous small or large irregularly shaped openings, referred to as "mechanical openings." This is in contrast to Cheddar cheese that exhibits "gas holes" or "slits" as the result of CO_2 formation from microbial activity; these openings tend to be more symmetrical and are usually spherical or elliptical, in shape, and shiny. The so-called late gas defect may occur in closed-textured cheese, but in this instance, the plug will exhibit a split appearance.

Crystals or White Specks Small "white specks" interspersed throughout a cheese's mass and/or on its surface most commonly occurs in mature cheese; however it may occasionally be a problem in young- and medium-aged cheeses. These white particles (Fig. 9.15) are generally assumed to be an admixture of calcium lactate, tyrosine, and other components. Sometimes these specks are so small that they may be only noticeable when viewed from a close distance.

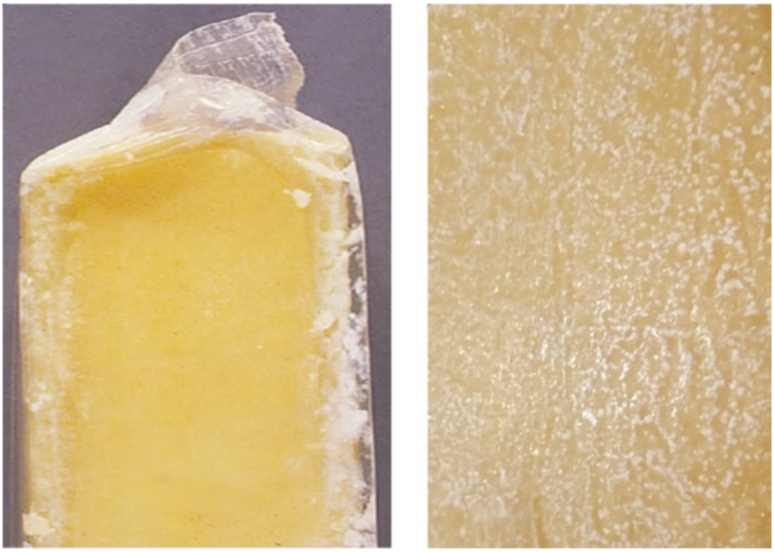

Fig. 9.15 The color/appearance defect of "white specks" or "surface precipitate" of calcium lactate crystals evident along loose edges of a package of mild Cheddar cheese (left); tyrosine crystals evident on surfaces of aged Cheddar cheese (right). (S. Clark images)

Curing of cheese that contains nonstarter lactic acid bacteria at elevated temperature, then followed by lower storage temperature, tends to favor accumulation of calcium D-lactate, which is an insoluble complex. The formation of calcium lactate crystals (CLC) is the most frequent cause of white specks in younger cheeses, and results when the level of lactic acid in the cheese, combined with available calcium, results in calcium lactate concentrations in excess of its solubility in the serum phase. The prevention of CLC formation is not guaranteed by manufacturing practices that reduce available lactose or limit production of excess lactic acid, but the current level of knowledge accepts these particular practices as appropriate procedures for limiting the defect (Johnson, 2004; Blake et al., 2005). Accumulation of tyrosine, on the other hand, may indicate to the evaluator that the cheese has been aged long enough for protein to partially break down and yield this amino acid. Some aged cheese that exhibits the combined appearance/texture characteristics of white specks also frequently exhibits a desirable "buttery"-like body.

Even an inexperienced judge should be able to associate the presence of crystals (and the possible associated mouthfeel) with an aged cheese; the cheese sample will most likely also have a fully developed intense flavor. Crystals in a younger cheese may be associated with a high-acid flavor. White specks, on their appearance alone, should not be considered a serious color defect. Their presence may be noted, but a deduction in score should not be made unless an excessive grainy or objectionable gritty mouthfeel is present.

For the CDPEC, crystals are only considered a defect when detected during mastication. It should be noted at this point that a "defect" from one person's perspective may be considered an attribute from another person's perspective. For instance, for aesthetic judges in the American Cheese Society Judging and Competition, tyrosine crystals are often considered a delightful “crunch” in aged Cheddar.

Fissures A fissured texture is characterized by an elongated slit or extended separation of the curd particles. The curd lacks cohesion, and such defects may be associated with seaminess. This defect is not serious, but such an affected cheese often lacks the desired meatiness of body.

Gassy (Pin Holes, Sweet-Curd Holes, Swiss Holes, Shot Holes, Slits, Fish Eyes, Yeast Holes) Gas holes in cheese vary in size but may be fairly uniform in distribution and shape. They are formed from gas produced by undesirable microorganisms within the cheese. The seriousness of these gas holes depends on the kind of organisms that form the gas and the relative size and frequency of the gas holes. As related earlier, all of the gas-related defects are lumped into the gassy category on the CDPEC scorecard.

Gas holes are referred to as “pin holes” when they are about the size of a pinhead, symmetrically rounded, evenly distributed, and/or show a tendency to be concentrated near the center of the cheese. Pin holes may result from the growth of undesirable bacteria from cheese milk, or a contaminated culture, or a “gassy” culture (formed CO_2) that contains *Lactococcus lactis* ssp. *diacetylactis* or *Leuconostoc* species. Formed gas may also affect the flavor of the cheese; occasionally an objectionable fruity flavor may occur. The development of numerous pin holes and other gas holes may lead to a “huffed” cheese, especially if the cheese is cured at higher temperatures. If there are sufficient gas holes in the cheese to weaken the overall body structure, it is termed “spongy” cheese; undesirable flavor(s) is (are) often associated with excess gas formation.

Slits, fish eyes, and yeast holes may be found in cheese made from poor-quality milk or starter culture that has been contaminated with yeast (or possibly coliform bacteria). The round, glossy-surfaced gas holes are the result of abnormal fermentation (Fig. 9.7a). Cheese that contains numerous yeast holes usually has a “spongy” body due to excessive gas production. During plugging, the cheese tends to sag immediately adjacent to the inserted trier. Such cheese usually yields a honeycomb-like plug. Yeast holes in cheese may flatten out as the cheese is cured, forming long narrow slits known as “fish eyes.”

The large, uniformly distributed gas holes found occasionally in Cheddar cheese are usually the result of a particular bacterial growth. There is often a correlation between their occurrence and the flavor (or off-flavor) of the cheese. Large gas holes are often associated with a peculiar sweetish, flavor reminiscent of Swiss cheese; consequently, they are sometimes referred to as “Swiss holes,” “sweet holes,” or “shot” holes. The specific flavor defect that often develops may not be highly objectionable, but it is not typical of Cheddar cheese.

Mealy (Grainy, Gritty) A cheese that is worked between the thumb and forefingers and shows a lack of uniformity and smoothness, as well as irregularly shaped, hard particles of cheese, is criticized as being mealy (grainy, gritty), depending on the particle size. This physical condition often may be correlated with a dry, corky-bodied cheese. When the manually worked cheese feels like cornmeal, and the cheese tends to spread in irregular patches under sliding pressure of the thumb over the forefingers, the texture is described as mealy. A mealy cheese tends to exhibit dryness and seems to release fat readily. Often, a mealy textured cheese also exhibits a short body with little elasticity. Mealiness is most often associated with sharp or aged cheese. The cheese judge should be able to detect a corn meal-like mouth-feel when the cheese sample is masticated and pushed against the roof of the mouth. Mealy should not be confused with crystals.

Open (Mechanical Holes) An "open," porous, or loose texture is traceable to the physical aspects of handling and pressing the cheese curd. Mechanical openings are characterized by their asymmetrical, angular shape and size and by the dullness of their surface linings (Fig. 9.8b). These irregular-shaped holes are derived from various conditions during the matting and pressing of the curd. There is little or no relationship between their presence and cheese flavor. In Cheddar cheese, as long as mechanical openings are not connected and are neither so numerous nor so large as to weaken the body or interfere with the integrity of the plug or slice, they should not meet with serious objection.

9.8.4 Flavor

Once the physical properties of the cheese have been assessed, the flavor characteristics should be evaluated. This is accomplished by (1) first noting the odor of the freshly drawn plug as it is passed slowly under the nose; (2) then smelling the warm, semi-soft cheese that results from the quick kneading of a portion of the plug between the thumb and forefingers; and (3) finally tasting a small piece of the cheese. The novice judge, however, should taste the sample not only to verify the odors previously noted but also to perceive the nonvolatile taste sensations – bitter, salty, sour, umami and sweet, which would otherwise go undetected. When a larger number of samples are being tasted, an occasional rinse of the mouth between samples is helpful. This prevents any non-liquefied portions, which may lodge between the teeth, from obscuring the flavor characteristics of subsequent samples.

High-quality Cheddar cheese should possess the characteristic "Cheddar flavor," which is best described as clean, moderately aromatic, nut-like, and pleasantly acidic. While the same general flavor qualities are desired in fresh, medium-cured, and aged cheese, the intensity of the characteristic Cheddar flavor will primarily depend on the extent of curing and curing conditions. Usually, aged cheese has a sharp, aromatic, intense flavor that is entirely lacking in young cheese. The flavor of high-quality Cheddar cheese has been likened to that of freshly roasted peanuts or hazelnuts by various investigators (Kosikowski & Mocquot, 1958; Van Slyke & Price, 1979; Wilson & Reinbold, 1965; Wilster, 1980).

The flavor of Cheddar cheese is ascribed to a complex mixture of compounds, produced by bacteriological and enzymatic action during aging. Singh et al. (2003) published an excellent review of the chemical and sensory aspects of Cheddar cheese flavor. The Cheddar flavor originates from (1) protein breakdown to simpler and more volatile organic compounds; (2) acid developed in the curd; (3) milk fat and milk fat breakdown products; and (4) the small amount of salt added before the curd is pressed. Due to the relatively high degree of solids and the nature of the organic constituents, Cheddar cheese has a distinct, desirable flavor when the appropriate bacteriological, enzymatic, and chemical changes have occurred during controlled manufacturing and curing. When the components of Cheddar flavor get out of balance, one or more distinct flavors may dominate and result in a distinctive flavor profile that may be described alternately as a defect or an attribute.

The beginner judge should try to appreciate that the finish, appearance, color, and body and texture characteristics reveal much regarding the flavor quality of the cheese. The evaluator should carefully study both the desirable and undesirable aspects of these quality criteria and note the flavors that may be associated with them.

9.8.5 Flavor Defects and Their Characteristics

Off-flavors in Cheddar cheese show wide variation. Descriptive terms are listed below and are described in subsequent paragraphs (see Table 9.4 for probable causes and remedial measures). Other descriptive terms such as brothy, nutty, diacetyl, etc. are incorporated in the discussion of the Cheddar cheese lexicon in Chap. 17, but are not included here due to lack of common use by graders and judges (Drake et al., 2001).

Flavor defect descriptors

- Bitter
- Feed
- Fermented
- Flat/low flavor
- Fruity
- Garlic/onion (weedy)
- Heated
- High acid
- Malty ("Grape Nuts®")
- Metallic
- Moldy (musty)
- Oxidized
- Rancid
- Sulfide
- Unclean
- Whey taint
- Yeasty

Bitter Bitterness is a basic taste noted only by the sense of taste on the tongue, and not from aromatic compounds perceived by the sense of smell. Bitter taste may occur in mild cheese but is found more frequently in aged cheese as an aftertaste. Certain lactic cultures, coagulating enzymes, and salt levels have been implicated in the development of this troublesome defect. Bitterness has been observed to develop in cheese made from both excellent-quality and poor-quality milk. "Sharpness" and the high flavor intensity of aged cheese should not be confused with a bitter taste. Sharpness gives rise to a temporary peppery sensation, whereas true bitterness is somewhat distasteful to most individuals, resembling the taste of quinine or caffeine. The bitter sensation is somewhat delayed in terms of its initial perception and tends to persist for some time after sample expectoration. Bitterness in cheese is observed by a taste sensation that typically occurs at the base or back of the tongue. Bitterness will normally intensify with maturation. If detected in a young cheese, the cheese should not be kept for sale as a sharp or extra-sharp cheese. Bitter is one of the most common off-flavors in Cheddar cheese.

Feed Some feeds, especially high volume roughages, may impart aromatic taints to cheese if fed to cows within a critical time frame prior to milking. The 0.5–3-h time period is the most critical. This is especially true of succulent feeds, silage, some commodities, brewery wastes, and some of the hays. A "feed" off-flavor is characteristic in that it is aromatic, sometimes pleasant (e.g., alfalfa), and can usually be readily detected by the sense of smell. A characteristic note (and mild aftertaste) of "cleanliness" is associated with most feed off-flavors, when the cheese sample is expectorated. Feed off-flavors usually "disappear" rather quickly and thus leave the mouth in a clean state of condition.

Obviously, the characteristic odor/taste of feed off-flavors varies with the type of feed consumed by lactating animals. The odor of a given raw milk supply is generally characteristic of a particular feed. In some US dairy regions, a severe feed defect is often observed early in the spring when the all-dry winter ration is terminated and changed to one that includes fresh green pasture. Also, severe feed off-flavors are likely to occur when there is a sudden change to a new, more odorous form of roughage, such as from alfalfa hay to corn or grass silage. The current trend for some producers to return to a seasonal, pasture-based feeding system or the requirement of organic production practices to include access to pasture may also contribute to feed off-flavors.

Fermented The fermented off-flavor in Cheddar cheese is suggestive of acetic acid (vinegar-like). Some nonstarter lactic acid bacteria (NSLAB), such as heterofermentative lactobacilli, may produce significant amounts of acetic acid in cheese during ripening. Acetic acid is one of the myriad of components making up cheese flavor that can exhibit an off-flavor when out of balance with other components.

Flat/Low Flavor Cheese exhibiting this defect is practically devoid of any Cheddar flavor. A flat flavor is particularly noticeable when the sample is initially tasted. Likewise, little odor is detectable. When associated with fresh or young cheese, the defect is not serious or objectionable, since full cheese flavor may eventually develop with additional aging. In an aged cheese, flatness (lacking flavor) represents a more objectionable defect. A cheese with a defect such as bitter or high acid should not be scored as a flat/low flavor sample.

Fruity The "fruity" off-flavor is peculiarly sweet and aromatic; it resembles the odor of fermenting or overripe fruit, such as an apple or pineapple. At low levels it may be considered complexity and appealing. At high levels, this flavor defect may be associated with high-moisture cheese, and a weak, pasty body. The fruity defect intensifies as the cheese ages and may eventually lead to an unclean or combined fruity and unclean off-flavor. The fruity defect is attributed to the presence of ethanol-forming microorganisms in the cheese milk or certain cheese cultures. Esters formed from available ethanol and organic acids are responsible for the fruity note (Bills et al., 1965; Vedamuthu et al., 1966; Bodyfelt, 1967).

Garlic/Onion This flavor defect is relatively easy to detect because the off-flavor resembles that of garlic, onions, or leeks. Defective cheese usually shows a moderate odor, unless the sample has been stored at a high temperature. When the sample is tasted, the off-flavor is often quite pronounced and usually requires a thorough rinsing of the mouth prior to tasting additional samples.

Heated (Cooked) The heated (cooked) off-flavor of cheese differs from the clean, distinct cooked flavor of pasteurized milk; in cheese, this defect more resembles the odor of old or spoiled milk, or the odor exhibited by melted Bakelite® forms of plastic. This off-flavor is somewhat suggestive of the unclean odor, in addition to whey taint. "Heated whey" is probably a more appropriate term to describe "heated" or "cooked" off-flavor in cheese. A related group of products that demonstrate the heated flavor are pasteurized process cheese, cheese food, and cheese spreads.

High Acid (Sour) Lactic acid is a normal component of Cheddar cheese flavor; however, an excessive acid or sour taste is undesirable. Depending on age, the normal pH range of Cheddar cheese should be 5.15–5.45. The "high-acid" (sour) defect generally results from a too rapid or excessive lactic acid production in the curd. High acid is by far the most frequently encountered flavor defect of Cheddar cheese. When a portion of high-acid cheese is placed into the mouth, a "quick" taste sensation is noted on the top and front sides of the tongue. This taste soon disappears (usually), leaving the mouth free of any off-flavor sensations. High-acid flavor may sometimes be associated with a dull, faded, or acid-cut color defect. For some individuals, the high-acid off-flavor is sharp and puckery to the taste, suggestive of lactic acid. Numerous other off-flavors and bitterness may occur in conjunction with a high-acid note.

Metallic The call for sodium reduction in the diets of some consumers has led to development of reduced-sodium Cheddar cheeses. Some "salt substitutes" replace sodium with potassium or other salts. One result of sodium reduction is the off-flavor metallic. Additionally, in recent years, some cheesemakers have incorporated sea salt into cheesemaking practices. The ions in sea salt sometimes provide metallic tastes. Metallic may be described as copper penny-like or prickly and is most readily noted at the gumline. Occurrence of a metallic (oxidized) off-flavor from metal-oxidized milk is quite rare, due to the reduction-oxidation potential of the cheese interior.

Malty ("Grape Nuts®") The growth of malty *Lactococcus lactis* strains in cheese milk, and a subsequently produced malty flavor compound (3-methylbutanal), is responsible for this off-flavor (Tucker & Morgan, 1967). When this compound is present in young (fresh/current) cheese at too high concentrations, malty flavor is the outcome. However, when present in appropriate concentrations and with other appropriate background compounds, 3-methylbutanal is the source of a pleasing "nutty" flavor in Cheddar cheese (Avsar et al., 2004; Carunchia Whetstine et al., 2006).

Moldy (Musty) A moldy or musty flavor defect often resembles the odor of a damp, poorly ventilated (potato) cellar. This defect is easily recognized by a characteristic smell. A slightly unclean off-flavor tends to persist after the tasted sample has been expectorated. The most frequent cause is mold growth on cheese surfaces, due to lost integrity of the cheese package and the admittance of air. In some cheeses where extensive mold contamination has occurred, a *Penicillium*-like mold (blue-green) growth may appear in the interior of the cheese, especially when it is open-textured. Serious economic losses, consumer dissatisfaction, and potential toxicological and allergenic consequences may occur from severe mold contamination of cheese.

Oxidized (Light-Induced) This off-flavor is characterized by a flat, cardboard-like taste, and a puckery (mouthfeel) sensation may linger. The sense of smell is of little or no value in detecting its presence. Oxidized cheese milk or light exposure in the dairy case is the probable source for this cheese off-flavor.

Rancid (Lipase) A "rancid" off-flavor in cheese is characterized by (1) a relatively slow or delayed reaction time; (2) a prominent odor that may be still noted after sample expectoration; and (3) an unpleasant, persistent aftertaste. The off-flavor is typically bitter, soapy, and usually somewhat repulsive. A rancid off-flavor in Cheddar cheese can usually be detected by the sense of smell. Rancidity is caused by activity of the enzyme lipase on milkfat; this yields volatile, unpleasantly flavored short-chain free fatty acids and their respective salts (or soap). When the concentrations of the free fatty acids from butyric (C_4) to lauric (C_{12}) exceed levels desired for a balanced Cheddar cheese flavor, they impart an off-flavor variously described as goaty, (cowy is ketone-like) unclean, bitter, or rancid. Rancid cheese usually results from abusive handling of cheese milk prior to pasteurization; however, the production of lipases by contaminating bacteria or the lipase activity inherent to raw milk may also contribute to rancidity, especially in aged cheese.

Sulfide (Skunky) The "sulfide" off-flavor of cheese is distinctive; it is similar to the odor of water with high-sulfur content or boiled eggs. The cheese judge should keep in mind that a low to modest level of sulfide is an important component of aged Cheddar cheese flavor and aroma; it provides complexity and appeal to aged Cheddar. However, when the sulfide note becomes dominant, to the point of obscuring other flavor characteristics, this is perceived as an off-flavor and a serious defect. In some regions of the world that produce Cheddar cheese, a moderate sulfide flavor note is considered essential or highly desirable in sharp or extra-sharp cheese; hence, it is not criticized when it appears. Sometimes an offensive sulfurous (skunky) or spoiled egg odor may be noted in aged cheese. Frequently, there is an associated bitter aftertaste, and/or a burning sensation within the mouth. Sulfide cheese often has a related sticky, pasty body. Usually, sharp or extra-sharp cheese is involved when this flavor attribute is incurred. Numerous sulfur-containing compounds can be formed during the aging process.

Unclean (Dirty Aftertaste) An "unclean" off-flavor is difficult to describe, since it often varies in intensity and lacks a definitive sensory description. Some describe unclean as, simply, "complex." At higher levels, this defect may suggest to the taster a general lack of cleanliness in producing the product, given the dirty, lingering, unpleasant aftertaste. This off-flavor persists long after the sample has been expectorated, and the mouth fails to "clean-up." An unclean off-flavor may occur in conjunction with other flavor defects such as high acid, bitter, and/or whey taint. Poor-quality or "old" milk used for cheese manufacture is a principal cause of the unclean flavor defect. Proteolytic and/or lipolytic enzymes, derived from psychrotrophic bacteria or nonstarter lactic acid bacteria, may cause undesirable chemical reactions to occur within the cheese and hence, result in an unclean off-flavor.

Whey Taint (Sour Whey) These terms describe various intensities of off-flavors in cheese associated with retained cheese whey. The slightly dirty-sweet/acidic taste and odor is characteristic of fermented whey. Ordinarily, the taste reaction of "whey taint" is perceived rapidly and is of short duration; whey taint is the early stage of unclean. The mouth tends to clean up soon after sample expectoration, unlike the unclean defect. Some cheese authorities liken whey taint to the occurrence of a "fermented/fruity" off-flavor, with an "unclean" off-flavor superimposed over it. Whey taint cheese often has the body (rheological) characteristics of a high-moisture cheese. Also, whey taint is sometimes found in young Cheddar cheese that exhibits a seamy defect. Some judges may confuse whey taint and high-acid off-flavors; however, only the former defect exhibits the distinctive aroma of fermented whey.

Yeasty This off-flavor may be identified by its sour, bread dough, yeasty, or somewhat "earthy" taste and characteristic aroma. Yeastiness in cheese may be detected immediately after the sample has been put into the mouth. Since this defect is caused by yeast growth, the cheese will usually have numerous medium- to large-sized gas holes, which may be readily identified by their surface sheen, spherical or fish eye shape, and frequency. Yeasty is a rare and serious defect.

Other Off-Flavors The off-flavors discussed above should be considered as the more common or frequently encountered ones in Cheddar cheese. However, the cheese judge should be alert to other possible flavor defects that may occur occasionally. Examples are an "atypical Cheddar flavor" and a "catty" (or cat-box odor) attribute; the latter is possibly caused by low concentrations of mesityl oxide in cheese reacting with sulfides to produce this aroma.

9.9 Grading Fresh or Current Cheddar Cheese

Cheddar cheese can be graded at any stage between the time at the end of pressing and the time of consumption. Experienced cheese graders agree that Cheddar cheese ranging from only a few days to a few weeks old is more difficult to grade than a more mature product. In grading a young or "green" cheese, the grader should pay close attention not only to the flavor but also to those conditions that might precede undesirable flavor development during ripening. There are occasions when a cheesemaker, cheese buyer, or processor would like to have fresh or "green" cheese graded, in order to (1) sell it on a quality basis; (2) determine the best use of the cheese; (3) determine whether cheese quality will withstand storage; or (4) monitor the day-to-day quality of the cheese. Different cheese-producing areas of the USA often grade cheese independently of each other; consequently, those assigned grades may differ slightly from Federal (USDA) cheese grade standards. Considering the purposes for which cheese is graded in different geographical regions, the variations in scorecards or grading forms and the wide interpretation of standards, there is little wonder that there is lack of uniformity existing in grading Cheddar cheese. Conversely, remarkable agreement exists in what constitutes high-quality or low-quality cheese, regardless of the geographical region or the grading agency involved.

Grading of Young Cheese for Storage Some Cheddar cheese is bought and sold when "green," or only a few days after removal from the press. Fresh, uncured cheese lacks the typical Cheddar flavor and body and must be graded on the basis of predicted quality development during early to mid-stages of the curing period. There is merit in grading fresh Cheddar cheese, in order to utilize the product to best advantage. However, some differences of opinion exist as to the value of judging "green" cheese to determine its future or "aged" potential. Since certain flavor, body, texture, and workmanship qualities have a bearing on the curing of cheese, a qualified cheese grader usually can reliably project or predetermine how a graded young cheese will develop with additional storage (curing time). Careful sensory evaluation of immature cheese (prior to storage) and records of manufacturing, moisture content, and of the relative quality of cheese milk are helpful factors in determining the probable success of cheese curing.

In grading young cheese for subsequent commercial use, Price (1943) suggested dividing Cheddar cheese into the following categories:

Long hold – The quality level necessary for the most particular or discriminating use of the cheese.
Short hold – Minor defects (slightly apparent), which will permit, short storage periods without loss in commercial value.
Immediate use only – Distinct defects (easily detected, obvious) which require careful sorting of the cheese according to given markets; immediate utilization of the cheese is perhaps mandatory.
Limited use – Major defects (quite serious faults), which restrict use of the cheese to a few markets, i.e., grinding purposes, process cheese, or immediate consumption as a "cooking cheese."
Culls – Inedible cheese not to be used for human consumption.

The specific product defects that necessitate placing cheese in the above respective classes are usually obvious and involve many of the defects listed on the cheese scorecard. Flavor is usually considered more critically than other factors, although body and texture, color, and appearance features of the cheese should not be overlooked.

9.10 Colby, Monterey Jack, Colby-Jack, and Flavored Cheese

In as much as the general manufacturing procedures and bacterial fermentations occurring in Colby and Monterey Jack cheeses closely parallel those of Cheddar cheese, these three related varieties tend to share common defects. Generally, due to higher moisture content, lower acid and salt content, which facilitate higher microbial and enzymatic activity, some sensory defects may reach greater intensity and frequency in Colby and Jack cheese than in Cheddar. The above factors tend to limit the keeping quality of Monterey Jack and Colby cheese, compared to Cheddar.

Flavor For cheeses 2–3 months of age, an acid flavor may be more apparent in Jack and Colby cheeses than in Cheddar. The likelihood that a typical, nutty, Cheddar flavor will develop in Colby or Jack cheese within several months is unlikely. The "acid flavor" tends to be more obvious in the two stirred curd cheeses, since there is no partial masking effect from a "Cheddar flavor." A notable exception is certain dry or low-moisture Monterey Jack cheeses, which can be aged 9 or more months and often develop a distinct, full, nutty flavor. Frequently, when conventional Colby or Monterey Jack cheese exceeds 100 days of age, a distinct bitter taste may develop, which reflects a possible limitation for aging of these cheese types beyond 3 months.

Body and Texture Defects Colby and Monterey Jack cheeses tend to have a weak body, due to their higher moisture content. This characteristic is anticipated and tolerated, up to a certain point. With respect to cheese texture, mechanical openings are expected and more tolerated in these two stirred curd forms of cheese, than in Cheddar. Occasionally, solid or "blind spots" occur in Colby and Monterey Jack cheese. These are usually related to the formation of curd lumps that developed before or during curd washing, cooling, or salting. The typical remedy is to try to continuously maintain the curd in a granular form by applying adequate agitation of the curd and uniform distribution of the salt. Applications of higher pressure to cheese hoops during pressing also account for the production of closed or blind Colby and Monterey Jack cheeses. Solid or blind cheese of these two types has apparently gained consumer acceptance; an open, granular, or stirred curd appearance gradually has become a less common feature of Colby and Monterey Jack cheese.

Flavored Cheese Cheddar and Cheddar-type cheeses are excellent carriers for a variety of added flavors (e.g., sun-dried tomato, caraway seed, sage, horseradish, dill) that are only limited by the imagination of the cheesemaker. The flavor and body and texture characteristics of a good cheese should be enhanced by characteristic and complimentary flavor and body and texture characteristics of the flavoring component. An excellent example results from the addition of jalapeño peppers during the salting step of any of the Cheddar-type cheeses. A properly manufactured cheese will age well and present an, evenly distributed flavor of the jalapeños. Even distribution of condiments is essential and should effectively represent the name on the package without detracting from the underlying high-quality cheese flavor that should be noted by the judge and ultimately the consumer.

9.11 Conclusion

Cheddar and related cheeses present a delightful but daunting task to the cheese grader/judge. However, learning how to evaluate this extensive class of cheeses provides judges with wide array of sensory skills to apply to many cheese styles. Students dedicating time to training in the use of the CDPEC scorecard for Cheddar cheese will find themselves well prepared to continue training as full-fledged judges/graders of Cheddar and Cheddar-type cheeses, with skills to apply to other categories of cheeses. Coupled with good cheesemaking record-keeping, learning to observe the fine balance of flavor, body, and texture and to detect defects in cheeses enables cheesemakers to produce the most consistent high-quality products to consumers.

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Chapter 10
Ice Cream and Frozen Desserts

Valente B. Alvarez

10.1 Introduction

Ice cream is among the most favorite desserts in the USA, and vanilla, chocolate, and strawberry are the preferred flavors. Ice cream is a frozen food made of a mixture of dairy products such as milk, cream, and nonfat milk, combined with sugars, flavoring, and inclusions, such as fruits and nuts. Functional ingredients, such as stabilizers and emulsifiers, are often included in the product to promote proper texture and enhance the eating experience. According to US standards, ice cream must contain at least 10% milk fat, before the addition of bulky ingredients, and must weigh a minimum of 4.5 pounds to the gallon. Ice cream containing at least 1.4% egg yolk solids is called French ice cream or frozen custard. Superpremium ice cream is a denser product because it contains 16–18% milkfat and low overrun (20–50% range). Ice creams with reduced fat levels, which are described later in this chapter, contain the same ingredients as regular ice cream, and follow the labeling guidelines established by the FDA. Soft-serve ice cream is a frozen dessert that is soft frozen just before serving on the premises, so the formulas differ from hard-frozen products. The fat content of soft-serve mixes is in the range of 4–12%, and the serum solids vary inversely from 11% to 14% with fat content (Marshall et al., 2003).

Ice cream is one of the most popular desserts in the USA, with approximately 5.83 billion liters (2.6 billion gal) produced in 2019 (USDA, 2021). Most of the ice cream produced in the USA is the hard-frozen type, but the production of soft serve has increased over the past decade. The US per capita consumption of ice cream,

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sherbet, and other commercially produced frozen dairy products was 18.7 pounds in 2019. It is estimated that 98% of all US households purchase ice cream (USDA, 2021).

Ice cream and related products are members of the "frozen dairy desserts family" and are defined in the Code of Federal Regulations (CFR) Title 21, Part 135. These frozen desserts are defined as follows:

Reduced fat ice cream contains at least 25% less total fat than the referenced product (either an average of leading brands or the company's own brand). *Light* ice cream contains at least 50% less total fat or 33% fewer calories than the referenced product (the average of leading regional or national brands). *Low-fat* ice cream contains a maximum of 3 g of total fat per serving (1/2 cup). *Nonfat* ice cream contains less than 0.5 g of total fat serving.

Mellorine is a food similar to ice cream but having the milk fat replaced in whole or part with vegetable or animal fat. The FDA Standard of Identity specifies that it contains not less than 6% fat and 2.7% protein. The milk-derived protein has a protein efficiency not less than that of milk protein. For mellorine containing bulky-flavoring agents, the minimal content of fat and protein is calculated in the same way as for ice cream. Vitamin A must be present at the rate of 40 IU per gram of fat (21 CFR 135.130).

Sherbets have a milkfat content of between 1 and 2% and slightly higher sweetener content than ice cream. Sherbet weighs a minimum 6 pounds to the gallon and is flavored either with fruit or other characterizing ingredients (21 CFR 135.140).

Water ices are similar to sherbets, but contain no dairy ingredients; no egg ingredient, other than egg white; and the mix need be not pasteurized (21 CFR 135.160).

Other frozen dairy desserts, including but not limited to gelato and frozen yogurt, are not defined in the CFR and are not regulated by the FDA.

Each product category may differ in the type of flavoring, the composition in terms of dairy ingredients and other food solids, and the extent of product overrun (increase in ice cream volume due to air incorporation). Table 10.1 summarizes the compositional differences of the major classes of frozen dairy desserts. The optional milk ingredients that these frozen dairy desserts may contain are listed in Table 10.2. Within the restrictions imposed by the 2022 CFR, 21 CFR 135.110 (Table 10.1), ice cream is basically defined as that food produced as a result of freezing, while stirring, a pasteurized mix that consists of one or more of the dairy ingredients listed in Table 10.2 and other non-milk-derived ingredients (that are safe and suitable). The latter serve functions such as nutritive carbohydrate sweeteners, stabilizers, emulsifiers, flavorings, and coloring agents.

The sensory evaluation of ice cream and frozen desserts is not easy. It requires training and continuous practice with prepared samples before a person can develop the necessary skills, knowledge, and senses to judge ice cream. In addition to the expertise of the judge, proper environmental conditions during evaluation are necessary to judge the products correctly. This chapter covers in detail the physical and chemical characteristics of the most common frozen desserts, the ingredients, and their influence on sensory attributes such as flavor, body, and texture. The possible causes and corrections of off-flavor, body, and texture defects are discussed as well.

Table 10.1 Federal Standards of Identity for the composition of frozen dairy deserts

Product	Weight (lb/gal)	Total solids (lb/gal)	Total milk solids (%)	Milk fat (%)	Whey solids (%)	Egg yolk solids (%)	Caseinates	Overrun (%)
Ice cream[a]	≥4.5	≥1.6	≥20	≥10	≤2.5	<1.4	b	90–100
Bulky-flavored ice cream[c]	≥4.5	≥1.6	≥16	≥8	≤2.0	d	b	
Frozen custard[e]	≥4.5	≥1.6	≥20	≥10	≤2.5	≥1.4	b	90–100
Bulky-flavored frozen custard[e]	≥4.5	≥1.6	≥16	≥8	≤2.0	≥1.12	b	
Mellorine[h]	≥4.5	≥1.6	g	f	g	i	j	
Reduced fat ice cream	≥4.5			k			b	
Light ice cream	≥4.5			l			b	
Low-fat ice cream				m			b	
Sherbet	≥6.0		2–5%	1–2%	0–4%	i	j	30–40
Water ices	≥6.0		0	0	0	0	0	25–30

From: Code of Federal Regulations Title 21, Part 135.110–135.160

[a]Increases in milk fat may be offset with corresponding decreases in nonfat milk solids, but the latter must be at least 6% in frozen custard and ice cream and 4% in low-fat ice cream. Corresponding adjustments may be made in bulky-flavored products

[b]May be added to ice cream mix containing not less than 20% total milk solids, providing that caseinates are prepared by precipitation with gums, ammonium caseinate, calcium caseinate, potassium caseinate, and sodium caseinate

[c]Adjustment in composition in bulky-flavored frozen desserts is determined by calculation based on the actual quantity of bulky flavor used. However, the analysis must never be lower than the minima given in the table

[d]Less than 1.4% egg yolk solids by weight of food exclusive of the weight of any bulky-flavor ingredients

[e]Also designated French ice cream or French custard ice cream

[f]Milk fat replaced by a minimum of 6% vegetable or animal fat

[g]At least 2.7% milk-derived protein having a protein efficiency ratio (PER) not less than that of whole milk protein, 108% of casein

[h]For bulky-flavored mellorine, in no case shall the fat content of the finished food be less than 4.8% or the protein content less than 2.2%

[i]Egg yolk solids are allowed

[j]Caseinates are allowed

[k]Ice cream made with 25% less fat than the reference ice cream

[l]Ice cream made with 50% less fat or 1/3 fewer calories than the reference ice cream, provided that in case of caloric reduction less than 50% of the calories are derived from fat

[m]Solids from concentrated, dried, and modified whey used singly or in combination may not exceed 25% of the total milk solids content permitted

Composition is determined by calculation based on actual quantity of the bulky flavor used. However, the milk fat content and the nonfat milk solids content must never be lower than 2 and 7%, respectively. (Total milk solids must not be less than 9%)

Table 10.2 Optional dairy ingredients approved for use in ice cream and frozen custard[a]

Cream	Fresh, dried, plastic (concentrated milk fat)
Butter and butter oil	
Milk	Fresh, concentrated, evaporated, sweetened condensed, super-heated condensed, dried, skim, concentrated skim, evaporated skim, condensed skim, super-heated condensed skim, sweetened condensed skim, sweetened condensed part-skim milk, nonfat dry milk, sweet cream butter milk, condensed sweet cream butter milk, dried sweet cream butter milk, skim milk that may be concentrated from which part or all of the lactose has been removed
Whey[b]	Whey and whey products recognized as GRAS by the FDA, whey solids are limited to not more than 25% of milk solids nonfat
Casein[c]	Precipitated with gums
Caseinate[c]	Salt of ammonium, calcium, potassium, or sodium
Buttermilk[d]	Fresh, condensed, or dried; for churning of sweet cream
Hydrolyzed milk proteins	Added as stabilizers at a level not to exceed 3% by weight of ice cream mix containing not less than 20% total milk solids

From the Code of Federal Regulations Title 21, Part 135.110
[a]The Federal Standards of Identity provide quality standards for certain of the above ingredients
[b]Generally recognized as safe
[c]Not considered to be milk solids (does not satisfy milk solids requirements)
[d]Titratable acidity of not more than 0.17%, calculated as lactic acid, for a solution of 8.5% total solids

The use of scorecards to evaluate and record the quality of ice cream is also part of this chapter. Special emphasis is given to the Annual Collegiate Dairy Products Evaluation ice cream scorecard. The information in this chapter should provide the necessary background and guidelines for individuals to become skilled judges of the quality of frozen dairy products after a reasonable period of rigorous training and practice.

10.2 Ingredients

The quality of ice cream may be influenced by several factors: (a) the quality of mix ingredients such as milk, cream, nonfat milk, sugars, flavoring, and inclusions; (b) processing conditions; (c) freezing; (d) packaging; and (e) handling and storage conditions. These factors determine the sensory attributes of the product as sweet flavor, body and texture, and cold sensation that are perceived by consumers. The quality and sensory attributes of ice cream can be evaluated through its color, microbial, chemical, and physical analyses, although these measurements are not necessarily a direct indication of the "eating quality" of the ice cream as perceived by the consumer in terms of the most desirable flavor, texture, color, appearance, and overall quality. That is the reason why human senses, as opposed to machines, are still used widely in evaluating ice cream products. Even though the perception and preferences of the sensory attributes vary among different individuals, judging and scoring of ice cream products are important tasks of the quality control programs of ice cream processors. Finished products are evaluated for sensory quality after freezing and throughout the different stages of storage, shipping, handling, and distribution.

The sweeteners. The sweeteners commonly used in ice cream are sucrose (cane or beet sugar), dextrose (corn sugar), and various corn syrups (Marshall et al., 2003; Goff & Hartel, 2013). Honey, when used, imparts both sweetness and a characteristic flavor. Corn syrup is produced by converting starch into a mixture of simpler sugars including dextrose, maltose, maltotriose, maltotetraose, and dextrins (in ascending order of molecular weights). Members of the mixture with lower molecular weights exhibit greater sweetness, while the higher-molecular-weight members have the ability to limit water migration and ice crystal formation more effectively. The dextrose equivalent (DE) designation of a given corn syrup provides an indication of the distribution of starch conversion sugars present. High DE values imply a high degree of conversion into dextrose, the simplest sugar produced from starch. Other available corn syrups are designated as high maltose and high fructose; the latter is produced by an additional processing step that converts dextrose into fructose. Fructose provides the most sweetness for a given amount of added sweetener.

In an aqueous solution, such as found in ice cream, approximately 2 parts of 42 DE corn syrup, 3 parts of lactose, or 1 part of high-fructose syrup are required to impart the equivalent sweetness of 1 part of sucrose (the common standard). The generally accepted sweetness level for vanilla ice cream is a 13–15% sucrose equivalent (equal to 13–15% sucrose in the mix).

The relative hardness of ice cream produced at any given temperature depends on what proportion of water is frozen at that temperature, which in turn largely depends on the freezing point of the ice cream mix and the temperature at which the finished product is stored (Tobias, 1981, 1982; Bodyfelt, 1983a, b; Bodyfelt et al., 1988; Goff, 2002; Clarke, 2006; Goff & Hartel, 2013). The freezing point of ice cream is particularly influenced by soluble solids, especially sweeteners. Furthermore, the amount of ice and the size distribution of ice crystals affect the relative hardness of ice cream (Wibley et al., 1998; Hartel et al., 2004; Amador et al., 2017).

During freezing, latent heat of water is removed and this results in the formation of ice crystals. The remaining solution becomes more concentrated in terms of the soluble constituents because of the transformation of a part of water into ice crystals by the freezing process. This process is called freeze concentration (Hartel, 1996; Marshall et al., 2003; Goff & Hartel, 2013). Viscosity and glass transition states influence the freezing process and textural properties of ice cream. Water bound by stabilizers is not available to freeze initially or to refreeze during subsequent storage (Miller-Livney & Hartel, 1997). Low storage temperature and the presence of stabilizers reduce the kinetic energy of water molecules, thereby reducing their mobility during temperature fluctuations of storage (Fennema, 1993). A high proportion of bound water in ice cream, or other frozen dairy desserts, serves to reduce the amount of water to be frozen. This increases the resistance of the ice cream to heat shock during storage with less chance of recrystallization, thus improving the body and texture of the product.

Mineral salts present in milk, lactose, and added sugars reduce the freezing point of the ice cream mix (Hartel et al., 2004; Goff & Hartel, 2013). The monosaccharides, fructose, and dextrose equally lower the freezing point of a solution (or a mix) and concomitantly reduce the freezing point to a greater extent by weight than the disaccharides sucrose, maltose, and lactose. The higher-molecular-weight sugars that are present in corn syrup depress the freezing point to a lesser extent than do disaccharides, when compared on an equal weight basis. Each of the various sugars used in ice cream bind water to a different extent. The higher DE sugars and dextrins in corn syrup are the most effective binders of water, with the exception of stabilizers. The low DE corn syrups (e.g., 36 DE and 42 DE) lack sweetening power compared to the higher DE corn syrups, but the low DE sweeteners limit water migration more effectively and therefore have greater "body building" properties in ice cream and reduced fat ice creams (Anter et al., 1986; Marshall et al., 2003).

Liquid sugars of poor-quality or corn syrups can be sources of off-flavors in frozen dairy desserts, especially in vanilla-flavored products (Marshall et al., 2003). Dark syrups, wherein nonenzymatic browning (Maillard reaction or caramelization) has taken place, may impart a stale, caramelized flavor. Certainly more serious is the fermentation of liquid sugars or corn syrups, which generally makes them unusable in ice cream. When conducting sensory evaluation of ice cream, one should be alert to the possible flavor shortcomings that can stem from certain sweetener sources. Indeed, one of the most common attributes of vanilla ice cream is "syrup flavor," which will be discussed fully later in this chapter.

Emulsifiers. Emulsifiers provide several important functions, such as decreased whipping time, controlled fat destabilization, enhanced smoothness of texture, increasing resistance to melting and shrinkage, and improved dryness (Pelan et al., 1997; Goff et al., 1989; Goff & Hartel, 2013). A degree of destabilization of fat globules is essential to produce ice cream with desirable body (Goff & Jordan, 1989; Amador et al., 2017). Fat destabilization is described as the following process: emulsifiers, being better surfactants than the proteins, displace proteins from direct contact with the fat globule surface (Segall & Goff, 2002; Goff & Hartel, 2013); during freezing of the mix, the fat globule partially crystallizes and is exposed to shearing forces, allowing separate fat globules to partially coalesce with one another (van Boekel & Walstra, 1981; Akbari et al., 2019). The partially coalesced fat globules stabilize air cells, forming three-dimensional network structures with the air cells (Berger, 1997; Zhang & Goff, 2004; Goff & Hartel, 2013). Emulsifiers also contribute to the formation of small, uniformly dispersed air cells; protect against texture deterioration due to heat shock; and provide a semblance of a "richness" sensation. Over-emulsification may result in fat churning, a grease-like mouth coating, and/or an "emulsifier" taste. At times, even lower levels of emulsifiers may impart an aftertaste when they and/or other ingredients are old, oxidized, or have deteriorated in some other way. Commonly used emulsifiers include lecithin, mono- and diglycerides of fatty acids, polysorbate 80 (polyoxyethylene (20) sorbitan monooleate), and polysorbate 65 (polyoxyethylene (20) sorbitan tristearate)

(Marshall et al., 2003). Depending on the specific emulsifier(s) used, the concentration may vary from 0.03% to 0.2% (Mann, 1997). Polysorbate 80 leads to more extensive fat destabilization compared to mono- and diglycerides (Hartel et al., 2004).

Stabilizers. There are many important functions of stabilizers in ice cream and related products (Goff & Sahagian, 1996; Vega et al., 2004; Abbas Syed, 2018). One of them is to bind water, which in turn promotes small ice crystal formation and helps keep ice crystals from growing in size during recrystallization, i.e., when storage temperatures fluctuate or become too high (referred to as "heat shock") (Donhowe & Hartel, 1996; Hagiwara & Hartel, 1996; Sutton & Wilcox, 1998; Flores & Goff, 1999). Small ice crystals are favored by ice cream evaluators, as large ones produce unappealing "coarse" or "icy" mouthfeel.

Stabilizers also prevent the separation of clear serum during meltdown by modifying the ice crystal/serum interface (Sutton & Wilcox, 1998; Goff & Hartel, 2013). Another stabilizer function is to develop viscosity in the ice cream mix, since a more viscous mix has a better capacity to retain air bubbles (Cottrell et al., 1980; Bolliger et al., 2000b; Chavez-Montes et al., 2004; Abbas Syed, 2018). Stabilizers are usually proprietary blends of gums such as guar, locust bean, carrageenan, alginates, and carboxymethyl cellulose (CMC). Depending on the type and concentration of gums in the frozen dairy dessert mix, and the milkfat and solid content of the mix, stabilizers are used at levels ranging from 0.15% to 0.5% (Clarke, 2006). The typical usage level for stabilizers in ice cream is 0.5% (Marshall & Arbuckle, 1996). Although most commercial ice creams contain stabilizers and emulsifiers in small concentrations, some manufacturers exclude these body and texture-modifying agents from the formulation of certain brands, especially those products categorized and promoted as "premium quality" or "all natural" (Tobias, 1981, 1982, 1983; Bodyfelt, 1983a, b; Bodyfelt et al., 1988).

Flavoring and inclusion agents. Space does not permit the listing of all the possible or sum total flavorings used in ice cream and other frozen dairy desserts. As a general principle, there is no point in comparing one flavor type against another, as the choice is generally a matter of personal preference. The evaluator should be aware that flavorings range from natural to artificial, but, as a general rule, the natural source may be preferred from several viewpoints. However, the use of natural flavoring is not always a guarantee of high quality. For example, some sources of fresh or frozen strawberries (as well as certain other berries or fruits) may be deficient (lacking) in flavor intensity, though used at the recommended level (Bodyfelt et al., 1988; Marshall et al., 2003; Goff & Hartel, 2013). Other possible problems with berries or fruits may involve (1) the utilization of the wrong, or a less satisfactory, variety; (2) improper stage of ripeness at harvest; (3) physical damage prior to preservation; (4) excessive and/or improper storage prior to preservation; (5) high and fluctuating temperatures in frozen storage; and/or (6) an inadequate quantity of fruit incorporated into the product.

The most popular flavor of ice cream in the USA is vanilla, which accounts for nearly one half of all ice cream sales (IDFA, 2017). Since vanilla is a delicate flavoring, it will not "cover-up" or mask potential off-flavors as effectively as stronger flavors such as mint or chocolate, which is not exactly a flavoring because the whole ice cream base formulation needs to change when chocolate ice cream is made. However, if used at the same level, double-strength vanilla is much more effective at covering up possible flavor defects in frozen ice cream than single-strength vanilla flavoring (Im & Marshall, 1998).

Off-flavors in the mix are more difficult to detect in the presence of stronger flavorings, such as mint. To manufacture a vanilla ice cream with an ideal flavor requires that (1) the dairy products, sweeteners, and all other ingredients be free of flavor defects; (2) the mix be correctly processed; and (3) the vanilla flavoring be of the highest quality. The perceived flavor should not only exhibit the desired intensity but also blend pleasingly with the background or the complementary flavor provided by the mix. While vanilla ice cream provides a rigid test for overall sensory and quality control, these general manufacturing requirements also apply to other ice cream flavors. A common axiom in the manufacture of dairy products is that "the quality of the finished product can be no better than the quality of the ingredients."

The rating for bacteria content must be performed in the laboratory, where equipment, laboratory technique, and additional time are required. Due to these requirements, bacteria are not evaluated in any sensory evaluation contests. In many situations, the results of the standard plate count and coliform count may not be available at the time the product is evaluated, in which case the "full score" may be allowed with a notation that the data were not available or the analysis not undertaken. As in milk evaluation, actual microbial counts are more meaningful than point scores. For instance, coliform counts of >50 or total plate counts of >500,000 CFU/ml require a score of "zero," but obviously the latter reported values would reflect a more inferior product.

10.3 The Ice Cream Scorecard

Measuring ice cream quality can be done by various standards, but numerical scores are helpful in ice cream operations, academia, and institutions that need to judge the quality of products based on established ideal characteristics. Bodyfelt et al. (1988) developed a scorecard and scoring guides for ice cream. The card had various category criticisms for flavor, body and texture, color appearance and package, melting quality, and bacterial content. The scoring guide for vanilla ice cream had a score range of 1–10 for flavoring system, sweeteners, processing, dairy ingredients, and others. The scorecard and guidelines were modified through the years and served as the basis for the development of the current Collegiate Dairy Products Evaluation Contest (CDPEC) scorecard. The scorecard in Fig. 10.1 is the one developed and approved by the CDPEC coaches committee and is used throughout the USA in college judging contests. The card has two category criticisms, flavor plus body and texture.

The scoring guides that accompany the scorecard are presented in Table 10.3. Scoring guides are useful in training new evaluators and in promoting

Ice Cream

SAMPLE 1

FLAVOR SCORE: **1 2 3 4 5 6 7 8 9 10** NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid	___ 6. Lacks Freshness	___ 11. Rancid
___ 2. Cooked	___ 7. Low Flavoring	___ 12. Salty
___ 3. High Flavor	___ 8. Low Sweetness	___ 13. Syrup Flavor
___ 4. High Sweetness	___ 9. Old Ingredient	___ 14. Unnatural Flavor
___ 5. Lacks Fine Flavor	___ 10. Oxidized	___ 15. Whey

BODY AND TEXTURE SCORE: **1 2 3 4 5** NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Crumbly	___ 4. Gummy	___ 7. Soggy
___ 2. Fluffy	___ 5. Icy	___ 8. Weak
___ 3. Greasy	___ 6. Sandy	

SAMPLE 2

FLAVOR SCORE: **1 2 3 4 5 6 7 8 9 10** NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid	___ 6. Lacks Freshness	___ 11. Rancid
___ 2. Cooked	___ 7. Low Flavoring	___ 12. Salty
___ 3. High Flavor	___ 8. Low Sweetness	___ 13. Syrup Flavor
___ 4. High Sweetness	___ 9. Old Ingredient	___ 14. Unnatural Flavor
___ 5. Lacks Fine Flavor	___ 10. Oxidized	___ 15. Whey

BODY AND TEXTURE SCORE: **1 2 3 4 5** NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Crumbly	___ 4. Gummy	___ 7. Soggy
___ 2. Fluffy	___ 5. Icy	___ 8. Weak
___ 3. Greasy	___ 6. Sandy	

Fig. 10.1 Scorecard of the Collegiate Dairy Products Evaluation Contest (samples 3–8 appear on separate pages)

standardization of judgments among different evaluators. Further modifications of the scorecard will be suggested later in this chapter when other frozen products are discussed.

Various flavor defects that may be encountered in vanilla ice cream are described as follows:

Acid:	Tingly taste sensation on tongue, may be accompanied by unclean or other bacterial flavors
Cooked:	Common, eggy, custard, not serious defect, scorched or burnt definite defect
High flavor:	Harsh taste when first placed in mouth, unbalanced blend.
High sweetness:	Candy-like sensation, not refreshing
Lacks fine flavor:	Harsh, lacks balance, not perfect, minor defect
Lacks freshness:	Stale, some marginally old dairy ingredient, slight old ingredient, or other flavors

Table 10.3 Scoring guide for flavor defects of vanilla ice cream

Flavor criticisms	Intensity of defect		
	S	D	P
Acid	4	2	U
Cooked	9	7	5
High flavor	9	8	7
High sweetness	9	8	7
Lacks fine flavor	9	8	7
Lacks freshness	8	7	6
Low flavoring	8	6	4
Low sweetness	9	8	6
Old ingredient	6	4	2
Oxidized	6	4	1
Rancid	4	2	U
Salty	8	7	5
Syrup flavor	9	7	5
Unnatural flavor	8	6	4
Whey	7	6	4

Normal range 1–10. Range of scores for each class of flavor quality: excellent 10 (no criticism), good 8–9, fair 6–7, poor 5 or less
S slight, *D* definite, *P* pronounced
U indicates product of unsalable quality. Official rules prohibit the use of such products in contest

Low flavoring:	Flat, bland, lacks vanilla
Low sweetness:	Flat or bland taste
Old ingredient:	Old or deteriorated dairy ingredients, persistent aftertaste, does not clean up
Oxidized:	Cardboardy, astringent, oily, tallowy
Rancid:	Persistently repulsive, unpleasant aftertaste, blue cheese, baby puke
Salty:	Quickly perceived taste
Syrup flavor:	Unnatural sweetness, (Karo) corn syrup, caramel, may be sticky or gummy also
Unnatural flavor:	Imitation vanilla, accidental mixing of another flavor with vanilla
Whey:	Graham cracker-like, stale condensed milk, slight salty taste, may be off color or crumbly

10.4 Techniques of Ice Cream Scoring

As indicated earlier in this chapter, scoring and judging ice cream correctly is not easy and requires knowledge and experience. Therefore, it is often done by students and professionals who were trained in contests like the CDPEC and dairy industry. With proper training, individuals are able to dependably evaluate the sensory quality of ice cream and other related products more reliably than the untrained consumer.

In the CDPEC, products that meet the standards of ideal ice cream are given the highest mark in the range 1–10 for flavor criticisms and 1–5 for body and texture criticisms. Ice cream with no criticisms is considered perfect and is given a score of 10 and 5 in each category, respectively. Ice cream products rarely receive a perfect score. When a defect is identified, the smallest deduction a judge can make is one point. The deduction can increase depending on the severity of the defects identified. Defects are described as slight, definite, or pronounced depending on the intensity of the defect. Those product samples (representative of a lot) that receive a "zero" in any one or more quality categories should or would generally be regarded as unsalable products.

Tempering the samples. The technique of judging ice cream (Bodyfelt et al., 1988) is markedly different in many respects from the judging of other dairy products. Since ice cream is a frozen product, it must be evaluated, in part, in that condition in order to ascertain the typical or desired body and texture characteristics. Consequently, arrangements must be made to store (temper) the samples at a uniformly low temperature so that the ice cream retains its appropriate physical properties, yet the temperature maintained must not be so low that the ice cream is intensely cold and unnecessarily hard. When ice cream is too cold, the recovery of the sense of taste from temporary anesthesia, due to extreme cold, requires a longer period than is expedient for satisfactory and efficient work. Furthermore, evaluators will have greater difficulty in determining the actual body and texture properties if the ice cream is too firm. Additionally, tempering is necessary for practical purposes since dipping will also be nearly impossible if the ice cream is really cold.

Generally, temperatures between −18 and − 15 °C (−0.4 and 5 °F) are satisfactory for tempering ice cream prior to judging (Goff & Hartel, 2013). This can be best achieved by transferring the ice cream samples from the hardening room to a dispensing cabinet at least several hours prior to judging, or preferably tempered overnight. This length of time ensures that the ice cream tempers uniformly. Exposing ice cream to room temperatures for tempering purposes is most unsatisfactory since the ice cream rapidly melts along the outer edges, while the center remains too firm for dipping.

If satisfactory evaluation is to be performed, the importance of proper tempering of ice cream and related products cannot be minimized. Significant, measurable loss of ice crystal structure occurs between −20 and –10 °C (−4 and 14 °F), and the frozen fraction of ice cream decreases rapidly from −10 to 0 °C (14–32 °F) (Eisner et al., 2004). Some freezer cabinets are not satisfactory for product tempering, as they do not maintain a uniform temperature throughout the unit. Temperatures should be measured at different locations throughout the cabinet to help insure uniform tempering of samples. Overfilling a tempering cabinet can cause some samples to be warmer than others, since crowded conditions inhibit the movement of air. Placement of all samples, if possible, at the same height within the cabinet (with air space between containers) usually helps insure uniform tempering.

Conditions for best work. Convenience is an important adjunct to efficient evaluation. The samples, therefore, should be arranged so that they are easily accessible without causing too much inconvenience in securing portions for sensory examination. This arrangement involves providing ample spacing of the samples to minimize or eliminate possible congestion when a number of people are conducting the product evaluation. Placing an especially designed "dolly" under the ice cream case so that the cabinet may be moved and/or arranged at will has been found to be a convenient form of mobility in the laboratory or evaluation setting (Bodyfelt et al., 1988). Thus, the ice cream is readily accessible, conveniently located, and properly tempered. The temperature of the room should be comfortably warm. Attempting to judge ice cream in a chilly room usually results in hurried work and hasty, questionable judgments; in fact, it is better that the room be too warm than too cold.

Sampling. When ice cream (or another frozen dairy dessert) is properly tempered, sample portions may be easily secured for completing all aspects of the sensory evaluation. Generally, a good-quality ice cream dipper, scoop, or spade, rather than a spoon, is preferred for obtaining samples (Fig. 10.2).

Exercising certain precautions is deemed advisable for the sampling process (Bodyfelt et al., 1988). If the product surface has been exposed, then any dried surface layer (to a depth of approximately 0.8 cm (1/4 in)) should be removed before securing the sample for evaluation. When a meltdown test is conducted, the test sample need not be large, but its volume must be uniform across all lots of ice cream being compared. For the meltdown examination, a No. 30 scoopful of ice cream placed on a clean, numbered petri dish is quite satisfactory. The petri dish should be set in a convenient place (but away from heat sources) where melting qualities may be observed from time to time during the overall evaluation process. Small samples for tasting may be removed from the product package by either a metal or plastic scoop (dipper) when desired. Individual, 15.2-, 20.3-, or 25.4-cm (6-, 8-, or 10-in) paper plates have been used satisfactorily for holding the individual samples during the course of tasting. One or more samples may be placed on the same plate for study and comparison. Care must be exercised that portions of several samples are not intermixed.

Fig. 10.2 Several types of scoops and spades used for dipping ice cream samples

The manipulation and conveying of sample portions to the mouth for tasting may be done by means of a clean plastic, bright metal, compressed paper, fiber, or wooden spoon. Some judges prefer metal or plastic spoons to all others for judging ice cream. Spoons should be easy to clean between samples. It is important that spoons not impart any atypical or foreign off-flavors to the product. Plastic, compressed paper, fiber, and wooden spoons are all generally satisfactory; providing an adequate supply is available so that heavily used or worn spoons may be discarded at will. Single-service plastic spoons are most commonly used. In using wooden spoons, precautions must be taken to guard against a slightly "woody" taste.

Intermittent or unrestricted dipping of "used" spoons into the container of ice cream should absolutely not be tolerated for reasons of personal hygiene. Having placed a reasonable-sized portion (a small scoopful) of ice cream onto an individual plate for sensory study, the evaluator can then taste from this "individual" sample as often as needed. The evaluator is free to secure additional samples from any product container (with the appropriate dipper) when needed, in order to complete the process of product evaluation.

10.5 Sequence of Sensory Observations

Since the physical condition of ice cream changes so rapidly when exposed to ordinary temperatures, the evaluator must be alert and constantly observing during the "time restrictive" sampling and evaluation process, in order not to overlook any possible sensory defects associated with a given product sample, particularly body and texture features. An orderly sequence of observations (Bodyfelt et al., 1988) has been found to be most effective in evaluating ice cream for sensory characteristics. The steps are listed in the following paragraphs.

Examine the container. Note the type and condition of the container, the presence or absence of a liner and cover on bulk containers, and any package defects that may be present.

Note the color of the ice cream. Observe the color of the ice cream, its intensity and uniformity, and whether the hue is natural and typical of the given flavor of ice cream being judged.

Sample the ice cream. During the course of dipping the sample, carefully note the way the product cuts and the feel of the dipper as its cutting edge passes through the frozen mass. Note particularly whether the ice cream tends to curl up or roll in serrated layers behind the dipper, thus indicating excessive gumminess or stickiness. The "feel" of dipping (i.e., the resistance offered), the evenness of cutting, the presence of spiny ice particles, and whether the ice cream is heavy or light and fluffy should be especially noted. The way the sample responds in the dipping process often gives a fairly accurate impression of its body and texture characteristics (Fig. 10.3).

The "scoopability" (rigidity) of ice cream as perceived by human subjects has been correlated with instrumental measurements. The effect of various ice cream mix compositions and processes on the microstructural (ice crystal and air-cell sizes) and sensorial (scoopability and creaminess) characteristics was studied using cryo-scanning electron microscopy (cryo-SEM) and oscillatory thermo-rheometry (OTR). Ice cream was prepared using conventional freezing and a combined freezing and low temperature extrusion (LTE) process. The LTE-processed ice cream was reported to have smaller ice crystals as the higher shear force of the process prevented aggregation. Air bubbles were better stabilized in LTE ice cream because of higher viscosity. However, the higher shear forces of the LTE process led to increased aggregation and partial coalescence of fat globules. The OTR storage modulus (G' – indicator of elasticity) and loss modulus (G'' – indicator of flowability) values were compared to sensory evaluation of scoopability and creaminess by an industrial sensory panel on a six-point scale. The sensory characteristics were reported to be a function of loss modulus. In the low temperature range ($T = -15$ °C) (5 °F), a lower value of G'' indicated less rigidity and improved scoopability. In the molten ice cream ($T > -1$ °C) (30.2 °F), higher G'' values corresponded to a higher degree of creaminess. The LTE-processed ice cream was reported to be more scoopable and creamier than conventional ice cream. It was concluded that OTR can be successfully used to quantify the quality of ice cream (Wildmoser et al., 2004).

Begin judging. After a sample portion has been secured, the examination for further body and texture characteristics and for flavor should begin immediately. As a general rule, little conception of the flavor may be gained by smelling the sample. Until the ice cream is melted within the mouth, the sample portion is so cold that for all practical purposes the odoriferous substances remain practically nonvolatile and, therefore, little or no aroma may be detected. When the sample is liquefied and warmed to near body temperature, detection of the flavor characteristics is not particularly difficult. This detection is best accomplished by placing a small teaspoonful or bite of frozen product directly into the mouth, quickly manipulating the sample between the teeth and palate, and simultaneously noting the taste and/or volatile sensations (Bodyfelt et al., 1988).

Since the body and texture characteristics of a frozen product are to be determined, the sample placed into the mouth should initially be in the frozen state. Immediately after placing a portion into the mouth, roll the sample between the

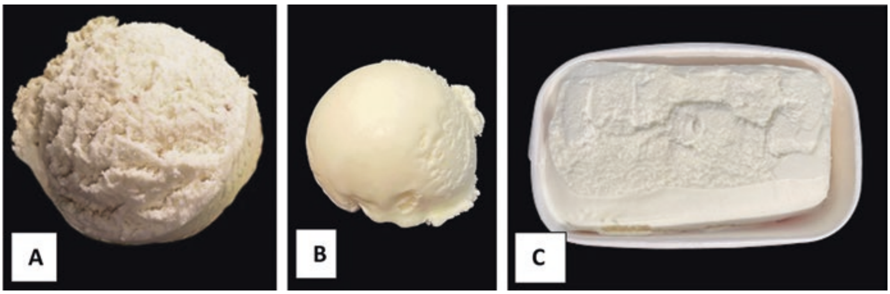

Fig. 10.3 Examples of vanilla ice cream defects observed when whipping: (**a**) brittle, crumbly, friable; (**b**) elastic, gummy, pasty, sticky; (**c**) shrunken. (Courtesy of Elizabeth C. Alvarez)

incisors and bring them together very gently, noting (relatively) how far apart the teeth may be held by the ice crystals and for how long. The evaluator should note also whether any grittiness is apparent between the teeth. A small portion between the incisors may reveal the presence of minute traces of a gritty or sandy texture (lactose, sucrose, or glucose crystals). By pressing a small portion of the frozen ice cream against the roof of the mouth, thus melting the sample quickly, the relative degrees of smoothness, coarseness, coldness, the presence or absence of sandiness, and the relative size of ice crystals may be determined. Certain body characteristics of the ice cream may become apparent by the resistance to mastication that the product offers in the mouth. Further discussion about the proper chew for ice cream evaluation is found later in the section on body and texture in this chapter.

Expect delayed taste reaction. When ice cream is first placed into the mouth, its low temperature temporarily numbs the sense of taste. The sensation of cold is usually predominant. Until the sensory nerve centers recover from the temporary anesthesia, a flavor sensation is usually not experienced. The duration of this temporary impairment of taste (Bodyfelt et al., 1988; Wehr & Frank, 2004) is dependent upon the size of the sample, its temperature, and its heat conductivity. In order not to needlessly impair the sense of taste, an evaluator should use as small or modest a sample as possible to accommodate evaluation of body and texture. A robust correlation between the melting of the ice crystals from −10 to 0 °C (14–32 °F) and the sensation of coldness in an ice cream sample has been established (Eisner et al., 2004). Evaluators should take care in consistent size of bites evaluated.

Sense the flavor. While manipulating the sample about the mouth to ascertain some of its body and texture characteristics, the evaluator should be aware that (1) the physical properties of the ice cream are constantly changing; (2) the period of temporary taste anesthesia (from coldness) is of fairly short duration; and (3) a hint of the flavor will soon manifest itself as an initial taste sensation. The judge should be alert and prepared to detect this sensation, whether it is prompt or otherwise.

The first perceived sensory reaction will probably be one of the fundamental tastes (if present), and in the order of salty, sweet, sour, and/or bitter. As the sample is warmed in the mouth, the volatile, flavor-contributing substance(s) will soon evoke a perceived aroma (smell). Since sweetness is practically always perceived prior to detection of volatile, odor-contributing substances, the characteristics of the sweetener should be noted at once. Ice cream may be perceived as pleasantly sweet, intensely sweet, lacking in sweetness, or "syrup flavor"; the latter denotes a departure from a simple, basic sweet taste.

By the time the quality and quantity of sweetness is assessed, other flavor notes will likely have registered with the taster, including possible off-flavors that may be traceable to the dairy ingredients. The judge should note, particularly, whether the flavor is harsh (coarse) or delicate, mild, or pronounced; whether the flavor seems creamy, pleasantly rich, or possesses a pronounced, objectionable, or unnatural taste; and whether the mouth readily "cleans up" after the sample has been expectorated. These are but a few of the numerous characteristics that should be observed and noted in the process of evaluating ice cream flavor (Bodyfelt et al., 1988).

After the sample has been held in the mouth for sufficient time to nearly attain body temperature, and the flavor characteristics noted, it should be expectorated. Occasionally, a sample may be swallowed, but this is the exception rather than the rule. When the sensory evaluation is in progress, the judge's focus should be on tasting and observing, not on satisfying one's sense of hunger. Unfortunately, in ice cream scoring, the keenness of flavor perception may soon be lost or destroyed. Some experienced judges may actually consume a small amount of ice cream just before judging begins in order to adjust their palates and mental processes to this product. But once judging is underway, absolutely all samples should be expectorated after completing the flavor evaluation task.

Note the melting qualities. By the time the flavor attributes have been determined, the samples previously set aside for the observation of melting properties should have softened sufficiently to yield an impression of those characteristics. The judge should observe whether each ice cream sample has retained its form and approximate size, even though some free liquid may have leaked (oozed) out, and whether the melted liquid appears homogenous and creamy, curdled, foamy, or watery (wheyed-off).

Record the results. Once all of the sensory observations have been completed, the judge should record the sensory observations on a scorecard and assign the appropriate numerical values. If the ice cream judge is to make efficient use of limited time and be reasonably accurate in one's observations, a certain routine or technique similar to that just described should be followed.

10.6 Requirements of High-Quality Vanilla Ice Cream

There are specific criteria for sensory quality that apply to each flavor of ice cream. However, since so many flavors of ice cream (and other related products) are produced in the USA, only a select few will be discussed in depth here. Vanilla ice cream is a logical candidate for in-depth coverage due to consumer popularity and to its vulnerability to off-flavors. Out of a total of the 10 most popular flavors of ice cream in the USA, vanilla and chocolate hold first and second place (IDFA, 2017).

10.6.1 Color and Package

Color. The color of vanilla ice cream or reduced fat ice cream should be attractive, uniform, pleasing, and typical of the specific flavor (French, old-fashioned, vanilla bean, etc.) stated on the label. Colorants may or may not be added to dairy frozen desserts. As long as the shade of color reasonably resembles the natural color (β-carotene pigment) of cream and is neither too pale nor too vivid, color criticisms are generally resisted for vanilla-flavored products. Ice cream flavors other than vanilla should also exhibit a color that is in harmony with and/or suggestive of the stated flavor on the package. The possible color defects of vanilla ice cream are discussed here.

Table 10.4 (Bodyfelt et al., 1988) is a guide for scoring the color, the appearance, and the package of vanilla ice cream; however, with minor revisions it can be adapted for all ice cream flavors.

Gray, dull. Though infrequently encountered, a gray, dull color is easily recognized by its "dead," soiled white, and unattractive appearance. Such ice cream suggests lack of cleanliness in manufacture, and, therefore, it is one of the more serious and objectionable color defects. If the gray color is caused by the use of flavoring with ground vanilla beans, which may be apparent by the presence of small pepper-like particles of the ground bean, the color should not be criticized. Ice cream that displays ground particles of vanilla bean (often labeled "vanilla bean") is in demand by some consumers and may be preferred in some locales of the USA.

Not uniform. Lack of color uniformity in vanilla ice cream is comparatively uncommon but may be easily recognized when it occurs. Although the most appealing color for vanilla ice cream may be a moderate creamy shade of white, certain portions may be darker or lighter than others. Particularly, this may be true of the top or bottom surface or portions next to the side of the container where some desiccation may have occurred. This defect is often associated with age (extended product storage).

If the color uniformity defect is restricted to the surface layer (which is usually discarded when taking samples), it is not considered serious. At times, streaks or waves of different color may be encountered throughout the mass of a vanilla ice cream. This appearance can be caused by varying overruns attained from multibarrel freezers or may derive from different freezers that have a common discharge.

Table 10.4 A scoring guide for color, appearance, and package of vanilla ice cream

Intensity of defect					
Defect[a]	Slight[b]	Moderate	Definite	Strong	Pronounced[c]
Dull color	4	3	2	1	–[d]
Nonuniform color	4	3	2	–[d]	–[d]
Too high color	4	3	2	–[d]	–[d]
Too pale color	4	3	2	–[d]	–[d]
Unnatural color	4	3	2	1	0
Soiled container	3	2	1	0	0
Product on container	4	3	2	1	–[d]
Underfill/overfill	4	3	2	1	0
Damaged container	3	2	1	0	0
Defective seal	2	1	0	0	0
Ill-shaped containers	4	3	2	1	0

[a]"No criticism" is assigned a score of "5." Normal range is 1–5 for a salable product. An assigned score of "0" (zero) is indicative of an unsalable product

[b]Highest assignable score for defect of slight intensity

[c]Highest assignable score for defect of pronounced intensity

[d]A dash (–) indicates that the defect is unlikely to occur at this intensity level

Sometimes, a nonuniform color may originate from successive changes in the flavor source (and associated color) throughout the freezing and packaging process.

Too high, vivid. A high color level is often objectionable because it appears unattractive and often connotes an "artificial" impression. Although individual preferences for color vary, evaluators have a general tendency to downgrade products that have an obvious, excessive intensity of color. Such a product conveys the idea of cheapness, imitation, poor workmanship, or a general lack of understanding and care on the part of the manufacturer.

Too pale, chalky, lacking. A pale, chalky, or snow-like color is the opposite of too high in color. This defect is not particularly serious, although a lighter-colored product may not have as much eye appeal as a creamy shade of white color. However, uncolored ice cream, especially vanilla, should not necessarily be criticized for lack of color. For special markets, ice cream without any form of added color is a must; many products meet that marketing objective, and it does not seem logical to penalize the color in those circumstances.

Unnatural. Unnatural color of ice cream should be recognized at a glance; the product appearance is not "in keeping" with the impression conveyed by cream (or milk fat). An unnatural color may be any shade of yellow, orange, or tan – colors that do not correspond to the true color characteristics of milk fat. Some more common off shades of color in vanilla ice cream include lemon yellows, light green yellows, orange yellows, and occasionally red yellows or tan browns. Where the use of food colors is permitted, some manufacturers may select a particular one or combination of colorants that make their vanilla ice cream(s) appear unique or distinctive. While the selected color may accomplish this purpose, it may nevertheless be faulted by some ice cream judges. Unnatural color may also arise from the use of extensive amounts of annatto-colored Cheddar cheese whey solids (Bodyfelt, 1979), of product rerun, of remelted ice cream, or of commingling of successive freezer runs of product (that have contrasting colors).

The criticism for unnatural color is a broad designation. As a general rule, this descriptor of appearance is applied to the various deficiencies or shortcomings in the hue of natural cream color. "Unnatural" color might also describe an ice cream whose color is gray, dull, high, vivid, pale, chalky, or nonuniform. Application of the most descriptive terminology possibly helps in pinpointing the source of the problem within manufacturing operations. Generally, the several color defects of vanilla ice cream do not occur at the "serious" level. Since different types of lighting will significantly affect color characteristics as viewed by human subjects, the type of light employed during examinations should certainly be standardized. Several so-called all-natural products have appeared in the US marketplace, which absolutely have no added color to any of the flavors of ice cream. Many consumers seem to prefer products that comply with the claim "no color added." However, in turn, many ice cream judges tend to severely criticize such aforementioned products (other than vanilla) for their appearance; the most common descriptor involved is "unnatural color."

Package. The ideal frozen dessert package or container should be clean, undamaged, full, neat, attractive (pleasant eye appeal), and protective of the product.

Multiuse containers (if used) should be free of dents, rust, paint, battered edges, or rough, irregular surfaces. In general, ice cream packages should reflect neatness and cleanliness throughout, giving the consumer the impression that by use of a clean, well-formed container, the manufacturer is definitely interested in supplying a high-quality product. Some more common package defects that may be encountered are a slack-filled container, bulging container, improperly sealed container, ill-shaped retail packages or product adhering to the outside of the container, ink smears, lack of a parchment liner on the top of bulk containers, and a container that is soiled, rusty, or damaged (the last two defects pertain to refillable containers).

These packaging defects, when they occur, are generally so obvious that additional descriptors or discussion hardly seem necessary. Encountering a high proportion of defectively packaged products from a production run is most unlikely, but such a problem might occur in the absence of adequate supervision. Just a few defective packages or containers present a problem of some magnitude because consumers will simply not select and purchase damaged units of products from the retail ice cream cabinet. Thus, evaluators must keep in mind an appropriate perspective that defective containers generally render a product unsalable.

10.6.2 Melting Quality

High-quality ice cream should show little resistance to melting when a dish is exposed to room temperature for at least 10–15 min (Bodyfelt et al., 1988; Goff & Hartel, 2013). During the melting phase, the mix should flow from the center (high) portion of the scooped ice cream. The melted product should be expected to form a smooth, uniform, and homogeneous liquid in the dish. Generally, ice creams with low-overrun melt more rapidly than those with high overrun (Sakurai et al., 1996; Goff & Hartel, 2013).

The melting quality may be observed by placing a scoopful of the sample on a dish and noting its meltdown response from time to time, as the other sensory qualities are being examined. Although fiber dishes may be used, petri dishes seem to permit more accurate observation of the melted ice cream; the contrast between the product and the dish background is greater. Hartel et al. (2004) reviewed factors affecting the melting rate of ice cream and described an ice cream melt procedure that involves placing the test sample on a stainless-steel screen. In setting out the samples and examining them for meltdown, some precautions are necessary:

1. Select a uniformly heated, well-lit area for placing and observing the samples (>20 °C (70 °F), if possible).
2. Set the sample out for meltdown at the beginning of the judging (if feasible).
3. Absolutely avoid dipping some of the samples with a warm dipper and others with a cold dipper.
4. Be sure that the sizes of the reasonably small samples used for the meltdown test are uniform in volume (use the same scoop or spoon for each sample).

5. Always use a flat-bottom dish (not a cup), so the melted ice cream is free to spread out.
6. Once melting has started, do not disturb the samples by tilting or swirling the containers.
7. Observe the melting quality at various stages of melting (Fig. 10.3) and score on the basis of the scheme suggested in Table 10.5.

The defects of melting quality frequently observed in ice cream judging will be elaborated.

Does not melt, delayed melting. This defect is easily recognized since the ice cream retains (or tends to retain) its original shape after it has been exposed to ambient temperature for a period in excess of 10–15 min. This defect is related to the use of an excess of certain stabilizers and emulsifiers, high overrun, the age of the ice cream, and several processing and product composition interactions that promote formation of a highly stable gel (even when the temperature is above the freezing point). This attribute is considered objectionable to some, as it conveys the impression that excessive amounts of product thickeners were used. However, in other cases, this attribute is an objective.

Flaky, lacks uniformity. This defect may be noted when the sample is about half-melted, but it is more noticeable when the sample has completely melted. Flakiness is shown by a feathery, light-colored scum formation on the surface. Sometimes it resembles a fragment of crust. Usually, no indication of wheying-off (water separation) accompanies the defect. Furthermore, it is not particularly objectionable. However, it is not in keeping with an impression of the highest quality since the product is not uniform or homogeneous in appearance.

Foamy, frothy, large air bubbles. A foamy meltdown is usually only noted when the sample is completely melted. Ice cream that exhibits many small, fine bubbles upon melting is not commonly criticized, but a sample that demonstrates a mass of large bubbles, 0.3–0.5 cm (1/8–3/16 in) in diameter, is criticized. The meltdown should be uniform and attractive; this is not the case when large air bubbles or excessive foam occur. The consumer may associate the presence of foam with

Table 10.5 Scoring guide for the melting quality of ice cream

		Intensity of defect	
Defect[a]	Slight[b]	Definite	Pronounced
Does not melt	3	2	1
Flaky	3	2	1
Foamy	3	2	1
Curdy	3	2	1
Wheying-off	3	2	1
Watery	3	2	1

Bodyfelt et al. (1988)
[a]"No criticism" is assigned a score of "3." Normal range is 1–3 for a salable product
[b]Highest assignable score for defect of slight intensity
[c]Highest assignable score for defect of pronounced intensity

excessive overrun, even though this defect may not be associated with high overrun, but rather with some of the particular constituents used in the mix.

Curdy. A meltdown with a curd-like appearance lacks product uniformity and is, for the most part, unattractive. The melted ice cream appears flaky; it separates from the mass in small distinct pieces rather than leaving the impression of a creamy fluid. The surface layer may exhibit formation of dry, irregular curd particles. To the layperson, this defect suggests souring of the milk or cream, although the cause is usually another matter. Any conditions that lead to the destabilization of proteins are potential causes of this defect in frozen dairy desserts. A combination of factors may be responsible, including (1) high acidity; (2) the salt balance (related to calcium and magnesium salts); (3) age of the ice cream; (4) certain adverse processing conditions (involving temperature, time, and method of heating, homogenization pressure and temperature, and rate of freezing and hardening); and (5) the type and concentration of stabilizers and emulsifiers.

The meltdown characteristics and the formation of a curdy/flaky appearance are influenced by the protein stability, fat agglomeration, and air cell size. In the industrial processing of ice cream, formulations and processing can be modified to increase the availability of surface-active proteins for foam stabilization (Zhang & Goff, 2004; Goff & Hartel, 2013). A partially coalesced three-dimensional network formed by the fat globules with air and ice is in part responsible for the melt resistance and smoother texture of the frozen dessert. The presence of surface-active proteins will stabilize the weak fat-serum interface first. Increased emulsification results in depletion of protein from the fat molecule that increases fat destabilization, hence decreasing melting rate and enhancing shape retention during the melting process (Bolliger et al., 2000c). Stabilizers increase the resistance of the frozen product to meltdown by decreasing the mobility of water through increasing the viscosity of the serum phase (Stanley et al., 1996; Goff & Hartel, 2013). This process has been previously explained in the separate section on emulsifiers and stabilizers. Except for viscosity, all of the factors listed above, either independently or in combination, affect fat agglomeration. Substantial fat agglomeration is responsible for the "slow melt" and/or an unattractive dry, "flaky" surface of the melted product (Abbas Syed, 2018). Protein destabilization will result in melting throughout and hence "curdy" ice cream. Occurrence of these undesirable conditions may further be prevented by minimizing temperature abuse (Stanley et al., 1996).

Wheying-off (syneresis). Wheying-off will usually be noted by the appearance of a bluish fluid leaking from the melting ice cream at the initiation of the meltdown test. If the sample is disturbed during melting or the observation is delayed, it may be difficult to see this condition. Whey separation may be noted in some ice cream and reduced fat ice cream mixes even before they are frozen. This separation is a common complaint of operators of soft-serve freezers who buy their mix from a wholesale manufacturer. These mixes tend to be stored longer and are subjected to more abuse than those mixes that are made and frozen within the same plant. Factors contributing to the difficulty include (1) the salt balance of milk ingredients, (2) the mix composition (a product with a high protein-in-water concentration can be expected to be less stable than one with a lower concentration), (3) certain adverse processing conditions, and (4) the extent of abuse (excessive agitation, air incorporation, and "heat shock").

Separation is a natural phenomenon occurring in soft-serve ice cream mixes; increasing the amount of whey proteins while maintaining the same protein content, and the use of *k*-carrageenan at >0.015% in the mix prevent visible separation, although it still occurs on the microscopic level. Locust bean gum and sodium caseinate are incompatible and undergo phase separation on a microscopic level. *k*-carrageenan has a much weaker stabilizing effect upon soft-serve ice cream emulsions formulated with sodium caseinate and locust bean gum as compared to skim milk powder emulsions stabilized with locust bean gum (Vega et al., 2005).

Watery, low-melting resistance. This defect is not consistent with the characteristics of the highest-quality ice cream. As the terms suggest, the sample melts quickly and the resultant meltdown has a thin, watery consistency. This defect is commonly associated with low solids or low stabilizer levels in the mix and may often be associated with a coarse, weak-bodied ice cream or ice milk.

Curdiness and delayed melting are two of the most common meltdown defects; they may occur simultaneously. Whey separation may be observed frequently, since protein destabilization is a common problem (Fig. 10.4).

Tharp et al. (1998) and Walstra and Jonkman (1998) reported that shape retention and melting rate depended on the degree of fat destabilization. Higher degrees of fat destabilization resulted in less fat content in the drip loss of melted ice cream samples (Tharp et al., 1998; Bolliger et al., 2000c). The presence of proteins or polysaccharides in ice cream formulations influences the shape retention of treated ice cream samples. Milk proteins affected melting and imparted body to ice cream products. A proposed mechanism for protein effects on body and texture is the formation of networks of phase-separated milk proteins and polysaccharides (Syrbe et al., 1998; Abbas Syed, 2018). Polydextrose was an important factor to improve shape retention in ice cream samples by binding water or reinforcing the existing fat network due to its complex branched structure (Smiles, 1982; Craig et al., 1996; Akbari et al., 2019). Ice cream with high overrun or fat tends to melt slowly. Air cells insulate and fat stabilizes the ice cream structure (Marshall et al., 2003; Akbari et al., 2019).

10.6.3 Body and Texture

Body and texture are important properties of ice cream and good-quality indicators. The associated body and texture defects are evaluated by biting and chewing the product. Different guidelines have been developed to evaluate the sensory attributes of ice cream (Bodyfelt et al., 1988; King & Arents, 1994). The following are the evaluation and scoring guidelines for body and texture used in the CDPEC.

Unfortunately, the terms "body" and "texture" are often used indiscriminately and loosely (Bodyfelt et al., 1988); adding to the confusion may be the combined use of the two terms, either in reference to one or to the other term. As it relates to

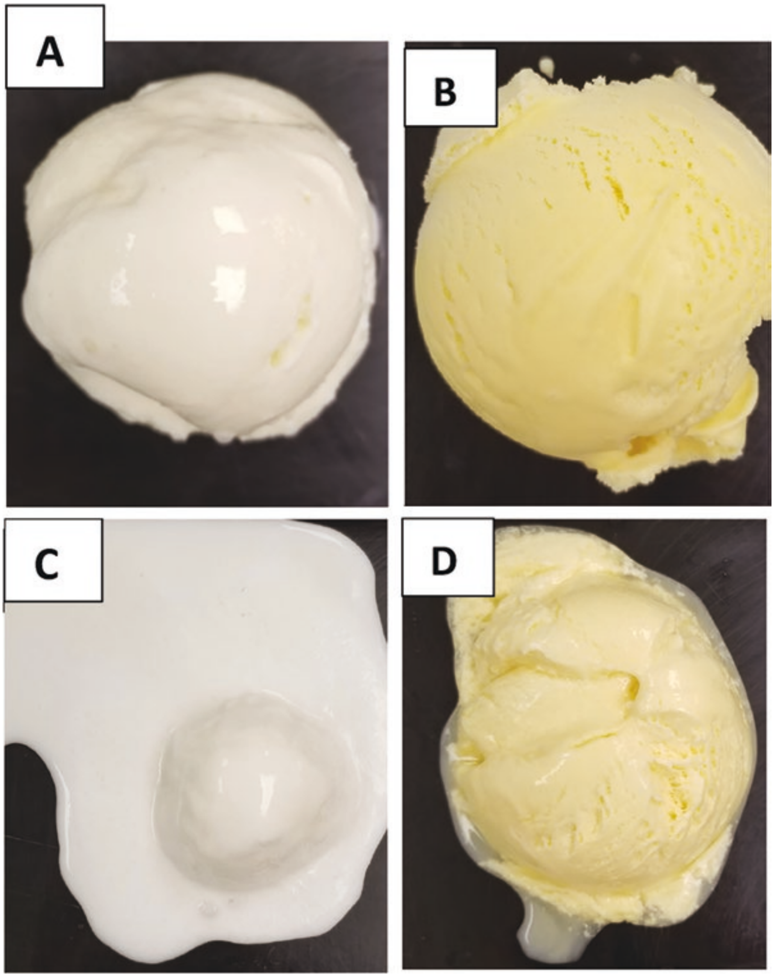

Fig. 10.4 Examples of various meltdown defects of ice cream as observed after elapse of 0, 10, 15, and 20 min: (**a**) the "ideal" melting characteristics; (**b**) does not melt; (**c**) curdy meltdown (non-homogenous); (**d**) wheyed-off (watery separation). (Courtesy of Stephanie Clark)

ice cream, *body* is best defined as the property or quality of the ice cream as a whole. *Texture* refers to the parts or structure of ice cream that make up the whole. Both the body and texture of ice cream may be partially determined by applying the senses of touch and sight when the evaluator observes the product's appearance on dipping. The desired body in ice cream is that which is firm, has substance (has some resistance), responds rapidly to dipping, and is not unduly cold when placed into the mouth.

The following is a description by Tharp (1997) about the "proper chew for ice cream evaluation" after transferring the portion to the mouth and beginning the oral manipulation of the portion: "As oral manipulation of the portion begins, it is important to remember that many of the desirable properties of ice cream are related to the presence of ice, so focus first on those properties – the relative firmness of body and smoothness of texture. The time available for that is relatively short, because the ice disappears quickly at body temperature. If dental sensitivity permits, begin the evaluation by biting down through the portion with the front teeth – iciness will be reflected by the perception of a crunchy sound. Then, move the portion about in the mouth with the tongue, cheeks, and lower jaw. Concentrate on the degree of resistance to that movement (body) and the smoothness of the product while it is still frozen sample (texture). There are two exceptions to the generalization that body and texture stimuli will disappear when the product has melted. First, the hard crystals that characterize the sandy characteristic will persist after melting, particularly the lactose crystals. Also, the sensations that constitute the greasy characteristic – a slippery coating on the inner surfaces of the mouth, especially on the teeth – will continue to be perceived after the portion melts. After melting, with closed mouth, concentrate on the nature of the flavor. Focus on the taste elements perceived in the mouth (sweet, salty, acid, bitter). Then exhale nasally in order to allow the vapors released from the warming product to contact the aroma perception area in the nasal cavity. Concentrate on whether the aroma is acceptable and, if not, on identifying the characteristics of the undesirable elements. Don't swallow when observations have been completed – it can lead to a feeling of satiety that dulls the senses. Rather, the melted product should be expectorated in some appropriate way. Multiple samplings may be necessary to clarify observations. Finally, reflect on the flavor sensations that remain after expectoration. These residual perceptions, referred to as 'aftertaste,' make up an important element of the overall flavor judgment. A good quality product leaves behind a fresh, clean sensation, consisting only of lingering hints of the characterizing flavor and the basic dairy character. Consideration of aftertaste often makes possible the specific identification of such characteristics as the whey flavor."

Firmness, resistance, and coldness are strongly influenced by the product's temperature. As emphasized earlier, proper tempering of the samples from −18 to −15 °C (0–5 °F) is essential, particularly for properly assessing the body of samples. The desired texture of ice cream is that which is fine, smooth, velvety, and carries the perception of creaminess and homogeneity throughout. Small ice crystals and small air cells are required for portraying good product texture. If the product is too cold when evaluated, the texture may appear worse than it actually is. Just the opposite is true when the product is too warm. An experienced evaluator of ice cream will have learned to partially compensate for a less than optimum tempering effort on the samples but will still definitely prefer to observe body and texture characteristics when the product is properly tempered. Proper tempering assures a competent, conscientious ice cream judge that more relevant and objective assessments of the body and texture are being achieved. The scoring guides for the body and texture of ice cream are given in Table 10.6. The various body defects that may be encountered in ice cream are termed or classified as follows:

Table 10.6 Scoring guide for body and texture defects of vanilla ice cream

	Intensity of defect		
Body and texture	S	D	P
Crumbly	4	3	2
Fluffy	3	2	1
Greasy	4	2	1
Gummy	4	2	1
Icy/coarse	4	2	1
Sandy	2	1	U
Soggy	4	3	2
Weak	4	2	1

Bodyfelt et al. (1988)
Normal range 1–5. Range of scores for body and texture quality: Excellent 5 (no criticism)
S slight, *D* definite, *P* pronounced
U indicates product of unsalable quality. Official rules prohibit use of such products in contest

Crumbly: Brittle, falls apart when dipped.
Fluffy: Large air cells, disappears quickly in mouth, very weak.
Greasy: A distinct greasy coating of the mouth surface after expectoration, a tallowy or Chapstick® sensation on the lips after evaluation.
Gummy: Opposite of crumbly, pasty, putty-like; feels somewhat sticky like gum between the tongue and roof of the mouth.
Icy/coarse: Most common texture defect, not smooth, ice crystals or particles.
Sandy: One of the most objectionable defects in ice cream; fine hard particles, sand-like, lactose crystals.
Soggy: Heavy, doughy, pudding-like, due to lack of air cells (low overrun).
Weak: Lacking body and resistance, low solids, watery, more like ice milk.

10.7 Description of Body Defects

Body defects shown in ***italic/bold*** are evaluated in the CDPEC.

Crumbly*, brittle, friable.* A brittle, crumbly, and friable body is evident by a tendency of the ice cream to fall apart when dipped. The product appears to be dry, open, and sometimes as friable as freshly fallen snow. The particles seem to lack the needed property to stick together or be retained as a common mass (Fig. 10.4). When such a sample is dipped, many loose particles are likely to be noted on the remaining ice cream or the dipping implement. The defect may be provoked by the use of certain gums, inadequate stabilization, too high an overrun, and/or low total solids in the mix (Marshall et al., 2003; Abbas Syed, 2018). Lower-fat ice creams (7%) tend to develop crumbly texture more readily than an ice cream mix with higher fat content (10%) (Roland & Phillips, 1999; Akbari et al., 2019). A similar defect is identified as *flaky* and *snowy*. In this case, a flaky, snowy-textured ice cream manifests itself by a tendency to fall apart when dipped. In this respect, it has the same characteristics as that noted in a crumbly body. The condition seems to be associated with low solids, low stabilizer, and/or high overrun in the product (Marshall et al., 2003).

Gummy*, pasty, sticky, elastic.* A gummy or sticky body is the exact opposite of a crumbly body. Such ice cream seems pasty, putty-like, and, under certain conditions of temperature and manipulation with a spoon, it somewhat resembles taffy (Fig. 10.4). The ice cream hangs together, so much so that it has a marked tendency to "curl" just behind the scoop as it is pulled across the surface, which leaves coarse, deep, irregular waves. Frequently, there is a correlation between a gummy body and a high resistance to melting; gummy ice cream often resists melting. If melting does occur, the mass often tends to retain its original shape.

The gummy body defect is associated with an excessive use of stabilizers, certain corn syrup sweeteners, or both (Marshall et al., 2003; Abbas Syed, 2018). One should recognize that all ice cream is sticky to some extent, due to the concentration of carbohydrates in the product. Ice cream should only be severely criticized when the stickiness is so severe that it is obviously pasty and would probably be difficult to dip or scoop. As an important economic consideration, gummy (or sticky) ice cream fails to yield as many scoops per unit volume as typical-bodied products.

Shrunken. A shrunken ice cream manifests itself by the product mass being withdrawn from the sides of the container. This defect is readily obvious when the package is first opened for examination, and the feature is not evaluated in the CDPEC. This defect may be associated with high overrun, low mix solids, fluctuations in air pressure, or substantial changes in altitude during product distribution (Dubey & White, 1997). However, under certain storage and/or transport conditions, any ice cream may shrink. Since heat shocking may be one of the contributing causes, the judge should be alert to correlate, if possible, this defect with a coarse, icy texture. All the reasons or causes of shrinkage are not clear to technologists; occurrences of the problem are often quite unpredictable. Product shrinkage may suddenly be encountered where none existed before, even when no changes were made in the product's composition or manufacturing procedures. A basic predisposition to shrinkage is apparently imparted to frozen dairy desserts by certain milk components, especially proteins (Goff et al., 1995: Abbas Syed, 2018). Certain environmental conditions, such as season of the year, stage of lactation, feed, etc., may unfavorably affect the normal formation of strong air cell walls (which contain proteins) in the frozen mix. Other associated factors seem to merely aggravate the conditions that predispose ice cream to shrinkage.

Soggy*, heavy, doughy, pudding-like.* A heavy, resistant body is best described by the terms heavy, doughy, or pudding-like. The descriptor "soggy" has also been used in association with this defect (CDPEC scorecards), although perhaps inappropriately. This defect can readily be noted when the product is dipped. Portions of an ice cream with this criticism, when placed in the mouth, seem colder than those free of the defect. Apparently, this is due to a greater heat conductivity of heavy-bodied products. This defect is associated with high solids content of the mix, especially increased fat and sugar (Dubey & White, 1997; Abbas Syed, 2018). Other suggested causes are too much stabilizer and/or a low overrun. Through product formulation, individual ice cream manufacturers can control the “degree of bite resistance” in the body of their ice cream. Some processors may purposely strive for an extremely heavy body in order to achieve product uniqueness. Many consumers seem to prefer a product with a great deal of bite resistance.

The ice cream judge should be aware of the wide range of consumer preferences and only criticize a heavy body as a defect when it is obviously “out of line.” Though this trend may change in time, many consumers are willing to pay a premium price for high solids, low overrun ice cream. The body of such products is generally quite resistant, firm, or heavy. A study of different levels of fat and sugar on the sensory properties of ice has determined that increasing levels of fat and sugar are associated with an increase in doughy texture (Guinard et al., 1997; Abbas Syed, 2018).

Weak*, watery.* A weak, watery body is usually associated with a low-melting resistance and a thin, milky, low-viscosity meltdown. A weak-bodied ice cream conveys the impression of having a low proportion of food solids, when a sample is placed into the mouth. The mouthfeel of the sample may more likely resemble reduced or nonfat ice creams (or the former, ice milks) more than ice cream. Such an ice cream may be easily compressed by slight pressure of a spoon or scoop. This defect may also be associated with coarse texture; low solids and high overrun also contribute to causing a weak-bodied ice cream. Weak body defects have also been attributed to heat shock (Morely, 1989).

10.8 Description of Texture Defects

Fluffy, *foamy, spongy.* A fluffy texture may be noted in high-overrun ice cream, with a general “openness” throughout the product. Such an ice cream tends to compress substantially upon dipping or applied pressure with a flat object. This defect is closely associated with a high overrun. A fluffy ice cream usually melts slowly in the dish, yielding a relatively small proportion of liquid, which is often foamy and spongy (Marshall et al., 2003). Fluffy is harshly criticized since the product may run outside of the standard of identity (4.5 lb/gallon).

Greasy, *buttery, churned.* This defect may be noted by the presence of actual butter particles in the mouth after the ice cream has melted, or by a distinct greasy coating of the mouth surface after expectoration. Another way to recognize this defect is by a tallowy or Chapstick® sensation on the lips after evaluation. Common causes of a greasy mouthfeel are inadequate homogenization, a relatively high milk fat content, and over-emulsification of the product. In soft-serve frozen dairy desserts, churning may be due to de-emulsification of milk fat during prolonged agitation in the soft-serve freezer. If fat globule aggregation exceeds a size of about 30–50 μm, visible fat particles form in the samples with the associated buttery defect (Eisner et al., 2004; Amador et al., 2017). High-fat mixes are more susceptible to this defect; incomplete homogenization and over-emulsification aggravate this problem.

***Icy, coarse**, grainy, ice pellets, spiny.* This defect ranks as the most commonly encountered texture defect in frozen dairy desserts. Such a product may be characterized by its structural makeup of comparatively large ice crystal particles; a feeling of unusual coldness within the mouth; a simultaneous lack of a smooth, velvety character; and a frequently associated rough visual effect. When a sample of a coarse or icy product (most common descriptors) is placed between the upper and lower incisors, a temporary resistance is exhibited before the incisors are finally permitted to come together. This form of a slight, temporary resistance should not be mistaken for another form of bite resistance provoked by another texture defect known as sandiness (discussed later). The resistance of coarse texture or iciness is quite temporary, almost instantaneous, while that of sandiness is of longer duration.

A coarse texture is due to comparatively large particles of frozen water; each ice crystal is sufficiently large that the coarseness is obvious. When extremely coarse, grainy textures are noted; the product is criticized as being icy or spiny. Ice cream samples with a pronounced icy texture may be readily noted during the dipping process from the "feel" of the scoop or spade as it strikes or breaks the tiny icicles or spines. A coarse, icy texture may be manifested by either the presence of localized, layer-like, ice crystals, or by grainy ice particles distributed throughout the product. The layer-like crystals are frequently found along the sides of the container where melting and subsequent refreezing may have occurred. Both kinds of ice crystals are objectionable, since the product lacks the smooth, homogenous, and velvety texture that is typically deemed most desirable for high-quality ice cream.

Ice crystals can be felt between the teeth and/or with the tongue, by immediately pressing the ice cream sample against the palate upon oral sampling (Stampanoni-Koeferli et al., 1996). As continuous melting of ice cream occurs in the mouth, larger ice particles are momentarily left behind, and they register a distinct cold sensation. Formation of ice crystals plays an important role in determining the quality of ice cream, and small crystal sizes are desirable (Adapa et al., 2000; Wildmoser et al., 2004; Drewett & Hartel, 2007; Amador et al., 2017). Ice crystals have a natural tendency to increase in size with increased storage time; the larger crystals selectively become larger at the expense of the small ice crystals, which disappear. As a result, ice cream frequently becomes more coarse with time in storage.

Much of the technology of ice cream formulation, freezing, and storage is designed to produce small ice crystals and delay their growth during storage or distribution. Since, almost invariably, ice cream will be exposed to some "heat shock" (temperature fluctuations and storage at higher than ideal temperatures), specific steps are advisedly taken to provide protection against fluctuations in storage temperature (Lucas, 1941; Tobias & Muck, 1981; Tobias, 1982; Bodyfelt, 1983a, b). Stable storage conditions at −20 °C (−4 °F) for 60 days prevented the observance of noticeable texture differences during the course of the shelf-life study of ice cream (Alvarez et al., 2005). Effective stabilizers and emulsifiers, microcrystalline cellulose, and low DE corn syrups are commonly used as "protective" agents (Stanley et al., 1996; Goff, 1997; Flores & Goff, 1999; Abbas Syed, 2018). Close control of production, inventories, and rotation of product to help ensure that the oldest product is used first are important measures to help keep storage time minimal.

Among the many possible causes of coarse-textured ice cream are the following:

Faulty formulation
Inadequate protection against heat shock
Ineffective or improper stabilization and/or emulsification
Inadequate hydration of dry mix constituents
Incomplete protein hydration
Inadequate homogenization
Insufficient aging of the mix
Too high product temperature out of the freezer
Extended interval between freezing, packaging, and/or transfer to the hardening system
Slow hardening
Too high a hardening temperature
Fluctuating storage temperatures
Extended storage and distribution times

Some production problems are mechanical, such as dull freezer blades, which prevent the ice cream mix from freezing properly, while other product quality shortcomings are traceable to inadequate management and supervision. Sensory evaluation helps to identify the nature of product defects and pinpoint deficiencies of production and distribution.

Sandy, *gritty.* A sandy texture is certainly one of the most objectionable texture defects encountered in frozen dairy desserts, but it is also one of the easiest to detect. Such a texture conveys to the tongue and palate a definite lack of smoothness and an associated distinct form of grittiness. When the sample melts, there remains in the mouth fine, hard, uniform particles that suggest fine sand. These particles are crystals of lactose.

The presence of these sand-like particles can be noted in several ways: (1) by pressing a thin layer of the suspect ice cream against the roof of the mouth with the tongue to secure quick melting; (2) by bringing the teeth together slowly on a portion of it; or (3) by pressing a small quantity of the product between the thumb and forefinger. Sandy texture should not be confused with the coarse, icy texture, which results from the presence of comparatively large ice crystals. The lactose crystals dissolve markedly more slowly than ice crystals; therefore, they may be noted even after the ice cream has fully melted.

A high percentage of serum solids, high total food solids, product age, and "heat shock" are all related to the development of this defect (Livney et al., 1995; Abbas Syed, 2018). When sandiness occurs, the judge should be alert to the likely presence of other defects that are commonly associated with frozen dairy desserts stored under unfavorable conditions (coarse/icy, and/or shrinkage, and/or whey flavor).

10.9 Flavor

High-quality vanilla ice cream should be pleasantly sweet, suggest a creamy background sensation, exhibit a delicate “bouquet” of vanilla flavor, and leave a most pleasant, but brief, rich aftertaste (Bodyfelt et al., 1988, Bodyfelt, 1983a; Kwak et al., 2016). The flavor intensity of the vanilla, the sweetener, and the various dairy ingredients should not be so pronounced that, when first tasted, one component of the overall flavor seems to predominate over the others. All of the ingredients should blend to yield a pleasant, balanced flavor (Piccinali & Stampanoni, 1996).

The flavor evaluation of ice cream offers some difficulties unlike those encountered in the scoring of butter, cheese, and milk. In comparison to most other dairy products, ice cream is intensely sweet. This is the first obstacle confronted by the ice cream judge. The sweetness is often so pronounced to inexperienced judges that they frequently find it difficult to identify other flavor notes that may or should be present. A second obstacle to the successful evaluation of ice cream flavor is simply taste bud fatigue due to the combined effect of sweetness and coldness on the organs of taste. A third obstacle for the ice cream judge is the mouth-coating effect of milk fat. Some of the taste bud sites may be partially coated or blocked by milk fat, and hence lessen the ease of taste perception (Stampanoni-Koeferli et al., 1996; Guinard et al., 1997; Goff & Hartel, 2013).

Usually, inexperienced evaluators look forward to the judging of ice cream with considerable enthusiasm. After tasting a few samples, however, this enthusiasm probably begins to wane. The appetite is satisfied, and novice judges may have to force themselves to continue judging a set of samples that have started “to taste alike.” Fortunately, experienced judges score ice cream with about the same ease as they evaluate other products. Some evaluators initially condition their mouths by tasting several samples, in order to adapt to the sweetness and coldness before actually placing flavor judgments on any of them. Frequent rinsing of the mouth with water between ice cream samples is apparently helpful for some evaluators, but this is primarily an individual preference as to whether or not it is a beneficial technique.

When evaluating ice cream for flavor, tasting is usually performed from a scooped sample on a plate. Taste sampling directly from the original container is not advised due to potential risk of personal sanitation (hygiene) problems and irreversible temperature abuse of ice cream samples. The authors and most ice cream judges prefer to evaluate one sample at a time. In this approach, the judge compares the flavor, body, and texture with a fixed, mental standard of the “ideal” product, rather than with that of another sample.

Due to the severe coldness of ice cream and reduced fat ice cream, some off-flavors may not be sufficiently volatile to be immediately detectable or recognizable. As pointed out earlier, the body and texture of the ice cream must be determined on the ice cream at the typical serving temperature, but any off-flavors present will become more apparent as the sample warms up. Warming occurs within the mouth as well as on the sample plate. After first assessing the body and texture of the sample, the evaluator may taste a warmer sample portion for at least one of several phases of the flavor judgment that should be completed. This approach may be somewhat complicated by the fact that the "flavor balance" may change with temperature and, hence, cause some of the flavor notes to dominate others at the higher temperatures, but not at the lower ones. Thus, the best observations of the actual "flavor balance" should be undertaken at normal consumption temperatures for frozen desserts. This approach is especially important when a number of samples must be evaluated in succession. The evaluator must try to maintain accuracy and objectivity, and in the process, avoid both mental and physical fatigue as well as taste, touch, and odor adaptation. When the human senses are continuously exposed to a given stimulant, sensory perception diminishes because of the phenomenon of adaptation.

Due to the numerous ingredients that may be used in ice cream manufacture, one may expect a wide variety of flavors and potential off-flavors. In general, all frozen dairy desserts are susceptible to the development of most of the off-flavors encountered in other dairy foods. The flavoring systems used for ice cream, reduced fat ice cream, and sherbet may be obtained from several sources, and each one is manufactured by different processes. Consequently, the given source of flavoring itself may contribute to a surprising variety of flavors or flavor notes. Additionally, ice cream possesses varying degrees and qualities of sweetness. The major flavor defects of ice cream and reduced fat ice cream may be classified according to their origin, as summarized in Tables 10.3 and 10.7.

Knowledge of the possible source of off-flavors is quite useful when troubleshooting, pinpointing, and correcting difficulties with sensory quality. While the aforementioned tables cover most of the anticipated problems, there is always the chance for the highly unusual or extraordinary to happen. For instance, the eggs may be oxidized, the cream may have an intense absorbed or medicinal off-flavor, or the liquid sugar or corn syrup may be fermented. Occasionally, when production and quality control personnel least expect it, an off-flavor may be encountered that defies description. As an aid to problem-solving, a description of some of the more common flavor defects of frozen dairy desserts is presented as a review for the prospective ice cream judge.

In evaluating ice cream, the judge should particularly note the kind, the quantity, and the relative quality of the flavoring used in the product. If the ice cream is vanilla, for instance, the judge should constantly keep in mind the desired delicate "bouquet" (aroma note) that is so highly prized and sought in a high-quality vanilla ice cream. The judge should not deviate from an established mental standard or predetermined "flavor profile" of the "ideal" vanilla ice cream. Both the pure vanilla (if used) or the vanilla/vanillin blend, and the amount used, should blend with the other ingredients to provide a pleasing, refreshing, and appetizing product. The judge should be eager for a second (and a third) bite of the ice cream if it is one of high quality. Four flavor defects related to the product-flavoring system may be experienced, which are described in the following paragraphs. Flavors showing in ***italic/bold*** are evaluated in the CDPEC.

Table 10.7 Classification of ice cream flavor defects according to their cause of origin

I. Off-flavors due to the ingredients used	
A. *The flavoring system*	
1. Lacks (deficient)	3. High flavor (excessive)
2. Lacks fine flavor (harsh, lacks balance)	4. Unnatural (atypical)
B. *Sweeteners*	
1. Lacks sweetness	3. Syrup flavor (malty, Karo-like)
2. High sweet	
C. *Dairy products*	5. Oxidized (cardboardy, metallic)
1. Acid (sour)	6. Rancid (lipolytic)
2. Cooked (rich, nutty, eggy)	7. Salty
3. Lacks freshness (stale)	8. Whey (graham cracker-like)
4. Old ingredient	
D. *Other ingredients*	
1. Eggs (eggy) 2. Stabilizer/emulsifier	3. Non-milk food solids
II. Off-flavors due to chemical changes (in the mix or product)	
1. Lacks freshness (stale, old)	3. Oxidized (cardboardy, metallic)
2. Rancid (lipolytic)	4. Storage
III. Off-flavors due to mix processing	
1. Cooked (rich, nutty, eggy)	2. Caramelized/scorched
IV. Off-flavors due to microbial growth in the mix	
1. Acid (sour)	2. Psychrotrophic (fruity/fermented, cheesy, musty, unclean)
V. Off-flavors due to other causes	
1. Foreign contaminants	2. Neutralizer

Bodyfelt et al. (1988)

10.9.1 Off-Flavors from the Ingredients Used[1]

Typically, the first perceived flavor or off-flavor in a frozen dairy dessert is one associated with the flavoring material used. Due to the volatility of flavor substances, it tends to register early with the olfactory center. A defective source of flavoring could contribute to any flavor defect.

High flavor *(excessive).* This flavor condition, when it occurs, is best recognized when the sample is first placed into the mouth. The intensity of the flavoring seems so striking or sharp that the desired, pleasant flavor blend is not achieved due to the harsh tones imparted by the flavoring level observed in the product. Ice cream that is too highly or excessively flavored is not severely criticized as a rule, especially if

[1]The following materials are directly from the previous edition (Bodyfelt et al., 1998) unless otherwise noted by the update reference.

the quality of the flavoring used is high. An associative "ethanol-like" note may be present.

High sweet. An ice cream that is observed to be excessively sweet tends to exhibit a candy-like taste sensation; this defect is readily noted upon the first stages of tasting. Too much sugar (or other form of sweetener) tends to interfere with the overall desirable blend of flavor(s). Another unfortunate characteristic of a given ice cream that is perceived as being too sweet is a general lack of refreshing property.

Lacks fine flavor *(harsh, coarse).* This criticism is generally used to describe an ice cream that is basically "good" or "very good," but for some less than clear reason, it seems to just barely fall short of being "perfect" or "ideal." In some instances, such an ice cream may simply lack an overall "flavor balance" (blend), but otherwise the product appears to be free of any hint of detectable flavor shortcomings. In other instances, the sensory dimensions of a pure (real) vanilla or a vanilla/vanillin blend may be determined by close sensory examination to be slightly less than expected or desired. Experienced ice cream judges are able to recognize the desirable, delicate, balanced flavor notes of a high-quality flavor. The novice judge should remember that "lacks fine flavor" is not readily described in more definitive or specific terms. Thus, this descriptor should practically be considered a "last resort" in describing a minor flavor defect related to the flavoring system. The observations of Gassenmeier (2003), considering the loss of vanilla flavor to xanthine oxidase–catalyzed oxidation, may also apply to the loss of fine flavor in ice cream, as natural vanilla extracts contain a number of complementary flavor compounds besides vanillin that are susceptible to oxidation.

Low flavor (lacks flavoring). An ice cream with this defect is often criticized as flat, bland, or deficient in the amount of added flavoring. Even though the ice cream may be pleasantly sweet and free from any dairy ingredient off-flavor, it seems to lack the characteristic delicate "bouquet" of excellent vanilla; the desired intensity is missing. The obvious cause of this defect is failure to use sufficient quantities of flavoring. However, there are instances when certain ingredients mask the vanilla flavor, thus invoking the "lacks flavor" criticism, even though the added quantity of flavoring seemed adequate to the manufacturer.

Xanthine oxidase, an enzyme active in raw milk, may catalyze the loss of vanilla flavoring by oxidation of vanilla to vanillic acid, when flavoring is added to raw ice cream mix and stored under refrigeration prior to pasteurization (Gassenmeier, 2003).

Lacks sweetness. An ice cream that lacks sweetness is readily noted upon tasting; the product simply manifests a distinct flat or bland taste. The desired or anticipated blend of flavor is missing. An adequate amount of sweetener is required to bring out the full-flavor "bloom" in a given flavor, whether it is vanilla, fruit, or chocolate ice cream. Since preferences for the desired level of sweetness vary among individuals, the product is not severely criticized for lacking sweetness, within reasonable limits, if this is the only flavor defect encountered. However, a severe deficiency in sweetener solids may give rise to readily evident defects in body and texture or mouthfeel.

Syrup flavor *(malty or* "Karo®"*-like).* A desired property of sweeteners in ice cream as well as other food systems is that they impart the basic sweet taste and simultaneously be free of other flavor notes. Some flavor technologists have coined the term "clean sweet" for sucrose. In the past, the more complex flavor imparted by some sweeteners was termed "unnatural sweetness." This sweetener off-flavor is still commonly encountered in certain forms of corn syrups and corn syrup solids; hence "syrup flavor" is the common descriptor for this characteristic defect. When honey is used as a sweetener, the resulting sweetness may be criticized as syrupy unless the ice cream is intended to be honey-flavored. Frequently encountered descriptions for syrup flavor might be malty, "Karo®"-like, Sugar Daddy®-like, caramel-like, molasses-like, marshmallow, or similar to low levels of burnt sugar. Some evaluators distinguish syrup flavor from high sweetness by the "catch" experienced in the throat, similar to the feeling after a dose of cough syrup. Certain forms or sources of corn syrup solids, corn syrup, and some liquid sugar blends with excessive levels of corn syrup, when used in ice cream in high proportion to sucrose, may convey a slight to distinct malty or caramel-like off-flavor. Too often, a syrup off-flavor may mask or otherwise interfere with the release of the given flavoring, especially delicate flavors like vanilla. Additionally, syrup off-flavor tends to be enhanced by the cooked flavor note of the mix. Simultaneously, a gummy or sticky body can often be associated with an ice cream or ice milk that has also been criticized for "syrup flavor."

Unnatural flavor (atypical). Frequently, the manifestation of "unnatural flavoring" in ice cream may convey the sensation of being too high in flavoring. The impression of unnatural flavoring may be of several types and intensities, depending upon the kinds and proportions of constituents used in preparation of the extract, emulsion, or flavor concentrate. For example, synthetic or imitation vanilla, which is often used to fortify vanilla extracts, may tend to produce a "quick," sharp, piercing, or burning sensation on the sides and base of the tongue. Generally speaking, the unnatural flavor criticism is observed more frequently in ice creams that are labeled "vanilla flavored" or "artificially flavored vanilla," than in products labeled "vanilla" or "real vanilla." Details of ice cream classification and associated labeling requirements (as a function of vanilla or vanilla-flavoring category added to the product) are summarized in Table 10.8. To minimize bias in ice cream judging or any product evaluation, it is crucial that the sensory observations be conducted without the evaluators examining the product labels before completion of the task.

Another form of unnatural flavor may occur due to the addition (usually unintentional) of extracts other than vanilla to the ice cream mix; the imparted flavors may be suggestive of spices, coconut, marshmallows, custard, candy, nuts, lemon, cherry, maple, "buttery," or "smoky." Numerous other unnatural flavors are possible in frozen dairy desserts, depending on the circumstances of manufacture. If one of the aforementioned or another atypical flavor notes are perceived in vanilla ice cream, the appropriate recourse is to criticize the sample for "unnatural flavor." This flavor also frequently arises through the accidental intermixing of two or more product flavors when ice cream freezing machines are converted from one flavor to another.

Table 10.8 Labeling requirements for various categories of vanilla ice cream according to the flavor source

Flavor declaration	Flavor requirements			
Ice cream type or category	Characterizing flavor declaration	Subsidiary flavor declaration	Sources	Quantity
Category 1	*Vanilla*	None	Vanilla beans, extract, or powder; *no artificial flavor* permitted	Sufficient to impart characterizing flavor
Category 2	*Vanilla* flavored	"Vanilla and artificial vanilla flavor" or "artificial flavor added" or "artificial vanilla flavor added"	Vanilla beans, extract, or powder plus artificial vanilla: i.e., twofold, or fourfold vanilla-vanillin extract (or powder)	Vanilla beans, extract, or powder, in combination with vanillin, not to exceed 1 oz. per "unit of vanilla constituent" as described in vanilla standards. Concentrations may be used where ratio of "vanilla constituent" and vanillin remain 1:1[a]
Category 3	Artificially flavored *vanilla* or artificial *vanilla*	None	Artificial vanilla, with or without vanilla beans, extract, or powder	If the amount of vanillin used is >1.0 oz. per "unit of vanilla constituent," the product must be labeled in accordance with this category. Product may be flavored exclusively or in part with other artificial vanilla, e.g., ethyl vanillin

Source: Adapted from Code of Federal Regulations 2006. Title 21, Part 135

[a]For example, if 1 gal of vanilla extract contains extractive from 26.7 oz. of vanilla beans, a maximum of 2 oz. vanillin may be used. One (1.0) unit "vanilla constituent" = total extractable flavor components of 13.35 oz. of vanilla beans with a moisture content less than or equal to 25%, or a proportionally greater amount of vanilla beans if >25% H_2O

In fact, this is probably the most common cause of this type of unnatural (or atypical) off-flavor in US commercial ice cream. This is unfortunate, since numerous consumers (through surveys) have indicated that they were the recipient of a "surprise flavor"; a "flavor" they did not bargain for at the time of purchase (Bodyfelt et al., 1988; Goff & Hartel, 2013).

The unnatural flavor problem also frequently arises through the accidental intermixing of two or more product flavors when ice cream freezing machines are converted from one flavor to another.

10.9.2 Dairy Products as a Source of Defects

***Acid** (sour).* An acid or sour off-flavor in frozen dairy desserts may be distinguished from other off-flavors by a sudden, tingly, taste sensation (on the tip or top of the tongue), plus an associated "clean and refreshing" mouthfeel. This flavor defect may be caused by the use of acid whey in the ice cream mix (Westerbeek, 1996; Abbas Syed, 2018). The off-flavor may also result from uncontrolled bacterial activity at elevated temperature; other bacterial off-flavors may also be present. In such cases, the flavor defect(s) may be more appropriately described as a combination acid (sour) and psychrotrophic bacteria-caused off-flavor (unclean, fruity, or putrid). The acidity (and/or psychrotrophic defect) may have developed in one or more of the dairy ingredients used, or the mix may have been stored at a favorable growth temperature for lactic acid forming or other types of bacteria. In any severe temperature abuse situation, the bacterial count would ordinarily be expected to exceed established regulatory limits. A serious processing and product handling error or disregard for quality control is evident when an acid taste is so intense that the evaluator is inclined to think of the sample as a sour product. Such a product should never reach the marketplace; the consumer would often be offended by the presence of this unusual off-flavor in a sweetened product such as ice cream.

Cooked. The "cooked" flavor of ice cream is commonly experienced. It is also referred to as "rich," "eggy," "sulfide," "custard," scalded milk, condensed milk, or caramel-like. These flavors, although they may differ slightly in some respects, actually have much in common. A cooked milk or cream "background flavor" is the characteristic flavor note of this group of heated flavor sensations. Depending on its intensity, this flavor sensation is usually somewhat delayed in terms of the initial perception, but then it tends to persist after the sample has been expectorated. A highly cooked or heated flavor of the product may tend to "mask" or modify the vanilla flavoring. The resulting flavor sensation may be rather pleasant, although it would usually be perceived differently than a pure vanilla flavor.

Cooked (or rich) flavor is not considered a serious defect in ice cream, unless it is so intense as to be perceived as caramel, scorched, or burnt. In fact, some manufacturers intentionally strive for a slight to moderate degree of cooked (rich, nutty, custard-like) flavor in vanilla ice cream. They believe, as do the authors (Bodyfelt et al., 1988; Goff & Hartel, 2013), that a slight to modest cooked flavor note helps convey a fuller, smoother, richer flavor in the product. Quite commonly, the dairy ingredients incorporated into ice cream will have already been pasteurized, but federal and state regulations require that the assembled or final ice cream mix must also be pasteurized. Second, or subsequent, heat treatment is likely to produce some degree of cooked flavor in the mix. As indicated earlier, this is not typically objectionable in ice cream; in fact, it may be quite desirable or preferred in many instances.

An excessive-cooked off-flavor usually results from using ingredients that have received such severe heat treatment that a scorched or burnt effect is attained. Mix pasteurization, under some adverse conditions, may also develop a cooked off-flavor. Even though pasteurization standards require heating at a minimum of 79.4 °C (175 °F) for 25 or more consecutive seconds, some manufacturers may opt to heat to near the boiling point or above. Some mixes may be ultra-pasteurized or commercially sterilized and aseptically packaged. Again, it should be emphasized that a moderate-cooked flavor is not particularly objectionable. However, an obvious scorched or burnt off-flavor is to be avoided.

Lacks freshness (stale). The descriptor "lacks freshness" or "stale" refers to a moderate off-flavor of ice cream and related frozen desserts. This flavor defect is generally assumed to result from either a general flavor deterioration of the mix during storage, or from the use of one or more marginal quality dairy ingredients in mix formulation. For instance, some old milk, old cream, or stale milk powder (nonfat milk solids) may have been incorporated as an ingredient. If the off-flavor imparted by the "marginal" ingredients were quite intense, then "old ingredient" would probably be the most appropriate criticism. However, if the other milk components and/or mix ingredients dilute the adverse sensory aspects of the dairy ingredient(s) in question, a lacks freshness (or stale) descriptor is more applicable. Some evaluators consider the lacks freshness defect as reminiscent of "freezer burn."

Occasionally, relatively small quantities of cream or milk used as mix ingredients may manifest an old ingredient, oxidized, rancid, or unclean defect. But, unfortunately, this situation was "missed" or overlooked by production and quality control personnel. Subsequently, dilution of the "offending" dairy ingredient(s) (by higher volume "quality" ingredients) results in an overall deterioration of flavor quality, which is commonly described as stale or lacks freshness. When ice cream and reduced fat ice cream lack freshness, there may or may not be a slight aftertaste. However, if the aftertaste is strong or persistent, the judge should look for or consider more serious defects such as old ingredient, storage, oxidized, or rancid.

Old ingredient. Nearly all dairy ingredients used in ice cream are subject to flavor deterioration with age (extended storage). Poor sanitation in milk handling and processing and subsequent bacterial action may produce psychrotrophic off-flavors or an "old milk" or "old cream" flavor. Through chemical reactions, milk and whey powders may become stale and caramelized in storage. Caseinates may acquire a stale and glue-like off-flavor; syrups may ferment. With storage, various deteriorative processes may occur in stabilizers, emulsifiers, and flavoring agents. The same descriptor, "old ingredient," is used to describe a relatively large number of possible flavor defects. The cause of the problem should be pinpointed by checking all possible ingredients, through sensory examination, for their potential to adversely affect the delicate flavor of the product.

To some evaluators, old ingredient and oxidized off-flavors may resemble each other to some extent. With increased age (storage), the judge can expect that some autoxidation may have occurred, along with other possible deteriorative changes. In many instances, the old ingredient defect will not be noted immediately after the sample is placed into the mouth; but usually an ice cream with this defect will exhibit a persistent aftertaste. Typically, the aftertaste will not be pleasant; the taste buds will fail to "clean-up."

Oxidized *(cardboardy, metallic).* In dairy products, the oxidized off-flavor may vary so widely in character and intensity that several terms or descriptors are used to distinguish between the various stages. In ice cream or low-fat ice cream, this off-flavor may be encountered to such a slight intensity that the product flavor seems flat or "missing." A further development of this off-flavor may be described more accurately as astringent, metallic, or puckery (with an associated mouthfeel of shrinking of the mucous membranes). Other, more moderate intensities of the off-flavor might be described progressively as oxidized, papery, or cardboardy. In the most intense stages of the oxidation of milk products, oily, tallowy, painty, or fishy are common descriptors. The oxidized off-flavor is usually noted soon after the sample is placed into the mouth; if intense, it may persist long after the sample has been expectorated. Depending on the intensity, such an ice cream may not be entirely repulsive to the evaluator or the consumer. However, an oxidized defect definitely conveys the idea that the product is not made from high-quality ingredients, is not refreshing, or may be stale or old. Generally, the evaluator or consumer is not very eager for a second bite of such a product. Hence, when an oxidized off-flavor occurs in frozen dairy desserts, repeat sales for the product (or brand) are not as likely to occur.

Some evaluators think of metallic off-flavor as a distinctly separate defect, even though this off-flavor is commonly considered another stage or degree of the generic oxidized off-flavor. Since stainless steel has replaced monel or "white metal" in milk handling and processing equipment, the metallic defect has substantially decreased as a problem. Historically, the conditions associated with the occurrence of a metallic off-flavor were equipment made of copper or copper alloys, improperly tinned equipment, rusty milk cans and utensils, and/or storage of milk products in nonstainless steel containers or vessels. The metallic off-flavor is characterized as having a peculiarly rough, astringent, puckery mouthfeel. As indicated previously, the metallic defect is often considered one of several stages in the series of off-flavors due to lipid oxidation. The light-induced form of the oxidized off-flavor (protein oxidation) is much less likely to occur in ice cream than the metal-induced form of oxidation.

Occasionally, a light-activated defect might be encountered in frozen desserts packaged in containers that employ the transparent, "see-through" lid, but it is usually highly localized on the top surface and only after direct exposure to light (Suttles & Marshall, 1993). Since light-oxidized flavor defect is rarely observed in ice cream, it is not evaluated in the Collegiate Dairy Products Evaluation Contest. An implication of work by Gassenmeier (2003) is that the enzyme xanthine oxidase may catalyze the formation of cardboard-tasting, lipid- and oxygen-derived off-flavors in an unpasteurized ice cream mix under refrigerated storage conditions. Light-oxidized off-flavor in ice cream is influenced mainly by the riboflavin content and susceptibility of unsaturated fatty acids to oxidation (Shiota et al., 2002; Schiano et al., 2017). Double-strength vanilla significantly masks off-flavors compared to single-strength vanilla and freezing with nitrogen gas instead of air decreases oxidized flavor formation (Im & Marshall, 1998).

Rancid. Fortunately, a rancid off-flavor is infrequently observed in ice cream (Tobias, 1983; Abbas Syed, 2018). A specific, delayed, reaction time of perception is characteristic of rancidity, and it has an attendant persistent repulsiveness. However, the sweeteners and flavoring may tend to mask any potential rancidity to the extent that unless the defect is quite pronounced, this off-flavor may not be recognized for what it actually is. If rancidity were to occur in ice cream, the peculiar blend of flavors and off-flavors would typically terminate as an unclean or unpleasant aftertaste, which is characteristic of the rancid defect. Rancidity is severely criticized since it indicates either utilization of mishandled dairy ingredients or serious processing errors that led to mixing raw milk or cream with homogenized milk ingredients.

Salty. Occasionally, a salty off-taste may be encountered in frozen dairy desserts. This taste may be readily detected, since the reaction time is relatively short; hence, it is a quickly perceived taste. A salty taste could be due to added salt, the use of salted butter as a milk fat source, or it may be associated with use of a high percentage of concentrated whey, whey solids, or milk-solids-not-fat (MSNF) in the formulation. High displacement rates of MSNF with whey solids (i.e., in excess of 20–25% replacement) seems to occasionally lead to a slight salty off-taste in ice cream or ice milk. Other sensory defects may accompany the higher usage rates of some sources of dry whey (see the following discussion on the whey off-flavor). To most evaluators, a salty taste in frozen dairy desserts seems distinctly "out of place" for this form of product; hence, it is usually criticized in line with the level of intensity and the specific flavor involved.

Whey ("Graham cracker-like"). The Federal Standards of Identity limits the maximum concentration of whey solids in ice cream to 25% of the MSNF (for products engaged in interstate commerce). While the quantity of whey used in the mix is certainly a factor in the possible transmission of whey off-flavors, an even more important aspect is the whey quality. The quality of whey solids should be carefully determined; especially important is a close scrutiny of the flavor characteristics (freshness and freedom from stale, old ingredient, or oxidized-like off-flavors). Freedom from off-colors, caking (free flowing), or lumping is also critical for dry whey. Preferably, the level of whey solids used in ice cream or ice milk should be below the flavor detection threshold for the "whey flavor." However, even lower levels of whey (15–17% displacement of MSNF) may be detected by sensory test when it is of poor quality.

A whey off-flavor in frozen dairy desserts is probably best described as being "Graham cracker-like" or similar to stale condensed milk (Bodyfelt, 1979, 1988; Goff & Hartel, 2013), with an associated slight taste of salt. Some evaluators consider the sweetness "cloying" (initially pleasingly sweet, then excessive). The whey off-flavor present in ice cream is very different from how whey manifests in other dairy products; the flavor results from the complex interactions among ice cream ingredients. Extremely old or poor-quality whey solids may reflect oxidized, cheesy, rancid, and/or unclean defects, and subsequently transmit these off-flavors to the ice cream. An unpleasant aftertaste may prevail, due to the amount and/or quality of whey solids used in the mix. Sometimes ice cream and related products that exhibit whey off-flavor may simultaneously display slight off-colors (reddish orange), as well as a friable, crumbly body and/or a gritty texture.

10.9.3 Off-Flavors Due to Chemical Changes in the Mix or Product

Lacks freshness *(stale, old).* This flavor defect may develop due to chemical changes that can readily occur in the mix or is caused by the use of a faulty ingredient in low concentration. It may also result from adverse conditions of producing, storing, transporting, handling, and distributing such perishable milk products cas ice cream, mixes, and finished products. This defect was discussed earlier and can be considered a light form of stronger defects like old ingredient, storage oxidized, or rancid. Lacks freshness can be distinguished when evaluating ice cream by its stale taste, some marginally old dairy ingredient, slight old ingredient, or other flavors.

Oxidized *(cardboardy, metallic).* This off-flavor is generally associated with chemical changes of the fat ingredient. Oxidized flavor can be identified as cardboardy, astringent, oily, or tallowy when evaluating ice cream. Processes of staling, "aging," autoxidation of milk lipids, hydrolytic rancidity, and bacteria-induced deterioration of milk proteins and milkfat represent a set of complex chemical and enzymatic activities that takes its toll on flavor stability of frozen dairy products and their mixes. The specifics of the possible off-flavors that can develop from these chemical changes have been described earlier in this chapter, but one new category that should be addressed is the so-called storage off-flavor.

Storage. The "storage" off-flavor generally refers to flavor that may develop either in the mix or in the frozen ice cream (or low-fat ice cream) during the storage period. When ice cream is stored for an extended period of time, the flavor loses its initial luster, even though no specific defects seem to stand out. In one instance, the product may simply lack the sensation of freshness. In another case, absorption of odors from the environment can cause the product to acquire a "storage-like" off-flavor, a form of "absorbed flavor" defect. Smoke, ammonia, and various chemical odors are but a few examples of absorbed substances that may be responsible. Serious storage flavor defects have been known to develop when odor, absorption, and chemical change or deterioration in storage occurred simultaneously. The storage off-flavor is commonly considered more serious or objectionable than the "lacks freshness" (stale) defect in ice cream.

10.9.4 Off-Flavors Due to Mix Processing

Cooked *(rich, nutty, eggy) and caramelized/scorched.* These are heat-induced off-flavors that might occur in ice cream and were discussed earlier under the heading of "cooked," within the section of this chapter on the role of dairy products imparted off-flavors.

10.9.5 Off-Flavor Due to Microbial Growth in the Mix

Acid *(sour), fruity-fermented, cheesy, musty, and/or unclean (psychrotrophic).* Each of these microbial-induced off-flavors is likely to occur as the result of varied degrees of temperature abuse in the handling of milk and cream ingredients and/or excessive storage temperatures of perishable mixes (i.e., higher than 4.4 °C (40 °F)). For descriptions of each defect enumerated above, the reader is directed to the discussion of microbial off-flavors of milk and cream discussed in Chap. 5.

10.9.6 Off-Flavors Due to Other Causes

Foreign *(atypical).* As a rule, a foreign off-flavor may be easily detected, but the exact substance or specific contaminant is often difficult to positively identify. This flavor defect is definitely atypical (foreign) for dairy products, or the ingredients ordinarily associated with good-quality ice cream. Detergents, sanitizers, paint, gasoline, pesticides, and other chemicals of chance contact are some of the possible serious offenders. Unfortunately, chemical substances may not only impart off-flavors but also be nauseating or toxic. Obviously, any products found to contain this defect must be severely downgraded and not marketed for human consumption.

Neutralizer. Although neutralization of lactic acid is not currently an accepted step in ice cream manufacture, the judge should be familiar with the flavor defects that may result from such an ill-advised contemporary practice. When neutralizer is used to reduce the developed acidity of milk ingredients or the mix, the end products formed by the chemical reaction of neutralization are left as residual compounds in the frozen product, where they may become apparent upon tasting. This off-flavor is recognized by a peculiar alkaline off-flavor (reminiscent of sodium bicarbonate (baking soda) or milk of magnesia). Sometimes, a slight bitter taste can be associated with neutralizer off-flavors, though this bitter note is usually rather mild. The taste reaction time for a neutralizer off-flavor is somewhat delayed, but the peculiar taste persists for some time after the sample has been expectorated. Any frozen dairy desserts exhibiting a neutralizer off-flavor are usually severely criticized by ice cream judges. In this era, the use of neutralizers in ice cream manufacture, or any type of dairy product, should certainly be discouraged, if not altogether eliminated. In those instances where a neutralizing agent might be used, the ice cream manufacturer is also likely to experience the development of other associated serious off-flavors (besides the neutralizer defect), namely, lacks freshness or stale, old ingredient, storage, and/or spoilage (psychrotroph) bacteria-related off-flavors.

10.9.7 Other Ingredients

Eggs (eggy). Part 135 of the CFR permits the use of egg solids, but regular ice cream must contain less than 1.4% egg yolk solids by weight, exclusive of the weight of any bulky-flavoring ingredients used. When the content of egg yolk solids (by weight) is 1.4% or more, the product must be labeled "frozen custard," "French vanilla," or "French custard" ice cream. Although not widely used in contemporary ice cream, eggs have, or have had, definite functional roles in ice cream – namely, stabilization and emulsification.

Egg yolks, whether in liquid, dry, or frozen form, do not necessarily impart an off-flavor to ice cream, but they may impart a characteristic "eggy" flavor note. This derived flavor is typical for egg yolks. However, off-flavored egg solids have the capacity, similar to off-flavored milk solids, to introduce certain unwanted off-flavors. Deteriorated, poor-quality whole eggs or egg yolks readily impart a flavor defect to ice cream. A characteristic "egg flavor," imparted by high-quality egg solids, is not that easy to distinguish, since this flavor note resembles the cooked (custard or nutty) sensation, although an egg flavor is usually more persistent. When used at low levels in ice cream (less than 1.4%), high-quality egg solids are usually compatible with the desired flavor blend. Since egg yolks have good emulsifying properties, some ice creams are formulated to contain them as a supplement to, or a substitute for, stabilizers and/or emulsifiers.

Stabilizer/emulsifier. These off-flavors are due to the incorporation of poor-quality, deteriorated, or excessive amounts of stabilizers and/or emulsifiers. Low-fat ice cream may be more susceptible to this defect since it generally contains higher concentrations of these body and texture-modifying agents than ice cream. Substances used as emulsifiers are somewhat prone to imparting an off-flavor generally described as "stabilizer-like" or "emulsifier-like." Occasionally, some of the mono- and diglycerides and other emulsifiers in proprietary blends of stabilizers and emulsifiers may exhibit some degree of lipid autoxidation. Hence, this form of stabilizer/emulsifier off-flavor may be confused with the generic oxidized flavor defect. Certain soft-serve low-fat ice cream and ice cream novelty products are more likely to manifest a slight to moderate intensity of emulsifier off-flavor than conventional ice cream. The novelty products and low-fat soft-serve ice cream rely on higher concentrations of polysorbates, mono- and diglycerides, or lecithin, to provide "drier," firmer products when drawn from the freezer; hence, they are more prone to this off-flavor than ice cream.

Non-milk food solids. On a rare occasion, other approved food solids (other than dairy derived, sweeteners, flavoring agents, and stabilizers/emulsifiers) may be incorporated into frozen dairy desserts for a special flavor effect, body and texture, or appearance function. Cookies, cake, and cheesecake are several examples that come to mind. It is conceivable that certain off-flavors could be imparted to ice cream from such sources, especially if used in relatively large quantities. Examples of materials cited here, however, should not be encountered in vanilla ice cream.

10.10 Other Frozen Dairy Desserts

Low-fat ice cream. As noted in Table 10.1, this product (formerly called ice milk) differs from ice cream principally in the quantity of milk fat content. Although low-fat ice cream is offered in a variety of flavors, vanilla is the most popular. For evaluating the sensory properties of low-fat ice cream, the ice cream scorecard and scoring guide (Fig. 10.1 and Table 10.3) are appropriate for all sensory quality parameters. Due to the lower milk fat content, low-fat ice cream would be expected to lack the typical richness, mouthfeel characteristics, and the overall flavor blend that most ice cream possesses. Also, the body and texture, as expected, can differ considerably from ice cream, due to the lower total solids content of low-fat ice cream. However, in spite of these inherent problems, many manufacturers have mastered the required technology and art for producing low-fat ice cream of excellent flavor, body, and texture. In fact, the sensory properties of many samples of low-fat ice cream may be practically free of criticism, even though they might be evaluated on the same general criteria as ice cream.

Mellorine. Despite the different language in the Federal Standards of Identity, except for the source and type of fat, this product generally resembles either low-fat ice cream (usually) or ice cream in composition. The ice cream scorecard and guide are generally applicable for conducting sensory evaluation, but certain additional defects that may be derived from vegetable or animal fats may be encountered and recorded as appropriate on the scorecard. Flavor defects of main concern in mellorine are the possibilities of oxidation, rancidity, the presence of a distinctive off-flavor derived from the specific fat source, and a lack of flavor or “blandness” (which can be attributed to varied fat sources other than dairy based). The relative hardness and melting properties of the fatty acids that constitute the fat can influence the body and mouthfeel of frozen mellorine (typically vegetable fat and/or other animal fats other than dairy, or in a blend with milkfat).

Frozen custard. Basically, this product is identical to ice cream except for the addition of egg yolk solids at a concentration of at least 1.4% by weight. Based on this requirement, frozen custard should not be criticized for having an egg solids flavor, unless a characteristic “poor egg solids” off-flavor is sensed (due to use of poor-quality egg ingredients). A greater tolerance for a “cooked” or “eggy” flavor should be extended in evaluating those products labeled “frozen custard,” “French custard,” or “French vanilla” ice cream.

Frozen bulky-flavored products. Due to the relatively small quantity of required flavoring, and a minimum dilution effect, ice cream composition remains essentially unchanged when it is flavored with vanilla or other extracts. However, some flavorings such as chocolate, fruits, bakery products, candy, and nuts are often added in relatively high proportions – hence, the applied term of "bulky flavors." Bulky flavors may be added to ice cream, reduced fat ice cream, or frozen custard. Federal standards allow for alteration of the product composition by bulky flavors, as indicated in Table 10.1. Numerous bulky-flavoring ingredients are used in ice cream; a few will be discussed to illustrate the applicable principles when sensory qualities are assessed by sensory methods.

In ascertaining the quality of bulky-flavored frozen desserts (actually any flavor), the evaluator should be alert to the possible occurrence of any of the defects that may be manifested in vanilla ice cream. Some of the milder off-flavors of ice cream may be masked or partially masked by some flavorings, but not by others. However, the judge should bear in mind that even a masked off-flavor may modify the overall perception of some flavorings in an undesirable way. A smooth, creamy texture is usually desired regardless of the type of flavorings used, but somewhat different or altered characteristics of body and texture should be recognized as the norm with some flavors of ice cream. Generally, the higher the quantity of bulky flavorings incorporated into any ice cream, the greater the tendency or likelihood for development of a coarse or icy texture, and/or possibly a weaker product body. This likelihood is primarily due to the dilution of solids, added moisture from some sources of bulky flavorings, and/or higher overrun. When the added flavoring material does not incorporate air, the ice cream portion may be excessively whipped to maintain minimum weight (e.g., 4.5 lb/gal).

10.10.1 Other Ice Cream Products

Other ice cream products are the results of manipulating the processing conditions and ice cream formulations. Under these altered conditions, the products have physiochemical properties that may be like regular ice cream products or have unique characteristics that are appealing to consumers. The properties that can be influenced by manipulating the conditions may include total solids content, nutritional values, sensory properties, sweetness, viscosity, freezing point, fat stabilization, hardness, melting rate, overrun, and others.

Slow-Churned Ice Cream The typical steps in ice cream production start with preparation of the premix of the ingredients, followed by aeration and freezing in a scraped-surface heat exchanger. When making slow-churned ice cream, after the aeration and freezing step, the mix is further processed in a low-temperature ice cream extruder. Freezing and aeration of ice cream and other frozen desserts are traditionally accomplished by a scraped-surface heat exchanger, where pasteurized, chilled, and aged liquid mixes are subjected to low chamber temperatures, high-speed dashers, and surface-scraping knives. The size and uniform distribution of dispersed ice crystals, fat globules, and air bubbles are most critical for the textural quality of finished ice cream, and the aeration and freezing steps are essential for their development (Shrivastav & Goswami, 2017). Scraped-surface ice cream freezers provide effective heat transfer and aeration to form the required ice crystals, fat globules, and air bubbles, but the attainable draw temperature is limited to approximately −5 °C (Bolliger et al., 2000a). At this temperature, less than 50% of the water in the formulation is frozen, so further freezing is typically conducted at approximately −40 °C in a hardening tunnel or hardening room for up to 3 h. During traditional hardening, ice crystals often grow and become detectable by consumers, as the ice cream loses its desirable creamy texture.

Low-temperature extrusion (LTE), also referred to as the "slow-churned" process, is an innovative rapid hardening and texturizing process that promotes the formation of smaller ice crystals through the application of low temperatures, high shear stresses, and high pressures (Shrivastav & Goswami, 2017; Goff & Hartel, 2013; Wildmoser et al., 2005). As ice cream exits the scraped-surface freezer, it enters the low-temperature extruder and is cooled to approximately −15 °C within minutes. This quick hardening often eliminates the need for traditional static hardening, and the ice cream remains pumpable due to the LTE's shear stresses that prevent accretion of ice crystals. This process also provides greater resistance to recrystallization during storage and distribution and results in a smoother texture. Additionally, LTE creates well-dispersed, small air bubbles and reduces the size of fat globules, which enhances creaminess and softens the texture, making slow-churned products easier to scoop (Goff & Hartel, 2013; Wildmoser et al., 2005). These enhanced qualities have led to the development of reduced-fat frozen desserts with similar textural attributes and improved ease of use when compared to traditional full-fat formulations (Goff & Hartel, 2013).

High-Protein Ice Cream Conventional ice cream has 4% protein and it is usually provided by skim milk powder. This level has been reported to be ideal for the sensory properties of the ice cream. High-protein ice cream can be created by the incorporation of whey protein concentrate (WPC) and milk protein concentrate (MPC) and has been shown to increase shape retention and viscosity of the product. However, increasing protein content up to 7% has been found to be detrimental to the quality attributes of ice cream with lower overrun and excessive hardness (Alvarez et al., 2005). Patel et al. (2006) observed that acceptable high-protein ice cream could be produced with a protein content up to 6.05% provided by MPC; the authors found an increase in the overall structure, viscosity, and reduction in the ice crystal size compared to the 3.78% ice cream. These changes were attributed to less free water available to form ice crystals. One week after manufacture, sensory overall structure acceptance was higher and iciness (related to crystal size) was lower at 6.05% protein content; however, at 7.19% protein concentration, the overall flavor acceptance was significantly affected. The authors reported that the vanilla flavor was masked by the WPC and that at a higher protein concentration, additional flavor needed to be added to overcome the effect on flavor. Similar results were reported by Daw and Hartel (2015), who evaluated the effect of different protein sources (skim milk powder, WPI, and MPC); the authors observed that increasing the protein concentration significantly affected the coalescence of fat globules and meltdown rates. Roy et al. (2022) evaluated the incorporation of whey protein isolate to increase protein content to 8 and 10%; the authors reported that the sensory attributes like body and texture decreased in the high-protein samples compared to the control (4% protein).

An increase in protein concentration of ice cream could enhance nutritional value, but it has been shown to significantly affect the physicochemical properties of the final product. Increasing protein content increases viscosity, lowers the overrun, increases the ice cream melt rate, and disrupts the fat stabilization process during manufacture (Daw & Hartel, 2015).

Lactose-Free and Reduced-Sugar Ice Cream Lactose and sugar are common ingredients in regular ice cream formulations. Addition of sugars is very important for sweet taste; it also helps in maintaining the solids content, helps to reduce the freezing point of the mix, and affects the texture and sensory properties (Chamchan et al., 2017). The common sweeteners used in ice cream are sucrose (cane or beet sugar), dextrose (corn sugar), and various corn syrups. The functioning and properties of these sweeteners are discussed earlier in this chapter. Lactose is a disaccharide that is made of two monosaccharides glucose and galactose linked by β-1,4 glycosidic bond. It is the principal carbohydrate present in milk and dairy products made from milk and is also referred to as "milk sugar" (Özdemir et al., 2018). There is a consumer trend toward sugar-free ice cream because of health concerns and weight issues. Thus, the industry is developing products replacing the sugar and high fructose corn syrup in ice cream formulations with low- or zero-calorie sugar substitutes.

Lactose-free dairy products are gaining much interest and is one of the fastest-growing sections in the dairy industry – it is expected to reach a turnover of $9 billion in 2022 (Dekker et al., 2019). Lactose-free ice cream is prepared by eliminating or reducing lactose for individuals that are unable to digest lactose due to absence of lactase enzyme, commonly known as lactose intolerance. In this case, lactose ingestion can cause mild to severe symptoms and digestive discomfort. Lactose-free ice cream can be prepared either by using lactose-free milk or powder and by using lactase enzyme (β-D-galactosidase; β-D-galactoside galactohydrolase, E.C. 3.2.1.23). The enzyme is usually added after pasteurization and incubated before freezing when used directly in ice cream making. Lactose is hydrolyzed into glucose and galactose, which is sweeter than lactose itself, thus partially eliminating the addition of sugar, thereby reducing the calories as well Harju et al. (2012). It is easy to digest and absorb glucose and galactose by lactose-intolerant people (Dekker et al., 2019).

Reduced sugar ice cream is prepared by reducing the high amounts of added sugars to make the product consumable for diabetic and obese people (de Medeiros et al., 2021). Another way to reduce sugar is the use of natural sweeteners that can affect the sensory perception in a positive way but does not increase the glycemic index and caloric value. There are several noncaloric sweeteners used in ice cream formulations such as sucralose, aspartame, acesulfame potassium, neotame, saccharin, and advantame. Sugar alcohols that have zero calories and zero carbohydrates are also used in ice cream formulations. Erythritol contains about 60–80% of the sweetness of sugar and is widely used. The most common natural sweetener is stevia, which has a sweetness level of 250–300 as compared to sucrose and is recognized as safe by the WHO and FDA (Alizadeh et al., 2014).

Removing lactose and reducing sugar have numerous effects on the final product. Lactose hydrolysis affects the texture and sensory properties (i.e., increases the viscosity, decreases the freezing point, increases sweetness, decreases total solid content). However, the added sugar is also reduced by 25%. Lactose hydrolysis also decreases the "sandiness" that is caused by the crystallization of lactose, a sensory defect that affects overall acceptability. Similarly, reduction of sugar affects the textural and sensory properties as well. It affects hardness and ice formation. The texture is usually hard and ice crystals increase in size and content, which reduces the overall acceptability as well. Sugar reduction also hinders melting, indicating the role of sugar in not only sweetness but ice content in the product. Moreover, the combined effects of lactose reduction/hydrolysis and sugar reduction give the highest acceptability properties (Abbasi & Saeedabadian, 2015).

10.10.2 Chocolate Frozen Desserts

The principal forms of chocolate flavoring for frozen dairy desserts are cocoa, chocolate liquor, or a combination of the two. Chocolate liquor contains the entire usable portion of the cocoa bean, including about 50% cocoa butter. Cocoas are made by removing varying amounts of cocoa butter from the liquor. However, the flavor character of cocoa or chocolate liquor from different sources can vary markedly. These flavor variations may be due to the source of the cocoa beans, climatic conditions during growth, fermentation conditions, whether Dutch processed (alkali-treated) or naturally processed, and the roasting conditions. Aside from flavor variations, the resulting cocoa may be light, dark, or red colored. Although the bulk of the characteristic flavor of chocolate is retained in the cocoa, some delicate, unique aroma constituents may be lost into the cocoa butter. Thus, the fat content of the given cocoa and the selected proportion of chocolate liquor to cocoa used in flavoring the ice cream will influence the flavor balance of the chocolate.

Chocolate ice cream often employs an added substance to modify or enhance the chocolate flavor; vanilla is most frequently used, but on occasion coffee, cinnamon, or salt may be added. The intent of the selected flavor modifier may be to mellow the chocolate sensation, diminish a certain harsh note, or simply to enhance or "bring out" chocolate flavor. However, the flavor modifier or enhancer should not be so intense as to actually predominate over the chocolate flavor of the ice cream.

The sweetness level of chocolate ice cream requires full consideration. Both cocoa and chocolate liquor are quite bitter, and thus, they demand a higher sweetness level in ice cream than vanilla or most other flavors. As an illustration, the sweetness level of vanilla ice cream is commonly between 13% and 16%, expressed as sucrose, while that of chocolate ice cream may be 17–18% (expressed as sucrose). Obviously, there are distinct variations in consumer preferences for the type and intensity of chocolate flavor in ice cream. Individual preferences may span the intensity range from “just a hint of chocolate” to an overwhelming “double chocolate,” from a light to a very dark color, and from a mellow, sweet to a bitter, harsh chocolate. In evaluating the flavor of chocolate ice cream, the judge’s personal preference should not prejudice the rating, insofar as possible.

The overriding requirements for regular or conventional chocolate ice creams are that (1) the true chocolate flavor be readily recognizable in a supposed “blindfold test,” (2) that the cocoa and/or chocolate liquor that is used be of high quality, (3) that no off-flavors be present, and (4) that any added non-chocolate flavor notes “contribute, but not predominate” in the overall chocolate flavor profile. Although some additional definitions of flavor terms and some new descriptors may need to be added, the ice cream scorecard and scoring guide in Figs. 6.1 and 6.2 can be applied to chocolate ice cream. Basic modifications are suggested in the following paragraphs.

Lacks fine flavor/harsh/coarse. These terms describe a lack of proper, expected, or desired chocolate flavor blend; an otherwise unidentifiable flavor defect or shortcoming of the chocolate; a flavor system that is somewhat lacking in the desired delicate volatile components of chocolate; or describes a product that merely seems not to project a “perfect,” “ideal,” or highly desirable flavor.

Lacks sweetness/bitter. This flavor defect of chocolate ice cream is self-explanatory. Adjustment of the sweetener level (increased amount) usually eliminates the defect in subsequent lots of the product.

Unnatural flavor/lacks chocolate character. These terms describe an artificial flavor; a chocolate flavor that is not readily recognizable as chocolate per se; or a flavor in which the non-chocolate components predominate. Basically, selection of another source of chocolate flavoring is suggested.

Other quality factors of chocolate ice cream. The body characteristics of chocolate ice cream are influenced by the relative proportions of cocoa and chocolate liquor used, as well as by the sugar content of the mix. Approximately 1.67 lb (0.74 kg) of chocolate liquor is required to impart the equivalent flavor intensity of l lb. (0.45 kg) of cocoa; hence, ice cream has higher total solids content when chocolate liquor is used exclusively or there is a high proportion of chocolate liquor to cocoa. But even when cocoa is used exclusively as the source of chocolate flavoring, the solids content of the mix is increased, and in either case, additional sugar (solids) is usually required and incorporated. The general effect of a product with higher solids content is a mix with increased viscosity (Wibley et al., 2004; Goff & Hartel, 2013). Descriptors listed on a conventional ice cream scorecard to describe body and texture defects are generally applicable to chocolate ice cream.

The various color defects listed on the regular (vanilla) scorecard also apply to chocolate ice cream, except that a gray off-color would not be expected to occur in chocolate. Departures from the desired range of chocolate color may be variously described as dull, not uniform, too high (too dark), too pale (too light), or unnatural (atypical).

When evaluating the meltdown characteristics, the package, or bacterial content, the same criteria apply equally to vanilla and chocolate ice creams. Chocolate ice cream is also made and/or packaged in combination with other flavors. Several examples are chocolate almond (or other nuts), chocolate marshmallow, chocolate mint, chocolate and berries, and other chocolate-based products sold under proprietary names; this list is by no means all inclusive.

10.10.3 Fruit Frozen Desserts

The flavor of berries and fruits (strawberries, peaches, etc.) may be imparted to frozen dairy desserts by fresh, frozen, or processed fruits, natural extracts (that sometimes contain other natural flavors), imitation flavors, or various combinations of these. The flavor character, body and texture, and the appearance of the finished product, are influenced by the type of flavoring used. Generally, the flavor of the given ice cream should be reminiscent of sweetened fresh fruit and cream (e.g., strawberries and cream or peaches and cream). To overcome the problem of seasonality, availability, and perishability of fresh fruit, frozen fruit preparations are commonly used (Bodyfelt, 1973, 1974; Goff & Hartel, 2013).

The choice of the particular variety of frozen fruit should be based on quality and its suitability for ice cream. For example, a considerably softer, riper, and more flavorful peach is required for ice cream than for pie baking. Processed fruit may often exhibit a cooked, "fruit preserves" type of flavor that may not be objectionable, but it is unlike the typical or more preferred flavor of fresh fruit. Processed preparations of some fruits may be used alone, quite successfully, in combination with other forms of flavorings, or as a part of a more complex flavoring system. Processed cherries and some types of processed berries produce popular ice cream flavorings, and processed pineapple has been successfully used in combination with other flavors (especially for sherbet).

The sweetness level of fruit ice creams tends to be slightly higher than that of vanilla; the sweetener should blend smoothly into the overall flavor sensation in a well-made ice cream. There are two basic reasons for the incorporation of more sugar into fruit ice creams. The first is to compensate for the tartness of the fruit and optimize the intensity of the fruit flavor. Actually, the sweetness level of ice cream (from the mix) may already be sufficiently high to accomplish that for some fruits; hence the second reason becomes more important for quality considerations of the product. That is, sugar is generally required in the fruit preparation to reduce the freezing point of the fruit particles to prevent them from being ice-hard when the ice cream is consumed. Frozen fruits typically contain about 20% added sugar (one part of sugar to four parts of fruit).

A few flavor terms on the regular ice cream scorecard must be redefined in order to apply this scoring tool to fruit-flavored ice cream. The suggested changes are enumerated in the following paragraphs.

Lacks fine flavor. This term describes the lack of a highly desirable flavor blend; an otherwise unidentifiable flavor defect of the fruit and/or fruit flavoring; a flavor that lacks the full impact of fruit at the peak of its flavor development; or a flavor that just seems to fall short of being "perfect" or "ideal."

Cooked/processed. The terms "cooked" or "processed" describe a moderate off-flavor produced by heat treatment of the mix and/or an off-flavor that resulted from heat processing of the fruit.

Unnatural flavor/lacks specific fruit character. These terms attempt to describe an artificial or atypical fruit off-flavor; a flavor sensation in which the specific fruit is not readily recognizable; or a flavor note in which other fruit or nonfruit components seem to predominate.

Lacks freshness/stale fruit. This set of flavor defect descriptors is generally self-explanatory, but may include associated terms such as "musty," "fermented," or "rotten."

Body and texture of fruit ice cream. Since fruit preparations may be used in rather high concentration in ice cream (15–24%), there is considerable dilution of the mix, which, unless it is compensated for in some manner, can lead to a coarse texture and a decidedly weaker body. For fruit ice creams, one slight modification, listed following, seems appropriate for the body and texture segment of the ice cream scorecard.

Coarse/icy/icy fruit. The descriptor used to describe the relative coldness and size of ice crystals in frozen dairy desserts is "expanded" to encompass potential problems that may arise from fruit particles added to the product.

Other quality factors of fruit ice cream. Both the color and appearance of fruit ice cream should be closely evaluated for esthetic appeal. As with other flavors of ice cream, the color may be dull, not uniform, too deep, too light, or unnatural (atypical). The appearance also should be checked for any of the following possible defects (where applicable):

Fruit particles too small
Fruit particles too large
Too few fruit particles
Too many fruit particles
Poor distribution of fruit
Atypical color of fruit particles

10.10.4 Nut Frozen Desserts

Pecans, walnuts, almonds, peanuts, macadamia nuts, hazelnuts (filberts), and pistachio nuts are among the most popular nuts added to ice cream in the USA. Generally, ice cream is flavored with either an appropriate background flavor for the nuts (butter pecan, chocolate almond, etc.) or a concentrate of the same basic nut flavor (e.g., pistachio, black walnut). The degree and the method of roasting the nuts (light or heavy roast; dry or butter roasted) provide interesting variables that manifest themselves in the sensory properties of the ice cream. The initial quality and freshness of the nuts must be good; no deterioration should occur as a result of storage. Since some types of nuts contain a high proportion of unsaturated oil, they can be highly susceptible to autooxidation. Some nuts (walnuts and hazelnuts) are also prone to the development of hydrolytic rancidity due to the presence of lipolytic enzymes.

The size of nuts in ice cream may range from intact, whole nuts to small, broken, or sliced pieces. Except in special cases, medium- to larger-sized pieces are generally favored. In any case, the nuts should retain their firmness, crispness, and freshness in the frozen product.

Vanilla (or chocolate) ice cream scorecards are generally applicable to nut-flavored ice creams. The following revisions of flavor descriptors are suggested for the flavor of nut ice creams.

Lacks fine flavor. This term describes a general lack of the desired flavor blend; an otherwise unidentifiable, slight flavor defect of the nuts or background flavor; or a flavor that simply does not quite attain the "ideal" or anticipated flavor.

Unnatural flavor. An artificial or atypical background flavor for the particular nut is described by the term "unnatural" off-flavor.

Salty/excessively salty nuts. These self-explanatory descriptors cover the instances of excessive incorporation of salt on the nuts or in the ice cream.

Oxidized/oxidized nuts/rancid nuts. Within nondairy segments of the food industry, a generic "oxidized" off-flavor is often referred to as a "rancid" off-flavor. However, walnuts and hazelnuts may also exhibit an actual rancid (lipolyzed) off-flavor due to the lipase content of these nuts if they have not been sufficiently roasted.

For assessing the body and texture of nut ice creams, one additional criticism is suggested below.

Nut meats lack crispness. This term is generally self-explanatory; the nut pieces absorb moisture and become somewhat waterlogged or soft in consistency.

Other quality factors of nut ice creams. Both color and appearance are important criteria in measuring the sensory qualities of nut ice cream. Appearance is primarily influenced by the size and uniform distribution of the nut meats, which help determine the eye appeal of the product. In addition to obvious color defects, the following defects of appearance are possible in nut ice creams:

Nut particles too small
Too few nut particles
Too many nut particles

Poor distribution of nut meats
Atypical color of nut meats
Inclusion of nutshell fragments (important for teeth safety)

10.10.5 Candy Frozen Desserts

Chocolate chip and mint candy are probably the most popular representatives of this group of products, though many others are produced by US ice cream manufacturers. The background flavor may be vanilla, chocolate, or another flavor that is compatible with the given candy (e.g., mint chocolate chip). As with fruit and nut ice creams, the evaluator should be somewhat familiar with the quality criteria of the added materials. General quality requirements for candy-flavored ice creams are (1) a pleasing flavor blend; (2) crispness of the candy components; (3) attractive color and appearance (size and shape); (4) adequate and even distribution of candy pieces throughout product; and (5) minimal or no color migration through the ice cream. Some ice cream manufacturers have reported some success with minimizing the occurrence of overly softened candy pieces and color migration by freezing the candy before its addition to the frozen product. The suggested sensory descriptors of defects for fruit and nut ice creams also apply to candy ice cream. The judge should try to note whether a given defect seems to pertain to the background flavor or to the candy itself. The various flavor defect definitions for chocolate ice cream also apply to the flavor of any added chocolate chips or pieces.

10.10.6 Variegated Frozen Desserts

A variegated ice cream should basically emulate an ice cream sundae, although the flavored syrup, sauce, or puree is dispersed throughout the product. Chocolate, fudge, marshmallow, butterscotch, peanut butter, strawberry, and raspberry are just a few of the flavors that may be variegated or marbled. The flavoring (or slurry) syrup is usually pumped directly into the ice cream as it emerges from the ice cream freezer; the variegating substance is intended to form a definite pattern within the product. Although some indication of the regularity or uniformity of the variegation pattern is obtained in the course of normal sampling of the ice cream, a more objective visual impression can usually be realized by examining both exposed surfaces, after cutting through the center of the container. Sometimes, several cross-sectional cuts may have to be made to properly assess the distribution or the "pattern" of the variegating material with the frozen product. Typically, the ribbon of syrup should be of medium thickness, and the pattern should essentially reach into all segments of the container.

Other quality criteria include the flavor and consistency of the variegating syrups used in the ice cream. In general, the flavor should be readily identifiable, be free of off-flavors, and produce a pleasing blend with the background or the "other" flavor(s) of the product. The syrup should not "settle out" or mix with the ice cream, but simultaneously, it should not be overly hard, gummy, crusty, or icy. The following modified definitions of flavor defects are suggested for better application in evaluating variegated ice creams.

Lacks fine flavor. A lack of the desired flavor blend; an otherwise unidentifiable flavor defect of the variegating syrup or background; or a flavor which just falls short of being "perfect" is implied by this descriptor.

Lacks flavor/variegating syrup lacks flavor. Self-explanatory.

Unnatural flavor. "Unnatural" describes an artificial or atypical off-flavor in the background flavor and/or in the variegating syrup.

Other quality factors in variegated ice cream. The body and texture of variegated ice cream should be similar to that of its unvariegated counterpart.

Low "heat shock" resistance is a typical property of variegated ice creams; consequently, it can be expected that frequently the body will be weaker and the texture more coarse than plain or regular ice creams. Another reason for a weak, coarse body in variegated ice creams is in the "overrun gradient" between the variegating syrups and the ice cream. The variegating syrups are usually quite heavy; at the time of freezing, air is incorporated only into the mix portion. If product is drawn at the same weight/unit as that of the product without variegating syrup, the ice cream mix portion obviously has to be much lighter. The same problem may be encountered in other bulky-flavored ice creams in which no overrun is formed within the more dense or solid-flavoring material.

Variegating syrup too hard, icy, or chewy. Due to the difference in physical and chemical properties, especially the "overrun gradient" between the variegating syrup and ice cream, a certain crustiness, chewiness, or iciness can occur in variegated ice cream. Appropriate composition of the variegating syrup (accounting for freezing point depression) should help guard against this defect.

Under color and appearance, the following possible criticisms for variegated ice creams are likely to occur:

Poor pattern of distribution
Too thick a ribbon
Too thin a ribbon
Syrup settled out (precipitated)
Syrup mixed with ice cream
Unnatural or atypical color (of the ice cream or the variegating syrup)

10.10.7 Direct-Draw Shakes

This product, similar in composition to low-fat ice cream, emulates the traditional milk shake (Holsinger et al., 1987). Depending on composition and whether a "thick" or "thin" shake is desired, the product is drawn from the freezer in the temperature range of −3.3 °C to −1.1 °C (26–30 °F). The mix may be flavored prior to freezing, or flavoring syrup may be added to the frozen shake and dispersed in a spindle-type mixer.

The finished product should possess a pleasing blend of flavor (chocolate is the most popular flavor) and be free of off-flavors. Opinions may vary as to the desired body and texture that appeals to the widest group of consumers. A thick, smooth-textured shake that draws through a straw is probably the choice of a majority of consumers. Product overrun is still another factor that affects coldness and mouthfeel. A product with a high overrun yields comparably less liquid as it melts in the mouth. A desirable range appears to be 40–60% overrun for direct-draw shakes.

Just as with soft serve, the sensory characteristics of shakes are also traceable to either the mix, the freezer, or to the procedures of the freezer operator (Tobias, 1969). The resolution of a particular sensory defect may be as simple as resetting a freezer control knob or as complex as reformulating the mix.

10.10.8 Frozen Yogurt

In some respects, frozen yogurt resembles ice cream, low-fat ice cream, and sherbet. This product is available in packaged, novelty, (Isik et al., 2011) or soft-serve form and in a variety of flavors, most commonly fruit flavors (Bodyfelt, 1978; Isik et al., 2011). Frozen yogurt does not have standard of identity other than that yogurt is required in the formulation. The general criteria used in the sensory evaluation of frozen yogurts are comparable to those used for sherbets or low-fat ice cream. "Chalkiness" may sometimes be observed in the mouthfeel of frozen yogurt; this is quite possibly the result of dehydration of proteins by the combined action of heat and acidity. The absolute levels of product sweetness and acidity, as well as the balance between sweetness and acidity, in association with the given flavor, are important considerations for frozen yogurt quality.

Table 10.9 outlines the elements of flavor for the sensory evaluation of frozen yogurt (Bodyfelt, 1993). This scheme assesses the given product-flavoring system, culture system characteristics, sweetener aspects, process-related considerations, and the potential for dairy ingredient off-flavors.

Table 10.9 Flavor elements of the sensory evaluation of flavored frozen yogurt

1. Flavoring system	(a) Ideal, natural-like, no criticism (b) Lacks fine flavor (lacks desired balance) (c) Lacks flavor intensity (d) Too high flavor intensity (e) Unnatural flavor (harsh, not typical of stated flavor(s); possible foretaste and/or aftertaste)
2. Culture-related aspects	(a) Acetaldehyde (green apple-like, coarse) (b) Bitter (c) Too high acid (d) Too low acid
3. Sweetener related	(a) Ideal, just right, balanced, helps flavor balance (b) Too sweet (c) Lacks sweetness (d) Syrup off-flavor (malty, Karo®-like)
4. Processing related	(a) Cooked (eggy-like, nutty) (b) Atypical (foreign)
5. Dairy ingredients related (delayed aftertaste)	(a) Lacks freshness (stale) (b) Old ingredient (c) Oxidized/metallic (d) Rancid (e) Salty (f) Whey

10.10.9 Soft-Serve Frozen Desserts

These products (usually low-fat ice cream or frozen yogurt) are commonly dispensed from a special freezer for immediate consumption by the consumer. Since the serving temperature is about −7.2 °C (19 °F), the hardening step is omitted, which eliminates the "damaging effects" of slow freezing and subsequent temperature fluctuations. As a result, soft serve should generally exhibit creamy, smooth mouthfeel properties, as well as provide excellent "flavor release."

Generally, the same requirements apply to the flavor of soft-serve as to the corresponding hard-frozen product (low-fat ice cream or frozen yogurt). Most of the body and texture criteria also apply, except that the desired or optimum characteristics should be partially redefined. The body should be fairly resistant and firm (to retain shape on a cone), but obviously not as firm as that of hardened products, which are stored and consumed at much lower temperatures (−13 °C (8 °F)). The desirable characteristics of soft serve (Tobias, 1969: Goff & Hartel, 2013) can be summarized as follows:

A desirable flavor blend and absence of off-flavors.
Smooth texture: Small ice crystals; no lactose crystals; no butter granules; and no excessive coldness.
Dry appearance; a pleasing color.
Some modest resistance to melting.
A reasonably firm, resistant body.

A neatly shaped serving portion that maintains its shape for a reasonable time before consumption.

When sensory problems are encountered with soft-serve frozen desserts, they may be traced to mix ingredients, mix composition, mix processing, age of mix, mix handling, mechanical and sanitary condition of the freezer, freezer operation procedures, and numerous other factors. For instance, on “slow business” days, the product remains in the freezer under intermittent agitation for an extended time. The effect on quality may be a progressively wetter, weak-bodied product (even though the temperature may be unaffected or even decreased); problems with overrun (weight of serving); fat separation (due to churning); and lactose crystallization (sandiness). A well-formulated mix, along with good mechanical condition of the freezer and a properly operated freezing machine, can minimize most of these problems.

Most of the soft serve on the market is low-fat ice cream, but ice cream, sherbet, water ices, and especially frozen yogurt are also available in many localities. Although vanilla is the predominant flavor (along with a number of “sundae” options), chocolate, fruit, or berry flavors and other flavor options are offered by more and more retail stores.

10.10.10 Sherbet

Sherbet is defined according to 21 CRF 135.140. Though poor-quality dairy ingredients may cause an off-flavor in sherbets, the mandatory low concentration of total milk solids (less than 5%) somewhat reduces this likelihood. In fruit sherbet, the quality is usually determined by the overall flavor blend of sweetness, tartness, fruit flavor intensity, and by how closely the given fruit flavoring emulates the true fruit flavor at its peak of quality. In nonfruit sherbet, quality differs with each specific flavoring; therefore, only a vague, general statement pertaining to the desired flavor can be made. In nonfruit sherbets, the flavoring and the sherbet base (mix) should be free of perceptible defects, and the frozen product should have a pleasing flavor blend.

The ice cream scorecard may be applied as a tool to evaluate the flavor of sherbets, if the evaluator considers the following additional criticisms and revisions of definitions.

Defective flavoring/peel flavor. Defective flavoring may be any off-flavor due to a manufacturing error, an oversight, or due to quality deterioration of the flavoring materials during shipment or storage. A “peel” off-flavor is commonly encountered in citrus fruits and is suggestive of an excessive concentration of essential oil of citrus, which is found in the peel.

Unnatural flavor. This describes an artificial flavor, a flavor that is lacking in true fruit character, or an off-flavor which is not recognizable as the flavor stated on the product’s label.

Lacks tartness or excessive tartness. Self-explanatory.

Other quality factors of sherbet. The texture of sherbets can be nearly as smooth as that of ice cream. The body of sherbet may range from weak to resistant, although a heavy or even slightly gummy body need not be considered defective. Probably the most common defects of sherbet body and texture are severe coarseness and crumbliness. Inadequate stabilization, "heat shock," high overrun, low solids content, and prolonged storage are usually responsible for the development of a coarse and icy texture. Inadequate stabilization may also be responsible for crumbliness. This defect seems to be more frequently encountered in orange-flavored sherbet, presumably due to some unexplained property of one or more orange oil constituents. Addition of an emulsifier to the sherbet mix is helpful in correcting or limiting the severity of the problem.

The sugars commonly used in sherbets are sucrose, corn syrups, and, to a lesser extent, dextrose (corn sugar). The body of sherbet may be hard or soft, depending on whether too little or too much sugar was used in the formulation. Several other sherbet defects, common in yesteryear, may still be encountered occasionally. "Surface crustation" may occur, particularly when the product surface is exposed to air. Effective stabilization and partial replacement (25–50%) of sucrose with corn syrup are good precautionary steps. "Ice separation" may occur in the continuous freezer by the action of centrifugal force. Ice builds up on the freezer wall and eventually breaks away and "lands" in the product. Increasing the viscosity of the unfrozen portion of the mix by proper stabilization helps control this problem. "Separation, drainage, or bleeding" of the unfrozen syrup within the sherbet may also be a problem of inadequate stabilization and/or holding the sherbet at too high of a storage temperature.

The ice cream scorecard is satisfactory for evaluating the body and texture of sherbets with the following minor modification.

Heavy/hard. The formulation and lower overruns (≤60%) of sherbet generally leads to a heavier or harder product at the typical serving temperature. Sherbets that may be formulated with lower levels of sweetener may not depress the freezing point adequately, hence a greater likelihood of a heavy/harder product at or near the serving temperature.

Both the color and appearance should be evaluated in sherbets, particularly in multiflavored products (e.g., rainbow sherbet) in which the distribution pattern of the different flavored products is a quality criterion, and in products to which fruit particles or confectionery were added. Suggested descriptors for possible color defects of sherbet are as follows:

Defective pattern
Too little added material
Poor distribution of added material
Poor appearance of added material

10.10.11 Sorbets and Water Ices

The US Federal Standards describes water ice as a food that is prepared from the same ingredients as sherbets, except that no milk fat, milk-derived ingredients, or egg ingredients (other than egg whites) are used. As indicated in Table 10.1, the minimum weight (Federal Standard) for water ices is 6 lb/gal. Sensory evaluation procedures for water ices differ little from those used for sherbet.

Water ices are products made from simple formulas and often low quality and less concentrated flavoring sources (i.e., popsicles and novelty bars on a stick). Water ices have been a long-time mainstay of the US frozen dessert industry and are generally sold through food retail and convenience stores.

French- and American-style sorbets are frozen combinations of pureed fresh fruits, fruit juices, and sweeteners; they contain no milk, cream, or eggs to reduce or control ice crystals. Hence, sorbets are constantly stirred during the freezing stage to limit or control ice crystals. High-quality sorbets are expected to exhibit a light and fluffy texture and are generally presumed to be at their best when consumed immediately after the freezing process. Some fancier styles of sorbets, originating from France and Italy, contain wines and/or liqueurs. Sorbets are commonly made fresh and sold directly to walk-up customers at retail stands and food service operations, although packaged and hardened sorbet is also available from the freezer cabinets of retail food stores.

10.10.12 Frozen Novelties

A group of products referred to as frozen novelties may be made of ice cream, low-fat ice cream, mellorine, sherbet, sorbet, ice, frozen yogurt, pudding, or combinations of several of these. They may be in many forms, such as bars (with or without a stick), coated or uncoated, "sandwiches," pre-packaged cones, and other numerous forms. Although they should be evaluated by the processor in ongoing quality assurance procedures, novelties are seldom, if ever, judged competitively. The flavor, body, and texture of these types of products should be evaluated just as critically as their packaged counterparts, but there are some unique, potential problem areas that should be identified (Tobias, 1980). A listing of some of the more common quality problems of various types of frozen novelties that require special attention include the following:

Incomplete coverage with coatings
Coating too far down the stick
Incorrect volumes
Coating too thick
Coating too thin
Cracked coating
Slipped coating

Overrun too high
Overrun too low
Defective flavor
Defective texture
Damaged wrappers
Sticking wrappers
Broken sticks
Sugar "bleeding" from bars
"Soggy" wafers or cones (lack crispness)
High coliform count
Brine contamination

Due to their relatively small size, frozen novelties are markedly susceptible to the irreversible, damaging effects of temperature fluctuations. "Heat shock" is probably the most serious problem, but unfortunately, once the product enters the distribution system, there is limited control of frozen storage temperatures.

10.11 Conclusion

The quality and sensory attributes of ice cream as perceived by the consumer in terms of the most desirable flavor, body, and texture can be evaluated, but it is not easy. For a successful and dependable sensory evaluation of ice cream and frozen desserts, judges/students need to have experience and knowledge about the effect of ingredients, product formulation, processing manipulation, and handling on the properties of the products. Additionally, due to the uniqueness of frozen desserts, it is important that samples are prepared properly, the evaluation is conducted in a suitable environment, and the numerical standards for measuring the quality of the product are available. These subjects were covered in detail in this chapter. Special emphasis was given to the scorecard of the Collegiate Dairy Products Evaluation Contest, along with the techniques and scoring guide for vanilla ice cream. The guidelines include the description and identification of off-flavors, body, and texture defects and their sources or causes. Sensory evaluation of other frozen dairy desserts that are commercially available was also included. The materials in this chapter provide useful tools to learn and understand the sensory evaluation of frozen desserts; however, it is essential to practice as much as possible to become an experienced and accurate evaluator of ice cream quality.

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Chapter 11
Concentrated and Dried Milk Products

Scott Rankin

11.1 Introduction

The common characteristic of various types of concentrated milk products is the reduced water content. Generally, water is removed as vapor under reduced pressure (a partial vacuum) at relatively low product temperatures (in the approximate range of 43–80 °C [110–176 °F]). Other nonthermal technologies, such as those involving membrane, have gained significant attention due to improvements in product quality and energy savings (Kotsanopoulos & Arvanitoyannis, 2015). The products in this category vary with respect to (1) the degree of concentration; (2) percentage of milkfat; (3) whether preserved or perishable; (4) the method of preservation (if preserved); and (5) the milk fraction(s) captured. Some forms of concentrated milk products are intended for beverage consumption, while others are primarily used as ingredients in the formulation of various food products. A thorough treatment of the chemical changes manifest in such dairy products as a result of high heat treatments, and long-term storage is available (Fox, 1995).

Currently, a growing volume of milk-derived ingredients is produced for beverage use. With pasteurized milk products of high quality readily available at reasonable prices, US consumers tend to resist purchasing milk products manufactured from rehydrated dairy ingredients. In areas or regions where modern dairy industry infrastructure does not exist, such as those having land, cold-chain, transportation, or resource constraints, dairy foods made from concentrated and dried milk products are more readily accepted and consumed. Considerable research has improved our understanding of the technical problems encountered in manufacturing, storing, and utilizing concentrated and dried dairy ingredients with regard to retaining or improving functional performance and flavor character. Additionally, a growing

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amount of scientific evidence suggesting that specific milk components or fractions have demonstrable nutritional values has further strengthened the market for such ingredients (Miller et al., 1999).

11.2 Concentrated Milk Products

Included here, verbatim and in order of relevance, are several definitions from the US Grade “A” Pasteurized Milk Ordinance (US Department of Health and Human Services, 2017), providing federally recognized definitions of concentrated and dried dairy ingredients:

Milk Products
Milk products include cream, light cream, light whipping cream, heavy cream, heavy whipping cream, whipped cream, whipped light cream, sour cream, acidified sour cream, cultured sour cream, half-and-half, sour half-and-half, acidified sour half-and-half, cultured sour half-and-half, *reconstituted or recombined milk and milk products*, *concentrated (condensed) milk*, *concentrated (condensed) milk products*, *concentrated (condensed) and dry milk products*, nonfat (nonfat) milk, reduced fat or low-fat milk, frozen milk concentrate, eggnog, buttermilk, buttermilk products, whey, whey products, cultured milk, cultured reduced fat or low-fat milk, cultured nonfat (nonfat) milk, yogurt, low-fat yogurt, nonfat yogurt, acidified milk, acidified reduced fat or low-fat milk, acidified nonfat (nonfat) milk, low-sodium milk, low-sodium reduced fat or low-fat milk, low-sodium nonfat (nonfat) milk, lactose-reduced milk, lactose-reduced reduced fat or low-fat milk, lactose-reduced nonfat (nonfat) milk, aseptically processed and packaged milk and milk products as defined in this section, milk, reduced fat, low-fat milk or nonfat (nonfat) milk with added safe and suitable microbial organisms, and any other milk product made by the addition or subtraction of milkfat or addition of safe and suitable optional ingredients for protein, vitamin, or mineral fortification of milk products defined herein.

Milk products also include those dairy foods made by modifying the federally standardized products listed in this section in accordance with Title 21 Code of Federal Regulations (CFR) 130.10-Requirements for foods named by the use of a nutrient content claim and a standardized term.

This definition shall include those milk and milk products, as defined herein, which have been aseptically processed and then packaged.

Milk and milk products that have been retort processed after packaging or have been concentrated (condensed) or dried are included in this (the Title 21) definition only if they are used as an ingredient to produce any milk or milk product defined herein or if they are labeled as Grade “A” as described in Sect. 11.4.

Powdered dairy blends may be labeled Grade “A” and used as ingredients in Grade “A” dairy products, such as cottage cheese dressing mixes or starter media for cultures used to produce various Grade “A” cultured products, if they meet the requirements of this Ordinance. If used as an ingredient in Grade “A” products, such as those listed above, blends of dairy powders must be blended under conditions which meet all applicable Grade "A" requirements. Grade "A" powder blends must be made from Grade "A" powdered dairy products, except that small amounts of functional ingredients (total of all such ingredients shall not exceed 5% by weight of the finished blend), which are not Grade "A" are allowed in Grade "A" blends when the finished ingredient is not available in Grade "A" form, i.e., sodium caseinate. This is similar to the existing FDA position that such dairy ingredient in small cans of freeze-dried starter culture need not be Grade "A."

This definition is not intended to include dietary products (except as defined herein), such as infant formula, ice cream or other frozen desserts, butter, or cheese.

Dry Milk Products

Dry milk products mean products resulting from the drying of milk or milk products and any product resulting from the combination of dry milk products with other wholesome dry ingredients.

Grade "A" Dry Milk Products

Grade "A" dry milk products mean dry milk products that comply with the applicable provisions of the Ordinance.

Concentrated Milk

Concentrated (condensed) milk is a fluid product, unsterilized and unsweetened, resulting from the removal of a considerable portion of the water from the milk, which when combined with potable water in accordance with instructions printed on the container label, results in a product conforming with the milkfat and milk solids not fat levels of milk as defined in this section.

Concentrated Milk Products

Concentrated (condensed) milk products shall be taken to mean and to include homogenized concentrated (condensed) milk, concentrated (condensed) nonfat milk, concentrated (condensed) reduced fat or low-fat milk, and similar concentrated (condensed) products made from concentrated (condensed) milk or concentrated (condensed) nonfat milk, which when combined with potable water in accordance with instructions printed on the container label, conform with the definitions of the corresponding milk products in this section.

Grade "A" Concentrated (Condensed) Nonfat Milk

Grade "A" concentrated (condensed) nonfat milk means concentrated (condensed) nonfat milk, which complies with the applicable provisions of this Ordinance.

Frozen Milk Concentrate

Frozen milk concentrate is a frozen milk product with a composition of milkfat and milk solids not fat in such proportions that when a given volume of concentrate is mixed with a given volume of water, the reconstituted product conforms to the milkfat and milk solids not fat requirements of whole milk. In the manufacturing process, water may be used to adjust the primary concentrate to the final desired concentration. The adjusted primary concentrate is pasteurized, packaged, and immediately frozen. This product is stored, transported, and sold in the frozen state.

Whey Products

Whey products mean any fluid product removed from whey or made by the removal of any constituent from whey or by the addition of any wholesome substance to whey or parts thereof.

Grade "A" Whey Products

Grade "A" whey products mean any fluid product removed from whey or made by the removal of any constituent from whey or by the addition of any wholesome substance to whey or parts thereof which have been manufactured under the provisions of this Ordinance.

Dry Whey Products

Dry whey products mean products resulting from the drying of whey or whey products and any product resulting from the combination of dry whey products with other wholesome dry ingredients.

Grade "A" Concentrated (Condensed) and Dry Whey and Whey Products

Grade "A" concentrated (condensed) and dry whey and whey products mean concentrated (condensed) or dry whey and whey products, which comply with the applicable provisions of this Ordinance. The words "concentrated (condensed) and dry milk products" shall be interpreted to include concentrated (condensed) and dry whey and whey products.

Title 21 of the CFR Section 131 (2020) contains specific standards of identity and compositionally based definitions for the following products of immediate significance to this chapter, including the following:

131.110 Milk
131.115 Concentrated milk
131.120 Sweetened condensed milk
131.125 Nonfat dry milk
131.127 Nonfat dry milk fortified with vitamins A and D
131.130 Evaporated milk
131.147 Dry whole milk
131.149 Dry cream

All sections are available directly from the US Government Printing Office and online. Although it is beyond the scope of this chapter to reproduce all of these sections in their entirety here, one complete section (131.125 Nonfat dry milk) is included as an example of the type and degree of coverage included in these federal regulatory documents.

11.2.1 Section 131.125 Nonfat Dry Milk

(a) Description. Nonfat dry milk is the product obtained by removal of water only from pasteurized nonfat milk. It contains not more than 5% by weight of moisture and not more than 1 and 1/2% by weight of milkfat unless otherwise indicated.

(b) Optional ingredients. Safe and suitable characterizing flavoring ingredients (with or without coloring and nutritive carbohydrate sweetener) as follows:

   1. Fruit and fruit juice, including concentrated fruit and fruit juice
   2. Natural and artificial food flavorings

(c) Methods of analysis. The following methods of analysis are from "Official Methods of Analysis," 21st Ed. (2019). Copies may be obtained from the AOAC INTERNATIONAL, 2275 Research Blvd, Ste. 300, Rockville, MD 20850 + 1 (800) 379–2622.

   1. Milkfat content: "Fat in Dried Milk – Official Final Action"
   2. Moisture content: "Moisture – Official Final Action"

(d) Nomenclature. The name of the food is "nonfat dry milk." If the fat content is over 1 and 1/2% by weight, the name of the food on the principal display panel or panels shall be accompanied by the statement "Contains __% milkfat," the blank to be filled in with the percentage to the nearest one-tenth of 1% of fat contained, within limits of good manufacturing practice. The name of the food shall include a declaration of the presence of any characterizing flavoring, as specified in Section 101.22 of this chapter.

(e) Label declaration. Each of the ingredients used in the food shall be declared on the label as required by the applicable sections of parts 101 and 130 of this chapter.

11.3 Sensory Considerations

Concentrated milk and derived milk products intended for use as a reconstituted beverage milk or as an ingredient in other applications are generally evaluated for sensory properties in a manner similar to the native, unconcentrated milk product by first reconstituting it with good-quality potable or even distilled water. Many concentrated dairy products may also be evaluated without reconstitution with the caveat that some tastes and aromas are generally more readily noticed after reconstitution or rehydration even after dilution with water. The phenomenon of improved detectability of concentrated milk product sensory attributes may relate to the entrainment or binding of flavor-active compounds within the dried protein and lactose-based particles such as are found in nonfat dry milk powder. Due to the generally higher sweet and salty background flavors of milk concentrates, dilution of the concentrate to the original composition provides a more typical set of test conditions for sensory evaluation. It is a generally accepted ideal that the reconstituted product should emulate its native counterpart in flavor, mouthfeel or consistency, and appearance. In addition to flavor defects, any visible evidence of immediate discoloration, thinning or thickening, particulate formation, or other abnormalities should be noted as defects (Hammer, 1919; Hunziker, 1949; Sommer & Hart, 1926). A generally accepted practice for preparing milk-derived powders for sensory evaluation suggests that an approximately 10% wt/wt solution in distilled water is adequate (Drake et al., 2003; Carunchia-Whetstine & Drake, 2007).

In the mid-1960s, considerable interest was generated in the market potential of a 3:1 sterile concentrated milk, although only relatively small quantities were actually produced. The major sensory problems of this product involved shortcomings of both taste and mouthfeel. The off-flavors that regularly developed in these products during storage were unique and somewhat difficult to describe given their absence from native milk. Judges commonly labeled these off-flavors of sterile milk concentrates as stale, caramel-like, or a combination of stale/caramel defect. These particular off-flavors could be associated with the browning reaction of heated milk (Arnold et al., 1966; Muck et al., 1963) and may not have been too far off of those encountered in commercially sterile milk (Zabia et al., 2012). Any possible future success of sterile milk concentrates will depend on processors' ability to prevent flavor and functional deterioration during storage.

Descriptive terminology as applied to concentrated milk products is somewhat confusing; hence, a review of several key terms should be helpful. For example, what is the difference between concentrated, condensed, and evaporated milk when the products' composition in all three cases may be identical? Evaporated and concentrated milk are clearly defined in the CFR, as is sweetened condensed milk. But what kind of product is referred to by the term "unsweetened condensed milk"? This confusion may be eased somewhat if it is assumed that "evaporated milk" represents a special type of sterile concentrated product, for which the composition and processing are clearly defined. A reasonable suggestion and historical industry convention is to reserve the term "concentrated" for products of beverage quality and use the word "condensed" when the milk product is primarily intended as an ingredient in cooking, baking, candy-making, or food manufacture.

In addition to meeting the legal composition and chemical requirements, high-quality evaporated milk should be creamy white in color, have a relatively viscous body, be uniformly smooth in texture, and possess a relatively mild, pleasant flavor free of noticeable off-aroma. Furthermore, the container should present an attractive appearance and exhibit a neat, well-applied label; the ends of the can or general integrity of any packaging should appear well-finished and show no evidence of tampering or misformation. The overall examination of the product includes flavor, body, and texture/viscosity and appearance (color, fat separation, and serum separation). Outside of other physicochemical or microbial parameters, the examination of evaporated milk may consider the following attributes:

Coffee whitening properties
Color
Container integrity
Curd tension
Fat separation
Fill of container
Film formation (protein "break")
Flavor

Gelation
Lactose crystallization/sandiness
Sedimentation
Serum separation
Viscosity
Whipping quality

Instrumental assessments of concentrated milks require the use of colorimeters, viscometers, electric mixers, and other specialized laboratory equipment. Sensory assessments employ scorecards or rating scales through either highly trained panelists or untrained consumer panels as defined in other chapters of this text. As with other commodities, dried and concentrated dairy foods are routinely evaluated by expert judges or graders, as are employed by USDA, using language published within specific standards of identities or product specifications. An example (see American Dairy Products Institute, 2002) may include such language as "Reconstituted Extra Grade dry whole milk flavor shall be sweet, pleasing and desirable. It may possess a slight feed flavor and a definite cooked flavor. It shall be free from undesirable flavors."

11.4 Examination Procedures for Evaporated Milk

Establishment of a clearly crafted protocol for examining evaporated milk can facilitate the evaluation of numerous samples and allow more defensible assessments over time. The steps outlined in the following paragraphs have been found most helpful in evaluating sample sets of evaporated milk (Bodyfelt et al., 1988).

Undue agitation should be avoided when cans of the product are transported to the laboratory. The product should be carried in an upright position and be placed vertically on the table to avoid remixing any possible precipitates (sediment) or fat layers into the product.

Examination of the can appearance should be done without lifting the can from the table. The upper end of the can should be noted for the degree of polish and seam integrity; the attractiveness of the label and the evenness of its application should be observed. The evaluator should insert a knife under the label and cut it from top to bottom. After partially or completely removing the label, the judge should note the condition or integrity of the can, especially with respect to freedom from rust spots or dents.

With an edge-cutting can opener, the evaluator should almost cut around the entire periphery of the upper end of the can and turn back the lid. By opening a can in this manner, both the container and the contents may be examined carefully.

Color Evaporated milk should display a light, uniform cream color but may tend toward a light brown color. In case of brown discoloration, the exact shade of the color may be determined either instrumentally with a colorimeter or by visual comparison with color charts (using a numerical or graphical intensity scale) or by noting and recording the relative intensity of darkening as follows: none, slight, distinct, and pronounced.

Uniformity Evaporated milk should be uniform or homogeneous as evidenced by the complete absence of a cream layer, curd formation, or destabilized milkfat. Product uniformity may be more readily determined with the assistance of a spatula. Results of the examination for product uniformity may be verified when the product is examined for body and texture. In the macroscopic examination of the product for uniformity, the evaluator should notice particularly the undersurface of the turned-back lid for possible adherence of cream or precipitated salts or sugars.

Study the Body and Texture The contents of the can should be poured slowly into a clean glass beaker; the judge should note the flow properties of the product. A smooth, relatively viscous evaporated milk should pour in a similar manner to a thin cream (without marked splashing action) without any apparent ropiness. The can is allowed to drain completely; when the container is empty, the evaluator should look for any possible types of deposits on the can's interior surfaces. If the bottom metal surface cannot be seen through the remaining film of evaporated milk, the can bottom should be scraped with a spatula to determine whether a firm, tenacious deposit is present. The can is set aside for later examination; the observer should proceed with an examination of the evaporated milk for viscosity and texture. This is done by spooning up some of the milk with a plastic or hard-rubber spatula and allowing it to drip back into the beaker. The evaluator needs to note the relative thickness and uniformity of the film that adheres to the spatula.

A test for examining the presence of particulate matter is achieved by examining a film of the milk through which a light source has been transmitted. By means of a 1.27–1.90 cm (1/2–3/4 in.) wire loop (or a cutaway spoon), the milk film is observed for surface evenness or uniformity. This is done by dipping the loop into the product and withdrawing it carefully to form a film across the face of the loop. Next, the milk film is held up to the light source, and the observer looks for curd particles of pinpoint size. The appearance of small grains throughout the film indicates protein destabilization or denaturation. If the milk appears rough, grainy, or lacks uniformity, these conditions may be associated with excessive viscosity and could also provoke the feathering defect in coffee.

Should evaporated milk lack uniformity of body/texture, the evaluator should try to determine the possible cause. Contributing factors may be destabilized milkfat or protein, the presence of precipitated salts, or foreign material. If destabilized milkfat is responsible, the defect generally will appear as a cream layer or as butter-like particles on the product surface. When denatured protein is the cause, the defect usually appears as either various-sized curds (distributed throughout) or as a form of gelation of different intensities. Salt deposits are responsible for formation of a hard, gritty precipitate that may have settled on the can bottom. Foreign material is the probable cause if the sediment is evident as a smudge-like discoloration on the can bottom; this is only evident when the last traces of the product contents are decanted. Lactose crystals may also be formed in such products and are noticeable as a gritty precipitate with poor solubility.

Observe the Condition of the Container The observer should especially look for either spangling, blackening of the seams, or container corrosion (rustiness). Spangling refers to the appearance of alternate clean, bright and dark, overlapping blotches on the surface (as though the tin were attacked by acids). Typically, any such blotches are well distributed over the inner surfaces of the can. Next, the container should be rinsed and the inner surfaces observed for any evidence of chemical activity. Discoloration and rusting may occasionally be noted on any part of the can, but it tends to occur particularly at the milk–air interface.

Determine the Product Reaction in Coffee Though the use of evaporated milk as a coffee whitener has declined, there is still merit in checking its color reaction and miscibility in coffee. Evaporated milk should impart a rich, golden-brown color to coffee. The coloring power of evaporated milk may be readily determined by adding approximately 10 ml of the product to 100 ml of test coffee of typical strength and temperature. Occurrence of an iron contamination of the product may be indicated by the development of a greenish-dark, muddy, slate-like discoloration in coffee. Thus, this off-color in an evaporated milk–coffee mixture can often be associated with container rust formation. Feathering in coffee is the result of protein denaturation and typically manifests itself as finely divided, serrated curds shortly after a susceptible evaporated milk has been added to extremely hot coffee.

Determine the Flavor For flavor determination, evaporated milk should be mixed with distilled water in a 1:1 ratio. Sampling and flavor evaluation or flavoring are conducted by the same procedure employed in evaluating fluid milk. High-quality evaporated milk (made by a conventional process) tends to have a specific milk/cream flavor, which some individuals find reminiscent of a delicate, high-quality mushroom soup.

The evaluator should bear in mind that the source of added water might have an adverse effect on the flavor of evaporated milk. Some experienced judges of evaporated milk prefer direct tasting of the final sterile concentrate rather than evaluating a diluted product. This method of sensory evaluation requires keen perception, but it has the advantage of eliminating the flavor diluting effect of the water used for product reconstitution.

The declining demand in the USA for evaporated milk has served to discourage the development of product forms. As a result of improved concentration technologies, such as membrane processes, various forms of concentrated milk products have gained a larger share of milk markets in this country. The body characteristics of conventionally processed evaporated milks have been markedly improved through the use of stabilizers that prevent physical separation during storage and help keep the product smooth and creamy throughout typical distribution cycles (Graham et al., 1981).

The evaluator should be aware that evaporated milk is intended to be a shelf-stable product; any evidence of bacterial growth, spoilage, or loss of container integrity is unacceptable. The defects that will be subsequently discussed are the result of physical causes and/or chemical activity, which proceed in the absence of any viable microorganisms (Bodyfelt et al., 1988).

11.5 Specific Sensory Defects of Evaporated Milk

Flavor The flavor defects that usually occur in evaporated milk are unlike those commonly encountered in fresh beverage milk, due to concentration under vacuum (which removes volatile off-flavors) and the extent of the applied heat during sterilization.

Probably the most common storage defect of evaporated milk results from the progressive age-darkening or browning of the product. No single term seems to describe this off-flavor adequately. Such terms as old, strong, slightly acid, sour, and stale coffee may suggest the nature of the defect. The term caramel, which is probably suggested by the brownish milk color, is not appropriately descriptive in this instance; however, it does suggest the chemical origin of the off-flavor. A caramel flavor, as in certain confections, generally connotes a pleasant, appetizing taste sensation; however, this agreeable response is definitely lacking when this flavor occurs in evaporated milk. A caramel off-flavor is associated with the age-darkening of evaporated milk. When a caramelized sample is first placed into the mouth, the flavor sensation is not particularly different from that of normal evaporated milk, but soon a distinctly old or slightly acid off-flavor is evident. This flavor defect may persist for some time, even after the sample has been expectorated. This off-flavor may be accompanied by an odor that suggests staleness. The underlying taste reaction of age-darkened evaporated milk is acidic. The extent of staleness is primarily a function of product age and storage temperature.

A study by Sundararajan et al. (1966) determined flavor changes that occurred during the storage of evaporated milk produced by the (1) conventional (long-hold retort); (2) high-temperature, short-time (HTST) (short-hold retort); and (3) aseptic (ultrahigh temperature – UHT) methods of processing. These workers concluded that the type of heat processing had a significant effect on the initial flavor score. The aseptic process yielded the best-flavored product initially and remained the best when the product was stored at 10 °C (50 °F) or 27 °C (80.6 °F) for about 2 months. After storage for 1 year, flavor scores of the HTST and aseptically made products were similar, but the flavor of conventional evaporated milk was significantly lower in quality. Flavor ratings of the conventionally processed product scored the lowest of the three product forms throughout the storage study. These investigators employed a fluid milk scorecard with a 40-point scale for flavor. The evaporated milk samples were evaluated after appropriate dilution. The initial flavor of the conventionally manufactured product was described as cooked and caramel. The off-flavors that developed during subsequent storage were variously described as acid, stale, storage, bitter, astringent, and puckery (mouthfeel).

Body and Texture Contemporary technologies applied to manufacture evaporated milk have resulted in improved quality control. This has resulted in improved product uniformity from batch to batch, as well as between processors. Currently, fresh evaporated milk is remarkably free of body and texture defects. However, when evaporated milk is held for extended time periods or under adverse conditions, some body and texture defects may be encountered, such as the following:

Buttery, fat separation
Curdy
Feathering
Gassy
Grainy
Low viscosity
Sediment

Buttery, Fat Separation The buttery defect appears as a 0.64–1.27 cm (1/4–1/2 in.) layer of heavy cream at the top of the can. The cream layer may be so dense and tenacious that it is not miscible with the remainder of the milk. Under such conditions, the shaken milk appears curdy, with floating masses of cream or butter particles within a liquid of relatively low viscosity. Several alleged causes of this defect are (1) inadequate homogenization; (2) high storage temperature; (3) extended storage period; and (4) improper handling while in storage, i.e., a combination of high temperature, excessive agitation, etc. The incorporation of stabilizing agents has helped to control this serious defect. Consumers object to this defect, since such milk fails to pour readily and thus creates the suspicion that the product may have spoiled. This body defect is not associated with any particular flavor defect. The occasionally noted thin film and/or surface streaks of cream are undesirable product features but do not dramatically alter the functionality of the product for the consumer relative to the more complete cream separation noted above.

Occasionally, discs of free fat, from 0.08 to 0.32 cm (1/32–1/8 in.) in diameter, may appear on the surface of evaporated milk; these rarely encountered droplets of hydrophobic milkfat in the product are referred to as “moon spots.” The fat appears yellowish, crystal clear, and as flattened spheres scattered sporadically on the surface. This defect seems to be associated with inadequate homogenization, destabilized protein, and low viscosity, which is probably accelerated by high-temperature storage. Such evaporated milk lacks the homogeneity of a high-quality product.

Curdy Curdy evaporated milk may be noted by the presence of coagulated protein particles interspersed throughout the milk or by a continuous mass of coagulum or soft gel. This condition differs from the buttery defect in that it is associated more with the formation of protein-based structure than with milkfat. With high milk quality, modern processing, and technical control, this defect is observed rarely in products consumed early in their shelf life. Nonetheless, a tendency toward age gelation should be watched closely. The presence and activity of the endogenous milk enzyme plasmin have been indicated as a cause of age gelation in several milk products with long shelf life (<3 months, ambient storage temperature). Plasmin activity is more common in milks from animals with high somatic cell counts; the enzyme is surprisingly heat stable, allowing its activity to continue work to hydrolyze milk proteins, namely, casein, throughout storage.

Feathering The feathering of evaporated milk in hot coffee is difficult to predict by macroscopic examination; as such, it is more routinely ascertained by actually testing the milk sample in hot coffee. Such a test was proposed by Whitaker (1931), wherein he surmised that, upon examination of 52 cans of commercial evaporated milk, feathering in hot coffee was not a common defect. In addressing the coffee-whitening problem, Mojonnier and Troy (1925) found that curd formation (when evaporated milk was added to coffee) was due entirely to excessive viscosity of the product. A more recent method for the assessment of feathering was published by Anderson et al. (1977). Such feathering, as a defect, is distinctively different from a commonly encountered use of the term "feathering" of cream or milk by baristas in the coffee service industry. This latter feathering phenomenon refers to the generation and application of a delicate milk-based foam layered on the surface of coffee-based beverages in contrast to the appearance of a surface-based layer is relatively insoluble milk solids (Fig. 11.1).

Gassy Fortunately, gassy evaporated milk is uncommon. This defect is manifested by bulged cans and sometimes by a hissing sound of escaping gas when the can is punctured upon opening. This defect can be due occasionally to certain physical–chemical causes, but microbial fermentation is the most typical cause.

Grainy Graininess, like curdiness, is related to the relative heat stability of milk proteins. A grainy evaporated milk is one that lacks smoothness and uniformity throughout; such a product appears coarse. If this defect is present, a film across a loop or an open-bottom spoon will transmit light unevenly. Grainy evaporated milk

Fig. 11.1 Image of surface of cup of coffee with added creamer showing the feathering defect. Although the bulk of the creamer readily combines with the coffee, some remains on the surface; the material residing on the surface is an example of surface feathering of coffee creamer. (S. Rankin image)

is often associated with an excessively heavy, viscous body. The evaluator should recognize that grainy evaporated milk does not actually contain “grains” of sediment. The presence of curd particles of pinpoint size may be noted when a light source is transmitted through a film of the product; hence, the visible grain is indicative of protein break or denaturation.

Low Viscosity A low-viscosity evaporated milk may be noted by its more water-like consistency; such milk lacks creaminess and pours from the container as readily as fresh milk. The viscosity of evaporated milk is related to heat stability. Highly stable milk and technical efforts to achieve high heat stability tend to produce low viscosity; by contrast, low heat stability leads to high viscosity in the finished product. The viscosity attained immediately after sterilization may change, depending on several factors (storage temperatures, especially). Thinning or thickening (even to the point of gelation) may occur as a result of product aging; this depends on such factors as solid content, preheating temperatures, type of sterilization process, milk quality, and initial viscosity. In conventional evaporated milk, the addition of stabilizers has simplified the control of viscosity.

Sediment Sedimentation, as observed in evaporated milk, may be of two distinct kinds; each type of precipitation may arise from entirely different causes. The sediment resulting from the settling of somatic cells (leukocytes), denatured protein, and/or foreign material (of possible colloidal nature) is usually darker in color than the product itself. Since these forms of sediment are readily miscible, they may only be seen when an undisturbed can is emptied slowly. This infrequent defect is not readily experienced by the consumer, since evaporated milk is subject to some agitation, especially when decanted through small puncture holes in the can top.

The second type of sedimentation that may occur in evaporated milk results from the crystallization of specific calcium and magnesium salts such as tricalcium phosphate ($Ca_3(PO)_2$), magnesium phosphate ($Mg_3(PO_4)_2$), and tricalcium citrate ($Ca_3(C_6H_5O_7)_2$). These forms of gritty-like sedimentation frequently accompany the aging of evaporated milk. The rate at which crystals form seems to be influenced by the nature of the milk, conditions of manufacture, and storage temperature. Sato (1923), Mojonnier and Troy (1925), and Gould and Leininger (1947) found these white, gritty, sand-like particles to be chiefly lime salts of citric acid or tricalcium citrate ($Ca_3(C_6H_5O_7{\cdot}4H_2O)$). Their rather bland, chalky taste suggests a form of calcium salt. These crystals vary from the size of a pinpoint to the size of a wheat kernel. They are usually found on the container bottom and may be noted when the contents are emptied.

Color The principal color defect of evaporated milk is browning. This color defect results from the Maillard reaction involving chemical interactions between lactose and milk proteins (and their hydrolysis products) upon severe heat treatment and subsequent storage. Numerous flavor compounds, including those involving hydroxymethylfurfural, are also produced during the course of the browning reaction, which can lead to corresponding flavor defects. The degree or intensity of the brown discoloration is related to the intensity (time and temperature) of the sterilization process and the storage temperature. Aseptic and HTST sterilization systems generally yield a lighter-colored product than the conventional retort (long-hold) process. However, additional darkening may occur during storage in all cases, as a function of age and the storage temperature of the product.

11.6 Sweetened Condensed Milk

A description of sweetened condensed milk can be found in 21 CFR 131.120 (CFR, 2020):

(a) Description. Sweetened condensed milk is the food obtained by partial removal of water only from a mixture of milk and safe and suitable nutritive carbohydrate sweeteners (Fig. 11.2). The finished food contains not less than 8% by weight of milkfat and not less than 28% by weight of total milk solids. The quantity of nutritive carbohydrate sweetener used is sufficient to prevent spoilage. The food is pasteurized and may be homogenized.

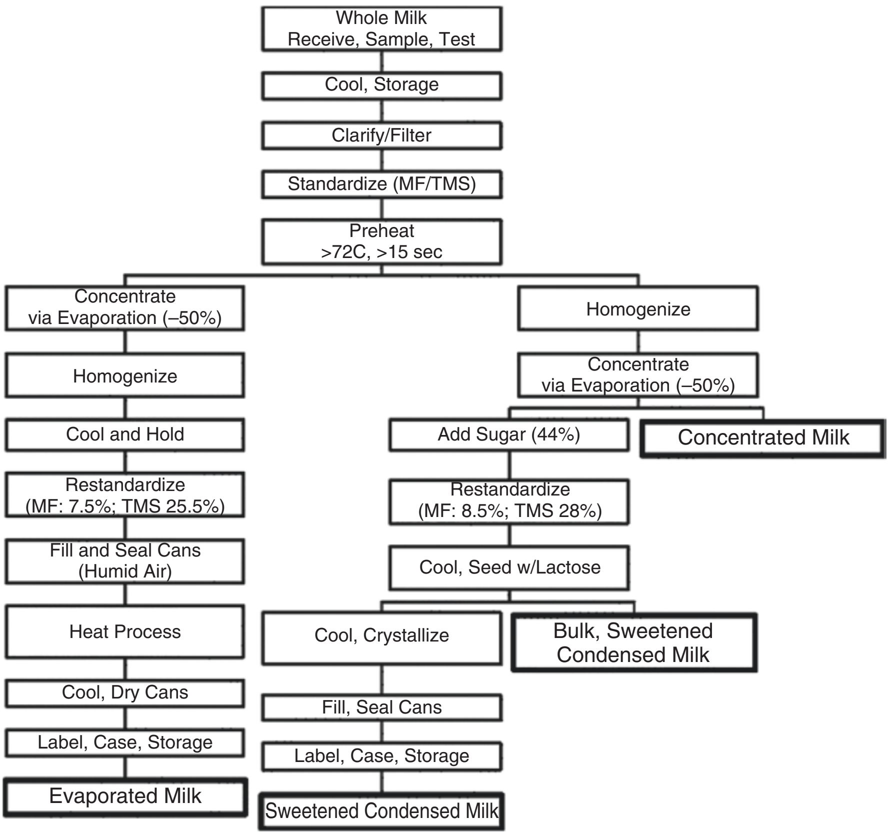

Fig. 11.2 Flow diagram for the manufacture of evaporated and condensed milks

(b) Optional ingredients. The following safe and suitable characterizing flavoring ingredients, with or without coloring and nutritive carbohydrate sweeteners, may be used:

1. Fruit and fruit juice, including concentrated fruit and fruit juice.
2. Natural and artificial food flavoring.

Sweetened condensed milk contains a sufficiently high percentage of sugar for preservation via mechanisms of high osmotic strength; thus, sterilization is not required for shelf stability. Additionally, the flavor sensation is predominantly (or overwhelmingly) sweet. However, beyond this intense sweetness, the flavor of this dairy product should be clean and pleasant, with a slight or trace aftertaste of milk caramel. The body of the product should be smooth and uniform; the color should be a light, translucent yellow (Fig. 11.1).

Whether sweetened condensed milk is used in the home kitchen or in a food processing plant, its primary function is as an ingredient in candy, cookies, pies, and ice cream and not as a beverage. Hence, its sensory properties are nearly exclusively evaluated in the research or quality control laboratories of processors or end users assessing ingredient performance. Careful consideration must be given to the functional properties of this product, but sensory characteristics are also important in the overall process of the quality evaluation of sweetened condensed milk before purchase or inclusion in manufacturing.

11.7 Examination Procedures for Sweetened Condensed Milk

The unique precautions and steps that were applicable in the evaluation of evaporated milk are not as germane to the examination of sweetened condensed milk (in consumer-size containers). However, a specified routine or protocol enables the evaluator to best utilize the available time with greater assurance that the examination is thorough and comparable to previous assessments. Hence, the following recommended procedure may be helpful (Bodyfelt et al., 1988).

The evaluator should place a representative container on a table for examination. The can should be in exactly the same (upright) position that it had assumed prior to examination. This readily enables the judge to open the container and make an initial examination of the top surface and product contents. Next, the evaluator should cut and turn back the container lid so that the condensed milk surface may be closely examined and the contents easily decanted from the container. The recommended order of visual examination is listed below.

Appearance of the Container The sweetened condensed milk container should appear to be in good condition. Since the container has not been subjected to high heat treatment, as in retorting (which dulls container surfaces), the can ends should be as bright as new tin. It is advisable that the evaluator develops the habit of carefully scrutinizing or observing the relative condition of all containers.

Appearance of the Product Surface The product surface should have the same color intensity as various underlayers of the condensed milk. The product should be uniform in consistency with no indication of lumps, free fat, or film formation.

Color With a spatula, the judge should spoon up some of the product and note the relative translucency of a condensed milk layer. The color should be uniform throughout rather than have a lighter-colored layer at the container bottom. The evaluator should determine whether the sweetened condensed milk has a creamy or a less desirable brownish color.

Viscosity Next, the evaluator should tilt the container at an angle and then note the relative ease with which the product is able to flow within the can due to gravity. The product is poured into a beaker. The observed pouring characteristics (flow) should resemble those of a medium-heavy molasses. There definitely should be no indication of a gel or custard-like formation. Flow characteristics (viscosity) can also be determined objectively by physical measurement.

Sediment After the can has been emptied, the evaluator should scrape the bottom and note the presence or absence of a thickened layer (which may be a crystalline, granular material). The color of the granules should be compared with the bulk of the milk and the size of any precipitated crystals measured against any suspended in the liquid.

Flavor After the above macroscopic examination has been completed, the judge should note the flavor characteristics. With the sample at a typical room temperature (e.g., 25 °C), a small teaspoonful of the sweetened condensed milk should be placed into the mouth; the evaluator needs to observe the mouthfeel, taste, and aroma sensations. The relative smoothness of the product and the grain fineness can be noted by pressing some of the sample against the palate with the tongue. By this time, the evaluator may have experienced a secondary taste reaction – a perceived flavor other than sweetness. This delayed flavor note usually represents a blend of the sensory perception of the added sugar and dairy ingredients.

11.8 Defects of Sweetened Condensed Milk

Flavor Sweetened condensed milk, due to its concentration under vacuum, tends to have none of the volatile flavors that may occur in fresh milk. Since this product is preserved by sugar rather than by heat, it should not exhibit those off-flavors that result from the higher heat treatments applicable to evaporated milk and certain other milk products. Hence, when this product is properly manufactured, it is remarkably free of flavor defects. However, several off-flavors in sweetened condensed milk have been noted to develop with increased storage time, as indicated below:

Metallic
Rancid
Strong
Tallowy

Metallic The metallic off-flavor of sweetened condensed milk is distinctly chemically induced; it is usually traceable to copper contamination. Hunziker (1949) stated that "sweetened condensed milk may have a pronounced, disagreeable metallic flavor – suggesting the puckery, copper-like taste of copper salts." Copper contamination should be encountered infrequently due to near ubiquitous use of stainless steel equipment in modern processing systems.

Rancid Fortunately, a rancid off-flavor occurs most infrequently in sweetened condensed milk. As discussed earlier in this book, rancidity results from milkfat hydrolysis due to enzymes secreted by spoilage bacteria or indigenous milk lipase, which may not have been heat inactivated or was active against the milkfat before the milk was pasteurized. If the milk source was rancid, the peculiar, offensive odor associated with hydrolytic rancidity may be readily noted when the can is first opened.

Strong The term strong or strong caramel is often used to describe the off-flavor that accompanies the progressive thickening and browning of condensed milk. While this particular flavor sensation must be classified as a defect, it is not usually a serious one. Unfortunately, a caked or gelled product, with its associated deep brown color, often suggests that the product may manifest extreme flavor impairment. However, such condensed milk occasionally may develop or display a rather pleasant caramel-like taste.

Tallowy Rice (1926) observed in the instance of tallowy condensed milk that on opening a tin, the sample may appear paler than normal. The aroma of the freshly opened product may be reminiscent of beef tallow and remains noticeable even after exposure to the air for several days. Tallowiness has become a rarely encountered oxidation defect in sweetened condensed milk. Elimination of copper contamination and prevention of exposure of milk to light and air are the most likely reasons why this off-flavor is practically extinct.

Off-Flavors Caused by Microorganisms Certain osmophilic and osmoduric microorganisms, including yeasts, molds, and bacteria, can tolerate high sugar concentrations and, under certain conditions, can grow and cause spoilage in sweetened condensed milk. The growth of these microorganisms or the activities of their enzymes may be accompanied by characteristic physical and appearance changes, gas production, off-flavors, and odors. Depending on the type of microorganism involved, the resultant odor may be acidic, stale, cheesy, unclean, or yeasty. Any products that show evidence of microbial activity should be considered unsalable.

Body and Texture Due to the relatively high percentage of sugar required for preservation, sweetened condensed milk exhibits a relatively heavy body (somewhat like molasses). Also, this product usually has a fine-grained, smooth, and uniform texture. However, the following body and texture defects may be encountered:

Buttons
Lumpy
Fat separation
Gassy
Sandy (rough, grainy, granular)
Settled
Thickened

Buttons Although they generally change the consistency of a portion of the product, formed "buttons" are visually observed as round, firm, cheesy curds at the product surface. These buttons result from the proteolytic activity of certain molds. Product losses due to button formation can be eliminated by preventing contamination by osmophilic molds and other microorganisms.

Lumpy Occasionally, a product may exhibit pronounced differences in viscosity (lumpiness) within portions of the container contents. Sometimes, portions of the product may have actually gelled. It should be determined whether this problem is due to possible microbiological contamination or some other cause.

Fat Separation Fat separation in sweetened condensed milk seldom occurs. This defect may be noted by either an off-color, fatty film at the surface and/or floating droplets of free fat. Milkfat separation may be due to improper homogenization and elevated temperatures during the course of storage.

Gassy Condensed milk that has developed gassiness may be recognized by a bloated or huffed can. This defect results from contamination by and subsequent outgrowth of gas-producing microorganisms. Hammer (1919) studied the formation of gas in sweetened condensed milk and found the causative agent to be a yeast, which he named *Torula lactis condensi*. A yeasty odor was associated with this gaseous condition. Today, the defect is rarely noted.

Sandy (Rough, Grainy, Granular) All of these terms are used interchangeably to describe sweetened condensed milk that contains detectable or oversized lactose crystals. The solid lactose particles are sufficiently large enough to impart a distinct grittiness and general lack of product smoothness, which is readily noticeable as the sample is tasted. This defect can be readily detected by the consumer. The condition referred to as sandiness is due to the presence of relatively large lactose crystals (>50 μm). The so-called smooth condensed milk has minute-sized lactose crystals, which seem to appear like a fine flour mixed into the condensed milk. If manufacturing conditions are not conducive to the formation of small lactose crystals (<50 μm), then large, coarse crystals are likely to form (sandiness). The sandy defect may also be caused by sucrose crystals, when the concentration of this sugar exceeds the saturation level.

Settled The term settled is used to describe a condensed milk in which a distinct settling of sugar crystals has occurred. The syrup that settles out forms a thick sugary layer on the container bottom. This sugar sediment consists primarily of lactose crystals, according to Hunziker (1949). Key measures for prevention of this defect include efforts to ensure small crystals and development of an adequate product viscosity to retard sedimentation.

Thickened Overly thickened condensed milk is one of the more common defects that can be encountered in sweetened condensed milk. The defect is manifested by an extensive gel formation, which leads to a product appearance more suggestive of a solid than a liquid. Excessively thickened condensed milk is usually associated with browning; both undesirable conditions become progressively more intense upon additional storage (especially at elevated temperatures). This defect varies markedly in intensity from a slight jelly to a firm custard consistency. As noted above, a high-quality sweetened condensed milk should pour like molasses. When the product is poured, it should gradually level out and leave no traces of folds on the surface. The formation of a gel, even a soft gel, is entirely undesirable. Both physical and chemical factors are commonly responsible for thickening of sweetened condensed milk, but certain microorganisms may also cause product thickening.

11.9 Other Concentrated Milk Products

The evaluation of other concentrated milk products differs little from that of the products previously described. Products such as milk protein concentrate, evaporated nonfat milk, and sweetened condensed nonfat milk should be evaluated in a similar manner to their water-containing counterparts. Obviously, one must allow for the absence of fat in evaluating both the flavor and tactile properties. Some products are produced to provide certain functional properties for specific applications. A good example is superheated condensed milk (or nonfat milk) for use as a milk ingredient in ice cream manufacture. This product should possess a desirable flavor and an appealing color as well as impart the desired body properties to ice cream. Instrumental measurements of viscosity should supplement sensory-derived assessments of product consistency. As a general principle, when a concentrated milk product is intended for beverage purposes, sensory evaluation should ascertain how closely the product quality approaches that of its unconcentrated, high-quality, fresh milk counterpart. When a concentrated milk is used as an ingredient, the primary question becomes “Does the quality of this product as an ingredient reflect the target quality of the finished product?”

11.10 Dry Milk Products

Since its commercial origin, dry milk has been graded on the basis of bacteria, moisture, and certain physicochemical properties. More recently, flavor and other sensory properties have become important criteria in grading dry milk products. In addition to compliance with regulatory standards, dry milk must also have good flavor characteristics if it is to gain consumer or processor acceptance. The relative importance of flavor character is governed to a large extent by the intended use of the product. The evaluator of dry milk should be familiar not only with the product standards and the associated laboratory tests but also with the appropriate flavor standards and potential flavor defects.

11.11 Methods of Producing Milk Powder

There are two principal methods of producing milk powder from concentrated milk, namely, the roller process (nearly nonexistent in the USA) and the spray-drying process. Numerous technical developments in the removal of water from concentrated milk have vastly improved certain properties of dried milk and facilitated the drying of several milk product forms that would not have been possible otherwise. It should be noted that by convention, native milks are first concentrated through evaporation technologies to facilitate the final drying steps, namely, spray drying, to proceed with more efficiency. One development that has served to improve the rehydration of dried nonfat milk is the process known as agglomeration or instantizing. This process involves slightly humidifying and then redrying previously dried milk (referred to as rewet agglomeration) to attain a more soluble, porous particle form. In newer spray-drying facilities, this process is achieved during the actual spray-drying process (referred to as single-pass agglomeration). Other drying technologies include foam drying, freeze drying, and fluidized-bed drying, although these methods have had a greater impact on foods other than dairy products and/or are used in conjunction with standard spray-drying technologies.

The additional concentration of fluid milk that occurs at the instant of drying and the type of drying process substantially influence the physicochemical properties of the resultant dry milk. Thus, certain qualities of the finished product provide clues to the method of product manufacture. A descriptive outline of several milk-drying methods and some characteristic qualities of the respective dry products are given below.

Atmospheric Roller In this process, milk is dried in the open air on the surface of revolving, internally heated drums. The dried milk film is shaved from the drums and pulverized. The end product is characterized by a relatively heavy body, coarse texture, and comparative insolubility when it is initially added to water. Under the microscope, the solid particles appear angular, flaky, and irregular; seldom are spherical-shaped grains or particles noted.

Vacuum Drum This drying process is similar to the atmospheric roller process except that the drum rolls are enclosed within a vacuum chamber and thus permit drying at reduced temperatures. This is advantageous from a product quality standpoint in that lower temperatures and times are necessary for dehydration, thus limiting numerous thermal degradation reactions. Vacuum-drum-dried powder readily solubilizes when added to water (similar to spray-process powder), but it may be easily distinguished from the latter by its appearance under the microscope. Grains of spray-process powder are generally spherical, whereas particles from the vacuum drum process tend to be distinctly angular and fragmented.

Spray-Drying Process In this process, concentrated liquid milk is atomized (either by a high-pressure nozzle or by a spinning disc) into a current of hot, dry air in a high-volume vacuum chamber. The spray-drying process is much more efficient at heat transfer/water removal than roller or drum drying, in part due to the substantial increase in surface area – about 35 m^2/l of milk. As such, the resulting particle size of the powder is remarkably small and readily soluble. Under the microscope, the grains appear bead-like or spherical and are of relatively uniform size.

Instantizing Instantizing, or agglomeration, is a unique modification of the spray process of drying, which is generally applied to the drying of nonfat milk for home use in beverage applications. The process may also be adapted to whole or low-fat milk powders. The instantizing process substantially increases the particle size and porosity of the given milk powder, which significantly minimizes the tendency to ball up when dried milk is mixed with water. Agglomeration markedly improves the dispersibility and reliquefaction characteristics of dried milks. Since the introduction of instantized milk products in the 1950s, a number of patents have been issued that cover two basic processes, the two-step and one-step processes (Graham et al., 1981; Hall & Hedrick, 1971). The two-step process, which appears to be the most commonly employed method, consists of bringing previously spray-dried milk in contact with water or steam (under appropriate conditions). The moistened particles adhere to each other and form distinctly porous, agglomerated particles of larger size, which are then redried to the desired moisture content. In a typical one-step instantizing process, the drying is conducted in such a manner to enhance particle clustering. The larger agglomerates that are formed are subsequently separated, and the final drying step occurs in a secondary dryer. A wetting agent (generally lecithin) may or may not be added during the agglomeration process.

Foam Drying In "foam drying," the product is dried after a liquid slurry is converted to a foam state. Two basic processes can be applied: (1) foam drying and (2) foam-spray drying. In the former process, a nitrogen-gassed, whole milk concentrate (50% solids) is initially foamed and then applied to a continuous belt that leads into a vacuum-drying chamber. In the foam-spray drying method, compressed air is injected into concentrated milk through a mixing device that is located between a pressure pump and the spray nozzle. The gas-injected milk subsequently forms a foam upon sudden ejection into a heated air chamber. The thin air-cell films that are formed dry as fragile, eggshell-type particles.

Freeze Drying "Freeze drying" consists of removing moisture from a frozen product by sublimation under high vacuum. A food product dried by this method retains many of its initial, natural qualities due to the relative absence of heat-driven reaction conditions. However, freeze drying and some of the other drying processes have enjoyed only limited application to dairy products. This limitation is due primarily to rather substantial economic constraints related to energy inputs and the lack of flow-through or continuous freeze-drying technologies of appropriate scale as compared to more conventional processes for the large-scale production of dried milk products.

11.12 Types of Dry Milk Products

As denoted in 7CFR58, 21CFR184, with additional product descriptions/standards under specific USDA, Agricultural Marketing Service publications, some common dry milk products are listed below:

Dry buttermilk and dry buttermilk product
Dry cream
Dry whey (sweet and acid)
Dry whole milk
Dry ice cream
Edible dry casein (acid); caseinates
Instant nonfat dry milk
Low-fat dry milk
Malted milk
Modified dry milk products
Nonfat dry milk (roller and spray process)
Whey protein concentrate (WPC35, WPC80)
Whey protein isolate
Milk protein concentrate

Each of these products may have standards of identity promulgated by the Food and Drug Administration (CFR, 2020, with quality standards set and administered by the US Department of Agriculture). Occasionally, state or local regulations apply to the manufacture and use of these dried milk products. In certain instances, a definition may not exist for the dry form of a product, but when it is reconstituted, the final product may have to comply with the definitions of its liquid counterpart. For example, dried ice cream mix has no definition (or standard of identity), but ice cream does. When dehydrated products are made into and sold as ice cream, the final product form must comply with the existing regulations that pertain to the respective type of frozen dairy dessert.

In the ensuing discussion, the major emphasis will be placed upon the sensory properties of dried milk products, although some details or other pertinent facts will also be provided. Some limited information from the CFR and several other documents related to dried milk will be cited. Since federal regulations may change from year to year, the reader is urged to consult the most recent edition of the CFR for current, authoritative information. Absolute compliance with USDA quality standards does not excuse failure to comply with certain rigorous provisions of the Federal Food, Drug and Cosmetic Act.

11.13 Dry Whole Milk

The Food and Drug Administration has defined dry whole milk in 21 CFR 131.147 (CFR, 2006) as follows:

Description. Dry whole milk is the product obtained by removal of water only from pasteurized milk, as defined in Section 131.110(a), which may have been homogenized. Alternatively, dry whole milk may be obtained by blending fluid, condensed, or dried nonfat milk with liquid or dried cream or with fluid, condensed, or dried milk, as appropriate, provided the resulting dry whole milk is equivalent in composition to that obtained by the method described in the first sentence of this paragraph. It contains the lactose, milk proteins, milkfat, and milk minerals in the same relative proportions as the milk from which it was made. It contains not less than 26% but less than 40% by weight of milkfat on an as is basis. It contains not more than 5% by weight of moisture on a milk solids not fat basis.

Other provisions include the optional addition of vitamins A and D (when added, the content is regulated) and incorporation of the following safe and suitable optional ingredients: carriers for vitamins A and D, emulsifiers, stabilizers, anticaking agents, antioxidants, characterizing flavoring ingredients with or without coloring and nutritive carbohydrate sweeteners (including fruit, fruit juice, fruit juice concentrates, and natural and artificial food flavoring).

Grading standards of the USDA are published through the Agricultural Marketing Service in paragraphs 58.2701–58.2710 (Effective April 13, 2001). They pertain primarily to basic dry whole milk, which optionally may be fortified with vitamins A and D or both vitamins. Two USDA grades are recognized: (1) US extra grade and (2) US standard grade. The grades are determined on the combined basis of flavor, physical appearance, bacterial estimate, coliform count, milkfat content,

Table 11.1 Classification of flavor for dry whole milk[a]

Flavor characteristics	US extra grade	US standard grade
Cooked	Definite	Definite
Feed	Slight	Definite
Bitter	NA	Slight
Oxidized	NA	Slight
Scorched	NA	Slight
Stale	NA	Slight
Storage	NA	Slight

"NA" means not allowed at any level
[a]USDA, AMS US Standards for Grades of Dry Whole Milk (April 13, 2001)

Table 11.2 Classification of physical appearance of dry whole milk[a]

Physical appearance characteristics	US extra grade	US standard grade
Dry product		
Unnatural color	None	Slight
Lumps	Slight pressure	Moderate pressure
Visible dark particles	Practically free	Reasonable free
Reconstituted product		
Grainy	Free	Reasonably free

[a]USDA, AMS US Standards for Grades of Dry Whole Milk (April 13, 2001)

moisture content, scorched particle content, solubility index, and titratable acidity. Tables 11.1, 11.2, and 11.3 summarize the requirements for the above two grades of dry whole milk. Definitions of the terms used in these tables are presented in a later segment of this chapter. Testing for certain other quality parameters may also be done at the option of the USDA or when examination is requested by an interested party. These optional requirements include vitamin addition (A and D), oxygen content (if gas packed), and protein content. Failure to meet "standard grade" or optional quality requirements (when the tests are performed), or a direct microscopic clump count in excess of 100 million/g, suffices to deny a given product the assignment of a USDA grade. Deficiencies in so-called good manufacturing practices by a processor may also disqualify products from eligibility for USDA grade assignment.

Specific details for conducting each of these tests or assays are included and described, as follows:

(a) Scorched particle content and solubility index shall be determined by the methods contained in the latest revision of 918-RL, Laboratory Methods and Procedures, USDA/AMS/Dairy Programs, Dairy Grading Branch, Room 2746-S, 14th and Independence Ave. S.W. Washington, DC 20250-0230.
(b) All other tests shall be performed by the methods contained in the latest edition of the "Official Methods of Analysis," published by AOAC International, 2275 Research Blvd, Ste. 300, Rockville, MD 20850; by the methods provided in the latest edition of the "Standard Methods for the Examination of Dairy Products,"

Table 11.3 Classification according to laboratory analysis of dry whole milk[a]

Laboratory tests	US extra grade	US standard grade
Bacterial estimate (SPC/gram) (max)	10,000	50,000
Coliform count (per gram) (max)	10	10
Milkfat content (percent)	Not less than 26.0, but less than 40.0	Not less than 26.0, but less than 40.0
Moisture content (percent)[b] (max)	4.5	5.0
Scorched particle content (mg) (max)		
Spray process	15.0	22.5
Roller process	22.5	32.5
Solubility index (ml) (max)		
Spray process	1.0	1.5
Roller process	15.0	15.0
Titratable acidity (lactic acid) (percent) (max)	Not more than 0.15	Not more than 0.17

[a]USDA, AMS US Standards for Grades of Dry Whole Milk (April 13, 2001)
[b]Mild solids not fat basis

available from the American Public Health Association, 800 I Street NW, Washington, DC 20001, or by methods published by the International Dairy Federation, available from the International Dairy Federation AISBL, 70/B, Boulevard Auguste Reyers, 1030 Brussels, Belgium.

11.14 Flavor Properties of Dry Whole Milk

Upon rehydration, ideal dry whole milk or whole milk powder (WMP) should have flavor characteristics that are clean, rich, sweet, fresh, and pleasant, not unlike that of fine pastry. Sensory defects may be due to either poor-quality raw material, handling, and processing of the fluid milk; the drying method; or extended or abusive storage conditions. The development of storage-based defects in dry whole milk is most difficult to control or eliminate. Carunchia-Whetstine and Drake (2007) highlighted the application of descriptive sensory analysis to document the flavor and flavor stability of WMP. This work denoted the relatively rapid onset of off-flavors (as early as 3–6 months) in WMP as primarily a function of the generation of lipid oxidation products. Descriptive terms used in their study to differentiate WMP over the course of a 24-month storage period include fishy, astringent, fatty/fryer oil, grassy/hay, and painty. Some additional common quality defects/terms encountered in dry whole milk are scorched, stale, and oxidized.

Scorched A scorched off-flavor is likely to occur in those products that have been subjected to excessive heat (during the drying stage) or have remained in the drying chamber too long. This product defect is usually accompanied by numerous scorched particles; sometimes dark discoloration occurs. Terms used to describe this defect include scorched, burnt, and burnt feathers.

Stale A "stale" off-flavor develops during storage, even in products that have been packed in modified atmosphere and/or contain an extremely low oxygen concentration in the headspace of the container. Dry whole milks stored with a moderately high level of oxygen in the headspace can develop this off-flavor. Effective preventive measures against the development of a stale off-flavor have been pursued by researchers for decades. Specific aids in inhibiting the development of stale odors may include the use of light and oxygen barrier packaging, storage of product at lower temperatures, and the exclusive use of only the highest quality raw milk. This defect is characterized as having stale, wet dog, and brothy flavor characteristics.

Oxidized, Tallowy The oxidized, tallowy off-flavor is an especially troublesome sensory defect of WMP. This off-flavor, suggestive of old tallow, renders WMP unpalatable. Frequently, various stages of oxidation may be noted. Numerous factors seem to affect the development and rate of oxidation, notably (1) storage and processing temperatures; (2) light exposure; (3) product acidity; (4) metallic salts; (5) water activity; (6) headspace oxygen content; and (7) the type of packaging. Differentiated from stale as being considered to involve more lipid-based precursors, typical flavor descriptors for this defect may include wet cardboard, tallowy, and painty.

11.15 Other Properties of Whole Milk Powder (WMP)

Tactile properties of WMP vary with the method of manufacture, the degree of concentration prior to drying, and the particle size and porosity after drying (Hall & Hedrick, 1971; Hunziker, 1949). Dry whole milk manufactured by the spray process may be extremely fine and uniform throughout, but two powder defects may occasionally be noted: lumpy and caked.

Lumpy Lumpy powder lacks definite homogeneity in appearance. Hard lumps the size of wheat grains or larger may be present in the powdered mass. This defect is found more frequently in spray-process forms of WMP. The lumps can result from insufficient drying, dripping spray nozzles, or particle exposure to moisture-laden air. Dry whole milk, because of its relatively high fat content, may contain so-called soft lumps. This condition is particularly characteristic of cold-stored products. It stems from the unintentional agglomeration of powder particles. This defect should not be confused with a "hard lumpy" product, wherein the formed particles (lumps) feel firm and sometimes even sticky when they are pressed between the fingers.

Caked Usually, the caked defect is not encountered in WMP. However, when it does occur, WMP loses it powdery consistency and becomes "solid as a rock."

When this solid mass is broken up, the product remains as chunks and thus fails to regain the original powdery state. This defect is considered most serious, since such an altered WMP has lost sales value for human use.

Color Dry whole milk is typically light yellow in color, but it can vary seasonally with the amount of pigmentation present in the milkfat. The color can range from a creamy white to a deep yellow. The possible defects of color in dry whole milk are *browned* or *darkened*, *scorched*, and *lack of uniformity*.

Browned or Darkened This color defect of WMP is associated with product age. When this defect occurs, the typical creamy color has been replaced by a distinct brown shade. Furthermore, this color defect is usually associated with a distinctive stale off-flavor. This defect is potentiated by conditions that favor general Maillard browning reactions, including water activity, high storage temperatures, extended storage times, and pH extremes.

Scorched Discoloration due to burning (scorching) of milk solids is more commonly associated with roller-processed powders than spray-processed products. Sections of large spraying systems, where even minor masses of product can accumulate, can also result in this defect. The powder color may vary from light to dark brown; rarely will burnt particles be so dark as to appear black. Milk powders that exhibit discolored particles or foreign sediment are severely discriminated and downgraded against the grading standards.

Lack of Uniformity This defect may be due to either partial discoloration (browning) that may develop after product packaging or the result of partial scorching during the manufacturing process.

11.16 Nonfat Dry Milk (NDM)

The Food and Drug Administration has two definitions for nonfat dry milk, as noted in 21 CFR 131.125 and 131.127 (2020). The only difference in the second definition is that the product is fortified with vitamins A and D. Nonfat dry milk (NDM) is defined as follows:

Description. Nonfat dry milk is the product obtained by removal of water only from pasteurized skim milk. It contains not more than 5% by weight of moisture and not more than 1 and 1/2% by weight of milkfat unless otherwise indicated.

Optional ingredients. Safe and suitable characterizing flavoring ingredients (with or without coloring and nutritive carbohydrate sweetener) as follows: fruit and fruit juice (including concentrated fruit and fruit juice) and natural and artificial food flavorings.

The following is the additional language for nonfat dry milk fortified with vitamins A and D:

Description. Nonfat dry milk fortified with vitamins A and D conforms to the standard of identity for nonfat dry milk, except that vitamins A and D are added as prescribed by paragraph (b) of this section.
(b) Vitamin addition.

(1) Vitamin A is added in such quantity that, when prepared according to label directions, each quart of the reconstituted product contains 2000 International Units thereof.
(2) Vitamin D is added in such quantity that, when prepared according to label directions, each quart of the reconstituted product contains 400 International Units thereof.
(3) The requirements of this paragraph will be deemed to have been met if reasonable overages, within limits of good manufacturing practice, are present to ensure that the required levels of vitamins are maintained throughout the expected shelf life of the food under customary conditions of distribution.

The USDA has quality standards for three types of NDM, namely, spray process, roller process, and instant. The details of these standards may be found by accessing the USDA, Agricultural Marketing Service (http://www.ams.usda.gov). A summary of the requirements is given in Tables 11.4, 11.5, and 11.6. The products covered by these standards must not contain buttermilk or any added preservative, neutralizing agent, or other chemicals. Conditions under which a "U.S. Grade" is not assignable vary for the different types of NDM. Only the "Extra Grade" is recognized for use as instant nonfat milk. For spray- and roller-process nonfat milk, failure to meet the requirements for US standard grade and/or a direct microscopic clump count in excess of 100 million/g results in nonassignment of a grade.

Table 11.4 US grade classifications of nonfat dry milk (reliquified basis) based on flavor and odor[a]

Flavor characteristics	US extra grade[b]	US standard grade[b]
Bitter	NA	Slight
Chalky	Slight	Definite
Cooked (spray and instant)	Slight	Definite
Feed	Slight	Definite
Flat	Slight	Definite
Oxidized	NA	Slight
Scorched	NA	Slight
Stale	NA	Slight
Storage	NA	Slight
Utensil	NA	Slight

"NA" means not allowed at any level
[a]USDA, AMS US Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant)
[b]Instant nonfat dry milk is allowed only as US extra grade

Table 11.5 US grade classifications of nonfat dry milk based on physical appearance characteristics[a]

Physical appearance characteristics	US extra grade	US standard grade[b]
Dry product		
Lumpy	Slight	Moderate
Unnatural color	NA	Slight
Visible dark particles	Practically free	Reasonably free
Reconstituted product		
Grainy	NA	Reasonably free

"NA" means not allowed at any level
[a]USDA, AMS US Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant)
[b]Applies only to spray and roller process. Only one grade, "U.S. Extra," is recognized for instant nonfat dry milk

Table 11.6 US Grade Classifications of Nonfat Dry Milk according to laboratory analyses[a]

Laboratory tests (or parameters)	U.S. extra grade[b]	U.S. standard grade
Bacterial estimate, standard plate count/g (max)	10,000	75,000
Milkfat content, % (max)	1.25	1.5
Moisture content, % (max)	4.0 (4.5 instant)	5.0
Scorched particle content, mg (max)	15.0	22.5
Solubility index, ml (max)		
Spray	1.2	2.0
US high heat[c]	2.0	2.5
Roller	15.0	15.0
Instant	1.0	
Titratable acidity, % (max)	0.15	0.17
Coliform count/g instant (max)	10	
Dispersibility, instant (max%)	85	

[a]USDA, AMS US Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant)
[b]Instant nonfat dry milk may be assigned only one grade, "U.S. Extra"
[c]Heat classification is as follows:
Low heat ≥6.0 mg undenatured whey protein nitrogen/g dry product
Medium heat 1.51–5.99 mg undenatured whey protein nitrogen/g dry product
High heat ≤1.5 mg undenatured whey protein nitrogen/g dry product

When NDM (especially the instantized form) is used as a beverage, a sensory comparison with fresh fluid nonfat milk is inevitable. Under ideal conditions, the sensory difference may not be that significant; even expert evaluators may find little to criticize in reconstituted NDM of high quality. However, there are several points to keep in mind. Fresh, liquid nonfat milk (or another liquid product) is not guaranteed to be free of flavor defects; in some instances, fresh nonfat milk may be inferior to the dehydrated and rehydrated product. Generally, there is no logical basis for comparing a good-quality fluid product with a poor-quality dry product or vice versa. Each product form should be evaluated for its own merits and defects (Fig. 11.3).

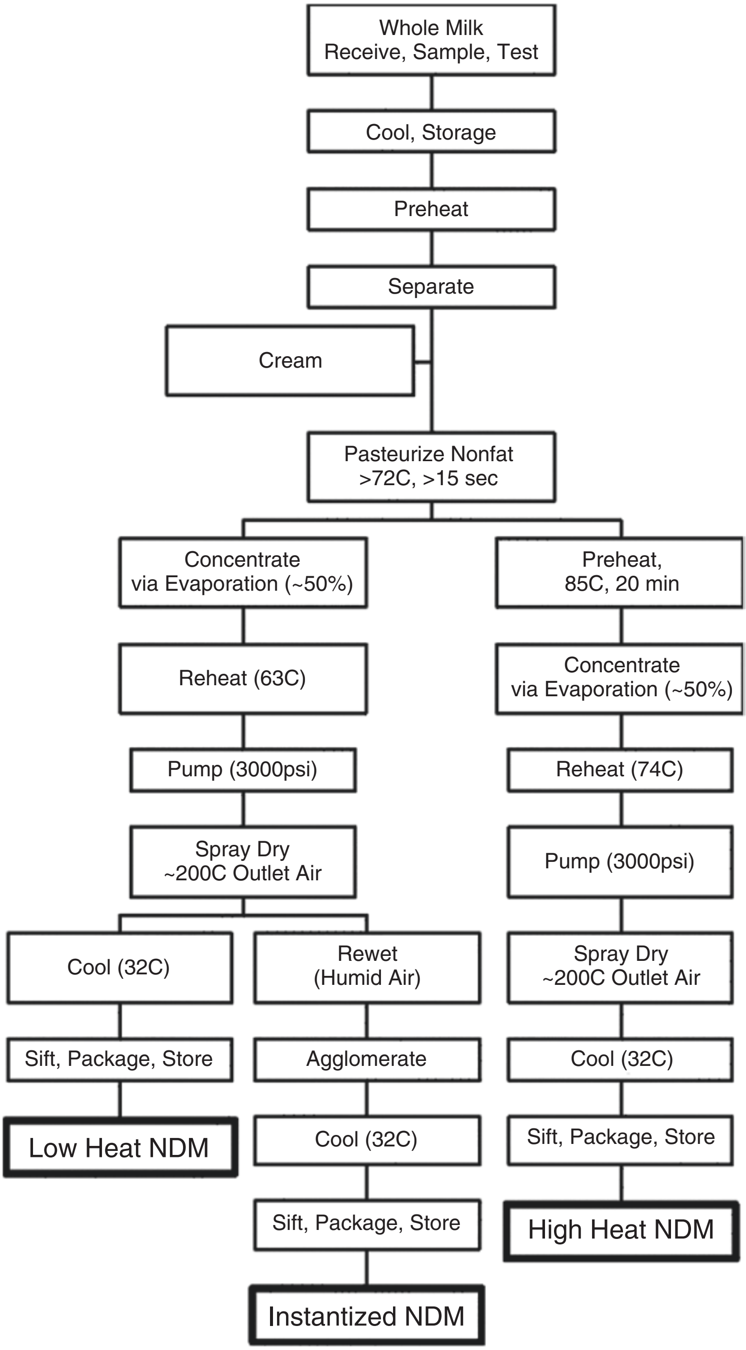

Fig. 11.3 Flow diagram for the manufacture of three forms of nonfat dry milk: low heat, instantized, and high heat

Fresh, fluid nonfat milk deteriorates with age (as do other highly perishable milk products), generally due to microbial activity. On the other hand, flavor deterioration in a dry product is most commonly due to chemical mechanisms such as the browning reaction, oxidation, and the process of staling. Also, since dry products may be in storage for months or years (as opposed to a maximum of several weeks for conventionally pasteurized fluid products), certain gradual chemical reactions generally have adequate time to manifest themselves. Thus, a sample of 1-year-old NDM may exhibit flavor characteristics inferior to that of fresh, fluid nonfat milk. However, a year-old NDM may be substantially more acceptable in flavor than a 3-week-old fluid nonfat milk.

A noteworthy supplement to the NDM (spray process) grading standard is the inclusion of criteria to distinguish the product based on heat treatment. Such details are not a grade requirement, with the exception of when the higher solubility index for high-heat powder is permitted. The nomenclature of the US Heat Treatment Classification with definition is as follows:

US High-Heat

The finished product shall not exceed 1.50 mg undenatured whey protein nitrogen per gram of nonfat dry milk.

US Medium-Heat

The finished product shall exceed 1.50 mg undenatured whey protein nitrogen per gram of nonfat dry milk and shall be less than 6.00 mg undenatured whey protein nitrogen per gram of nonfat dry milk.

US Low-Heat

The finished product shall be not less than 6.00 mg undenatured whey protein nitrogen per gram of nonfat dry milk.

The abovementioned assay for whey protein nitrogen, in essence, is intended to measure the degree to which heat-labile whey proteins are affected as a function of the thermal treatment of the whey. Manufacturers will produce powders differentiated as such for specific food applications where the presence of undenatured whey proteins may be desirable or, conversely, undesirable relative to their functionality, e.g., high-heat powder as an ingredient in bread dough, low-heat powder used to fortify cheesemilk. Methods for the conduct of this assay are described as follows:

The whey protein nitrogen test shall be performed in accordance with DA Instruction 918-RL, "Instruction for Resident Grading Quality Control Service Programs and Laboratory Analysis," Dairy Grading Branch, Dairy Division, Agricultural Marketing Service, U.S. Department of Agriculture, Washington, DC, 20090-6456, or the latest edition of "Standard Methods for the Examination of Dairy Products," as referenced earlier in this chapter.

Medium-heat powder is considered a type of globally available standard in the manufacturing industry. Low-heat powder is used and available primarily in the USA for use in the manufacture of cheese, and high-heat powder is used primarily in the baking industry.

Whereas US labeling regulations have prohibited the use of the term "skim" when referring to any dairy product, the term "skimmed milk powder" or SMP is recognized internationally by codex nomenclature standards. SMP has a higher allowable milkfat content (1.5% max) as well as a higher allowable moisture content (5%). The criterion for protein content is also different, requiring a 34% milk protein in milk solids nonfat of 34%. Specific additives are allowed to be used in the manufacture of SMP including stabilizers, firming agents, acid regulators, emulsifiers, anticaking agents, and antioxidants.

11.17 Sensory Properties of NDM

Flavor The flavor of high-quality NDM should be similar, when reconstituted, to that of fresh fluid nonfat milk. Due to the extremely low milkfat content, NDM does not possess the rich pastry flavor of products of higher fat content. The flavor should be clean, sweet, and pleasant, but NDM may possess a slight cooked or heated flavor. Likewise, the off-flavors found in reconstituted NDM have much in common with those of WMP but differ in their relative importance. Caudle et al. (2005) demonstrated a reduction in consumer acceptance toward products formulated with off-flavored NDM powders. Interestingly, Lloyd et al. (2004) demonstrated that even extremely aged samples of NDM were acceptable to consumers for use in an emergency. Some common flavor defects of NDM include scorched, stale, storage, old, and oxidized/tallowy.

Scorched As in the instance of WMP, a scorched off-flavor is also developed in NDMs that have been subjected to abnormally high heat during processing. This defect is usually accompanied by an excessive number of scorched particles in the product; a darker, slightly brown color may be observed.

Stale, Storage, Old This flavor defect is frequently encountered in NDM. This particular off-flavor is even more quick to occur and distinct in NDM than in WMP. Usually, this flavor defect is accompanied by a slight to definite darkening of the powder color. However, some staleness may frequently be detected before any change in color is noted. As pointed out elsewhere in this chapter, there are some reasons for considering stale and storage off-flavors as separate entities. Many graders of milk powders do not attempt or even make the effort to distinguish between these two off-flavors. In old, darkened products, a sharp, slightly sour taste may be detected after the first sensation of staleness has completely disappeared. This slightly sour taste is quite similar to that noted in darkened evaporated milk, which may have resulted from storage at a high temperature for an extended time. Lea et al. (1943) variously described this off-flavor as burnt, stale, or glue-like. They reported that the so-called burnt flavor may have stemmed from a blend of the toffee flavor (derived from milkfat) and slight lactose caramelization and that quite possibly the stale off-flavor was derived from protein deterioration. Recent work (Caudle et al., 2005) has described the storage-based flavor of NDM with such terms as animal-like, wet dog, and fryer oil. Additional recent references include Karagul-Yuceer et al. (2001), Drake et al. (2003), Karagul-Yuceer et al. (2004), and Drake et al. (2006).

Oxidized, Tallowy This off-flavor is less frequently encountered in NDMs than in WMPs. Since tallowiness is a fat-associated off-flavor, it develops when appreciable fat constituents are present. Nonfat dry milk contains a negligible amount of milkfat available to undergo autoxidation; nonetheless, under certain conditions, an objectionable oxidized or tallowy off-flavor can develop. Studies have indicated that lipid oxidation products are present in stored NDM (Karagul-Yuceer et al., 2001, 2002). Of particular note for the dried milk products judge is that a tallowy product tends to have a pronounced odor, whereas a stale powder does not exhibit an intense odor.

11.18 Physical Characteristics of NDM

Fineness and Homogeneity The grain fineness of high-quality NDM is dependent upon the characteristics of spray nozzle(s) or atomization device, the extent of concentration prior to spray drying, the extent of deficiency of pulverization, and the mesh of the bolting when the product is roller-dried. Nonfat dry milk manufactured by the spray process usually exhibits a fine, uniform particle size (Fig. 11.4). The dried product made by the roller process is much more coarse and less homogeneous, unless it is extensively pulverized after drying.

Instant NDM is usually quite granular; the product should pour as readily as corn meal, hence the name, and should readily hydrate when added to water. In contrast, non-instantized spray-dried NDM is light, dusty (nearly airborne) and has flow characteristics similar to flour (see Fig. 11.3). Upon addition to water,

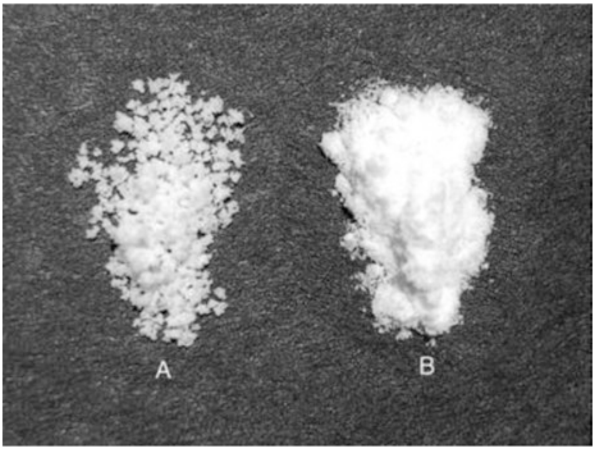

Fig. 11.4 Samples of instantized (**a**) and non-instantized (**b**) nonfat dry milk powders; note the large, porous structures of the instantized product allowing for improved wettability properties as compared to the fine structure in sample B where clumping can readily occur during rehydration

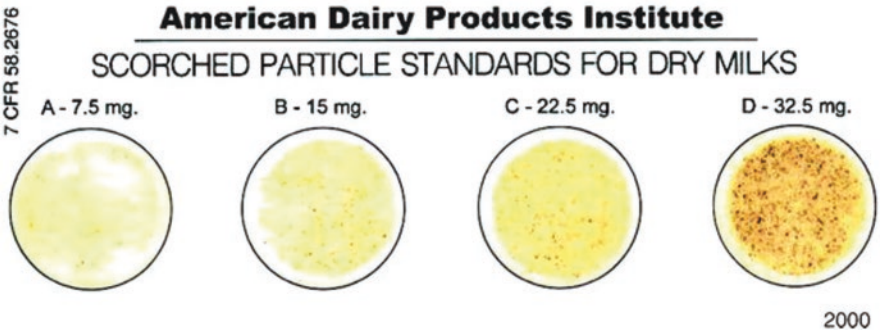

Fig. 11.5 A scorecard depicting standards or grades of dry milk relative to the appearance/mass of scorched particles. (ADPI, 2002)

non-instantized product, while easily hydrated, readily forms clumps or small nodules that can hinder further processing steps or is at least visually unappealing to consumers.

Color Nonfat dry milk, like dry whole milk, should be uniform in color and be free of foreign specks and burnt particles (see Fig. 11.5). NDM should exhibit a creamy white or light yellow color, though it may vary slightly in intensity with season of the year. Under certain conditions, NDM tends to darken in color with aging; the light yellow color darkens to a distinct brown. This appearance defect is usually associated with a stale off-flavor. For reasons not well understood, spray-process products seem to be more susceptible to age darkening (and to a greater intensity) than roller-process powders. However, dry powders made by both processes are susceptible to this defect.

11.19 Dry Buttermilk

The definitions and standards (USDA, Agricultural Marketing Service (effective February 2, 2001 for dry buttermilk (protein ≥30%) and dry buttermilk product (protein <30%) are defined as follows:

(a) Dry buttermilk (made by the spray process or the atmospheric roller process) is the product resulting from drying liquid buttermilk that was derived from the churning of butter and pasteurized prior to condensing at a temperature of 161 °F for 15 s or its equivalent in bacterial destruction. Dry buttermilk shall have a protein content of not less than 30.0%. Dry buttermilk shall not contain nor be derived from nonfat dry milk, dry whey, or products other than buttermilk and shall not contain any added preservative, neutralizing agent, or other chemicals.

(b) Dry buttermilk product (made by the spray process or the atmospheric roller process) is the product resulting from drying liquid buttermilk that was derived from the churning of butter and was pasteurized prior to condensing at a temperature of 161 °F for 15 s or its equivalent in bacterial destruction. Dry buttermilk product has a protein content less than 30.0%. Dry buttermilk product shall not contain nor be derived from nonfat dry milk, dry whey, or products other than buttermilk and shall not contain any added preservative, neutralizing agent, or other chemicals.

The two US grades of dry buttermilk and dry buttermilk product, "US Extra" and "US Standard," are determined on the basis of "flavor, physical appearance, bacterial estimate on the basis of standard plate count, milkfat, moisture, scorched particles, solubility index, titratable acidity, and protein content." The US grade requirements for dry buttermilk are summarized in Table 11.7.

The flavor of dry sweet cream buttermilk should be clean, sweet, and pleasant; it should have a somewhat richer flavor than NDM. Whereas NDM contains less than 1.5% of milkfat, dry buttermilk is allowed not less than 4.5%. With this much milkfat present in sweet cream buttermilk, the product can possess a richer, fuller flavor than NDM. On the other hand, the evaluator should remember that buttermilk is rich

Table 11.7 US grade classifications of dry buttermilk based on flavor, physical appearance, and laboratory analyses[a]

Quality attributes (or laboratory tests)	US extra grade	US standard grade
Flavor		
Unnatural	NA	Slight
Offensive	NA	NA
Physical appearance		
Lumpy	Slight	Moderate
Visible dark particles	Practically free	Reasonably free
Bacterial estimate per g (max)	20,000	75,000
Butterfat content, % (min)	4.5	4.5
Moisture content, % (max)	4.0	5.0
Scorched particles, mg (max)		
Spray	15	22.5
Roller	22.5	32.5
Solubility index, ml (max)		
Spray	1.25	2.0
Roller	15.0	15.0
Titratable acidity, %	≥0.10 to ≤0.18	≥0.10 to ≤0.20
Protein		
Dry buttermilk (min)	30.0	30.0
Dry buttermilk product	<30.0	<30

"NA" means not allowed at any level

[a]USDA, AMS US Standards for Grades of Dry Buttermilk and Dry Buttermilk Product (February 2, 2001)

in lipid constituents that are quite susceptible to oxidation. Thus, dried buttermilk powders are frequently quite vulnerable to rapid flavor deterioration and may have unpredictably high flavor variability, even lot to lot from a specific manufacturer. Off-flavors noted in dry buttermilk (stored under adverse conditions) in a study by Davis (1939) included various intensities of stale, old, musty, sharp, bitter, soapy, coarse, cheesy, rubbery, acid, fruity, tallowy, and putrid. A wider range of off-flavors will probably be noted in evaluating buttermilk than when judging NDM for flavor. The USDA standards with respect to flavor of dry buttermilk products evaluated as reconstituted products are as follows:

For US Extra Grade: "Shall be sweet and pleasing, and has no unnatural or offensive flavors."

For US Standard Grade: "Should possess a fairly pleasing flavor, but may possess slight unnatural flavors and has no offensive flavors."

Although a great deal of research on buttermilk has not been published recently, some work detailing the compositional and functional characteristics (Sodini et al., 2006) as well as the possible nutritional value of buttermilk fractions (Rombaut et al., 2006) is available in the current literature.

11.20 Dry Whey

The US standards for dry whey are available through USDA, AMS (effective December 14, 2000). Whey and dry whey are therein defined as follows:

"Whey" is the fluid obtained by separating the coagulum from milk, cream, and/or skim milk in cheesemaking. It shall conform to the applicable provisions of 21 CFR 184.1979. The acidity of the whey may be adjusted by the addition of safe and suitable pH adjusting ingredients. Moisture removed from cheese curd as a result of salting may be collected for further processing as whey if the collection of the moisture and the removal of the salt from the moisture are conducted in accordance with procedures approved by the Administrator.

"Dry Whey" is the product resulting from drying fresh whey which has been pasteurized and to which nothing has been added as a preservative. It shall conform to the applicable provisions of 21 CFR 184.1979. It contains all constituents, except moisture, in the same relative proportions as in the whey.

Only a single grade of dry whey, "US Extra Grade," is recognized; compliance is determined on the basis of flavor, physical appearance, bacterial estimate, coliform count, milkfat content, moisture, and scorched particle content (see Table 11.8). Acidity is not a component of the US grading requirement; however, acidity may be assigned as sweet (<0.16% TA), as a stated percentage %TA (>0.16 to <0.35) or as acid whey (>0.35%TA).

The flavor characteristics of dry sweet whey will vary with the whey acidity and the drying process. The flavor of good-quality dry whey is usually pleasantly sweet,

Table 11.8 US grade classifications of dry whey based on flavor, physical appearance, and laboratory analyses[a]

Category	US extra grade standard
Flavor	
Bitter	Slight
Feed	Definite
Fermented	Slight
Storage	Slight
Utensil	Slight
Weedy	Definite
Physical appearance	
Color	Uniform
Free flowing	Reasonably
Lumpy	Slight pressure
Visible dark particles	Practically free
Bacterial estimate/g (max)	30,000
Coliform	10
Milkfat content % (max)	1.5
Moisture content % (max)	5.0
Scorched particles, mg (max)	15.0

[a]USDA, AMS US Standards for Dry Whey (December 14, 2000)

with a subtle or slightly subdued acid aftertaste. Such assessments can be made by rehydrating (10 g sample to 100 g distilled water tempered to 24 °C; see ADPI, 2002). The flavor may change markedly during storage toward a stale, slightly sour flavor, accompanied by a definite browning of the product. Bodyfelt et al. (1979) studied the quality impact of dried wheys of various degrees of age and flavor quality on vanilla ice cream mix. Gas–liquid chromatography analyses indicated several pyrazines and 2-furfural to be partially responsible for mix off-flavors, variously described by the investigators as lacks freshness, stale, and whey flavor. More recent work on whey powders denotes additional detail on composition and function (Banavara et al., 2003), flavor (Mahajan et al., 2004), and browning chemistry (Dattatreya & Rankin, 2006) as well as shelf life estimation (Dattatreya et al., 2007) relative to the development of brown discoloration. One approach to the attenuation of whey color development involves the use of bleaching agents focused on denaturing water-soluble, annatto-based pigments (see Croissant et al., 2009).

The initial flavor quality of whey depends on such factors as (1) the quality of milk from which the cheese was made; (2) the type of cheese manufactured; (3) the method of whey handling immediately after curd draining; (4) the elapsed time between draining and pasteurization; and (5) the extent of adherence to good manufacturing practices. The manufacture of cheese requires the combined activity of microorganisms and enzymes, but these biochemical activities must be suddenly terminated in the whey to prevent off-flavor(s) development (Carunchia-Whetstine et al., 2003).

Acid whey, the by-product of cottage cheese and other acid-set cheese types and other dairy foods that recover low pH whey, e.g., Greek yogurt manufacturing, represents a significant challenge to dairy plants due to decreased functionality and lower levels of valuable constituents. Although specific details are not readily available, many plants continue to dispose of rather than further refine acid whey for value-added opportunities.

Another major category of dried dairy ingredients involves the use of membrane separation and fractionation technologies and includes such products as whey protein concentrate and whey protein isolate. By subjecting either a native milk or whey stream to a membrane separation system, specific fractions of these original streams can be recovered, concentrated, and dried into powders with specific uses (Kotsanopoulos & Arvanitoyannis, 2015). Literature detailing the manufacturing and composition (Kumar et al., 2013) and sensory properties (Russell et al., 2006; Carunchia-Whetstine et al., 2005) is available. Because of the increased value and functionality of such products, continued work has focused on the application of these novel ingredients in model and authentic food systems. Advancements in separation technologies coupled with other unit operations such as hydrolysis or catalysis have resulted in increases in market opportunities and a modest proliferation of ingredients that are permutations of the general fractionation and concentration technologies. A complete listing of the collection of such ingredients is beyond the scope of this work but includes such ingredients as whey protein concentrate and isolate of various compositions, demineralized whey, individual whey protein fractions, glycomacropeptide, lactose, and mineral concentrates.

11.21 Edible Dry Casein and Caseinates

The USDA, AMS definition (effective July 20, 1968) of edible dry casein (acid) is cited as follows:

1. For the purposes of these standards, edible dry casein (acid) is the pulverized or unpulverized product resulting from washing, drying, or otherwise processing the coagulum resulting from acid precipitation of skim milk which has been pasteurized before or during the process of manufacture in a manner approved by the Administrator.
2. The product shall have been produced in a plant under conditions suitable for the manufacture of human food and packaged in a container which will prevent contamination, deterioration, and/or development of a public health hazard under normal conditions of storage and transportation.

Two grades of edible dry casein are recognized, "U.S. Extra" and "U.S. Standard," which are assigned on the basis of flavor and odor, physical appearance, bacterial estimate on the basis of standard plate count and coliform count, protein content, moisture content, milkfat content, extraneous materials, and free acid. Additional optional tests include *Salmonella* or *Staphylococcus*, percent metals (Cu), yeast, ash, and mold (as listed in Section 58.2805) and particle size. The requirements and recommended criteria for edible dry casein are summarized in Table 11.9.

Table 11.9 US grade classifications of edible dry casein (acid) based on flavor and odor, physical appearance, and laboratory analyses[a]

Category	US extra grade	US standard grade
Flavor and odor	Bland natural flavor and odor and free from offensive flavors and odors such as sour and cheesy	Not more than slight unnatural flavors or odors and free from offensive flavors and odors such as sour or cheesy
Physical appearance	White to cream colored physical appearance; if pulverized, free from lumps that do not break up under slight pressure	White to cream colored physical appearance; if pulverized, free from lumps that do not break up under moderate pressure
Bacterial estimates:		
Standard plate count/g	≤30,000	≤100,000
Coliform count/0.1 g	Negative	≤2
Protein content, *N* × 6.38, dry basis, %	≥95	≥90
Moisture content, %	≤10	≤12
Milkfat content, %	≤1.5	≤2
Extraneous materials	Scorched particles not more than 15 mg and free from foreign materials in 25 g	Scorched particles not more than 22.5 mg and free from foreign materials in 25 g
Free acid	Titrated to not more than 0.20 ml of 0.1 N NaOH per g	Titrated to not more than 0.27 ml of 0.1 N NaOH per g
Optional tests (recommended criteria):		
Ash (phosphorus fixed) %	≤2.2	
Copper, ppm	≤5.0	
Lead, ppm	≤5.0	
Iron, ppm	≤20.0	
Yeast and mold, per 0.1 g	≤5.0	
Thermophiles, per g	≤5000	
Reducing sugars (as lactose) %	≤1.0	
Staphylococcus (coagulase positive)	Negative	
Salmonella in 100 g	Negative	
Particle size – 30, 60, 80 or other specified mesh		
30 mesh	100% must pass 30 ASTM screen, 10% may pass 60 ASTM screen	
60 mesh	99% must pass 50 ASTM screen, 10% may pass 80 ASTM screen	
80 mesh	100% must pass 60 ASTM screen, 85% may pass 80 ASTM screen	

[a]USDA, AMS US Standards for Grades of Edible Dry Casein (Acid) (July 20, 1968)

Caseinates Acid casein is commonly recovered as a more usable form such as sodium, potassium, or calcium caseinate. In the salt form, caseinates have found wide application as food ingredients, principally in nondairy foods such as bakery products, dairy product analogs, processed meats, and coffee whiteners, due to their increased solubility relative to the acid or rennet forms. A blend of caseinate and whey solids may be made to emulate the composition and functional properties of nonfat dry milk. In various food applications, caseinates perform specific functions. How adequately a given lot or source of caseinate performs the various food ingredient functions should be a primary criterion of the quality evaluation process for these milk-derived products. Hydrolyzed sodium caseinates are also available as highly functional protein-based food ingredients.

Casein (rennet) and caseinates are subject to variations in sensory quality either during the manufacturing process or as a result of deteriorative changes that occur during storage. The USDA standards specify freedom from offensive flavors and odors; off-flavors such as sour and cheesy are identified. A stale off-flavor may develop during storage, which may be related to a similar off-flavor that occurs in stored dry milk, sterile milk, and evaporated milk. More research is needed to better chemically characterize this off-flavor and to learn the mechanism(s) of the stale flavor formation.

In the process of manufacturing casein, the curd is washed to remove impurities and residual milk components. Lactose is one of several compounds that may be retained in excessive concentration if the casein curd is not adequately washed. The USDA standards establish 1% as the upper limit for lactose in casein. The presence of lactose in casein products unfortunately potentiates the Maillard (browning) reaction, especially when casein has been converted to a more alkaline caseinate. A brown pigment need not appear for off-flavors to manifest themselves, because pigment formation occurs in latter stages of the nonenzymatic browning, after numerous flavor compounds and precursors have been formed. Thus, low residual lactose levels should be sought in dry casein products.

A frequent and serious flavor defect in caseinates is referred to as gluey. As the term implies, this off-flavor is suggestive of protein degradation. Under alkaline conditions (as with caseinates), protein degradation occurs at an accelerated rate. Work to determine the chemical cause of off-odors in rennet casein identified such compounds as guaiacol, indole, and ρ-cresol was conducted by Karagul-Yuceer et al. (2003).

11.22 Dry Milk, Other Milkfat Levels

With the introduction of the Nutrition Labeling and Education Act of 1990, some traditional dairy product nomenclature was revised to comply with this cross-commodity standard, e.g., skim milk was renamed as nonfat milk. One dry product, low-fat dry milk and its accompanying descriptions, definitions, and standards was also affected in this regulatory shift. What was once present as "Lowfat Dry Milk" in 21 CFR 131.123 no longer exists as a discrete product under the new labeling laws. Products that are intermediate to nonfat and whole dry milks now come under the labeling/nomenclature and compositional requirements of 21 CFR 101.62, Nutritional Content Claims For Fat, Fatty Acid, and Cholesterol Content of Foods.

11.23 Dry Cream

The FDA standard of identity for dry cream may be found in 21 CFR 131.149 (2020). The following is the description and list of optional ingredients for dry cream:

Description
Dry cream is the product obtained by removal of water only from pasteurized milk or cream or a mixture thereof, which may have been homogenized. Alternatively, dry cream may be obtained by blending dry milks as defined in Section 131.125(a) and 131.147(a) with dry cream as appropriate, provided that the resulting product is equivalent in composition to that obtained by the method described in the first sentence of this paragraph. It contains not less than 40% but less than 75% by weight of milkfat on an as is basis. It contains not more than 5% by weight of moisture on a milk solids not fat basis.

Optional Ingredients
The following safe and suitable optional ingredients may be used: emulsifiers, stabilizers, anticaking agents, antioxidants, and nutritive carbohydrate sweeteners. Characterizing flavoring ingredients, with or without coloring, is as follows: fruit and fruit juice, including concentrated fruit and fruit juice; natural and artificial food flavoring.

No specific classification for grades of dry cream has been issued by the USDA. Off-flavors in dry cream products parallel those that develop in dry whole milk (i.e., stem from oxidation of lipid components during storage). In addition to lipid oxidation, browning reactions and staling are significant quality problems of dry cream. Dry creams have many applications as food ingredients, especially in the formulation and manufacture of finished products in regions where a consistent source of fresh cream is difficult to secure.

11.24 Dry Ice Cream Mix

Dry ice cream mix products differ from the other dry products in that mere reconstitution with water does not yield the finished product, in this case, frozen ice cream or low-fat ice cream. The reconstituted mix generally requires added flavoring, and this mixture is then frozen. Thus, evaluation of the dry mix following reconstitution may not be adequate, since the sensory properties of the resultant frozen product are of paramount interest. As a rule, a mix that has inferior flavor characteristics can be expected to yield an ice cream of poor flavor quality. Freezing characteristics, body and texture, and color/appearance are additional quality considerations for the product.

Dry ice cream or low-fat ice cream mix may be made by spray drying the liquid mix, although a portion of the sweetener may be withheld prior to drying to avoid excessive browning. The remaining required sugar can be subsequently dry-blended with the dry mix. Alternatively, the entire dry mix may be assembled by dry-blending all of the various ingredients, such as nonfat dry milk, dry cream, sugars, and any stabilizer/emulsifier. A concern would exist as to whether the reconstituted mix can then be frozen without re-pasteurization (assuming the initial mix was pasteurized). Dry ice cream (and low-fat ice cream) mixes are subject to the development of exactly the same defects as dry whole milk and dry cream. These defects result from heat treatment, browning reactions, staling, and oxidation processes.

11.25 Miscellaneous Dry Products

A partial list of miscellaneous dry milk products includes milk protein concentrates and isolates, instant chocolate drink, instant hot cocoa mix, instant breakfast drinks, dry cheese, casein/whey blends, malted milk, nondairy coffee whiteners, and other, novel dairy fractions such as whey protein phospholipid concentrate and de-lactosed permeate. Products of this type are generally formulated according to proprietary specifications; some are covered by specific patents. Sensory quality control of dry-milk-based foods depends on maintaining a high level of consumer acceptability; this embraces flavor, physical appearance, rehydration characteristics, and product functionality. Some of these products are manufactured by drying from a high-concentration liquid slurry state, while other dry products may be assembled as the result of dry-blending various ingredients.

11.26 Scoring and Grading Dry Milk

Several sensory terms have been adopted in an attempt to classify flavor defects of various dry milk products. Unfortunately, these particular descriptors have not been used that consistently between technologists or researchers involved with dry milk products. As early as 1957, a committee of the American Dairy Science Association (Thomas, 1958) proposed definitions for the flavor and appearance characteristics as well as for the packaging of dry milks. A suggested dry milk products scorecard is presented in Fig. 11.5, and a suggested scoring guide for flavor is offered in Table 11.10. A typical recommendation for the evaluation of dry milk products involves rehydrating the product to a reasonable concentration (e.g., 10% w/w

Table 11.10 A suggested scoring guide for the flavor of dry milk (reliquified basis)

	Scores for a given intensity				
Defect	Slight	Moderate	Definite	Strong	Pronounced
Acid	2	1	0	0	0
Astringent	8	7	6	5	0–4
Bitter	6	5	4	3	0–2
Chalky	8	7	6	5	0–4
Cooked	9	8	7	6	5
Feed	8	7	6	5	0–4
Fermented	6	5	4	3	0–2
Flat	9	8	7	6	5
Foreign[a]	2	1	0	0	0
Gluey	2	1	0	0	0
Metallic	4	3	2	1	0
Neutralizer[b]	0	0	0	0	0
Oxidized/tallow[c]y	4	3	2	1	0
Rancid (lipolysis)	5	4	3	2	0–1
Salty	7	6	5	4	0–3
Scorched	4	3	2	1	0
Stale	4	3	2	1	0
Storage	7	6	5	4	0–3
Unclean/utensil	5	4	3	2	0–1
Weedy	3	2	1	0	0

"No criticism" is assigned a score of "10." Normal range is 1–10 for a salable product where 10 represents a product of ideal flavor character. A sample may be assigned a score of "0" (zero) if the defect makes the product unsalable

[a]Due to the variety of foreign off-flavor sources, a fixed scoring range is not appropriate. Some foreign off-flavors warrant a score of "0" (zero) even if the intensity is slight (i.e., gasoline, pesticides, lubricating oil)

[b]The use of neutralizers is not authorized except in whey

[c]When an oxidized off-flavor has progressed to the tallowy stage, the assigned flavor score should be "0" (zero)

solution), allowing the product to fully rehydrate (Lloyd et al., 2004) and sampling the product at the appropriate temperature. Higher sampling temperatures (e.g., 45 °C) tend to make volatile aroma compounds more apparent to the imbiber. While such a practice may yield an overly sensitive assessment, it may be appropriate when the powder will be used in a food that requires a concentration step (i.e., cheese manufacture) or that has an extremely sensitive flavor profile. The lists below contain terms and brief definitions that have traditionally been used for the quality evaluation of most dry dairy ingredients. A more complete analysis of the sensory attributes of dried dairy ingredients requires descriptive sensory analysis. Both this technique and sensory attributes specific and descriptive of dried dairy ingredients are addressed elsewhere in this book (Fig. 11.6).

Product ID		**Date**	Sample #							
Flavor		Criticism/Score ---------------------->								
No Criticism	10	Acid								
Normal Range	4 to 8	Astringent								
Unsalable	0 to 3	Bitter								
		Chalky								
		Cooked								
		Feed								
		Fermented								
		Flat Foreign								
		Gluey								
		Metallic								
		Neutralizer								
		Oxidized/Tallowy								
		Rancid (Lipolysis)								
		Salty								
		Scorched								
		Stale								
		Storage								
		Unclear/Utensil								
		Weedy								
Physical Appearance		Criticism/Score ---------------------->								
No Criticism	5	***Dry Product***								
Normal Range	2 to 4	Caked								
Unsalable	0 to 1	Lumpy								
		Unnatural Color								
		Reconstituted Product								
		Charred Particle								
		Dark Particle								
		Grainy								
		Undispersed Lumps								
Packaging		Criticism/Score ---------------------->								
No Criticism	5	Ruptured Vapor Barrier								
Normal Range	2 to 4	Soiled								
Unsalable	0 to 1	Unsealed								
Laboratory Tests		Criticism/Score ---------------------->								
No Criticism	5	***Chemistry***								
Normal Range	2 to 4	Alkalinity of Ash (mL/100g)								
Unsalable	0 to 1	Alkaline Phosphatase (U/L)								
		Ash Phosphorous Fixed (%)								
		Copper (ppm)								
		Fat (%)								
		Iron (ppm)								
		Lead (ppm)								
		Moisture (%)								
		Oxygen Content (%)								
		Protein (%)								
		Reducing Sugars (as Lactose %)								
		Undenatured Whey Protein Nitrogen (mg/gram)								
		Vitamin A (IU)								
		Vitamin D (IU)								
		Functionality								
		Dispersibility (Modified Moats-Dabbah method (%))								
		Mesh (Screen %)								
		Scorched particles (mg)								
		Solubility Index (mL)								
		Titratable Acidity (% Lactic acid)								
		Microbiology								
		Coliform Count (per gram)								
		Direct Microscopic Count (per gram)								
		Salmonella Count (per 100 gram)								
		Staphylococcus Count (Coagulase+) per gram								
		Thermophilic Count (per gram)								
		Total Plate Count (per gram)								
		Yeast and Mold Count (per 0.1 gram)								

Signatures: ______________________

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Fig. 11.6 A suggested dry milk product scorecard

11.27 Flavor Descriptors of Dry Milks

As a preface for purposes of providing definitions for the intensities of specific sensory attributes, the USDA has defined the following terms:

Slight
Detected only upon critical examination.

Definite
Not intense but detectable.

Acid The term acid is used to describe the odor and taste (primarily) that result from the action of lactose-fermenting bacteria in milk and milk products to produce lactic acid that typically exhibits a clean, distinct sour taste.

Astringent Astringent refers to a puckery type of mouthfeel sensation similar to that produced by a chemical such as aluminum ammonium sulfate and tannic acid; unripe bananas may also be used as a standard. There is an associated tactile sensation to the astringent off-flavor; the mucous membranes of the palate and/or tongue tend to shrink (Sano et al., 2005).

Bitter The bitter defect resembles the taste sensation imparted by bitter substances, such as quinine, caffeine, and certain milk-protein-derived peptides. This defect is often associated with the growth of proteolytic microorganisms in milk (certain psychrotrophs and some spore-forming bacteria).

The USDA employs comparable definitions of bitter for several dry milk products. For instance, in describing bitterness in dry whole milk, the USDA states "Similar to taste of quinine and produces a puckery sensation." The USDA Explanation of Terms sections for graded dairy products states "Distasteful, similar to taste of quinine." A direct statement such as "resembles the taste of quinine or caffeine" seems to be an adequate definition of bitterness.

Chalky This descriptor of a common off-flavor in concentrated milk products suggests the inclusion of fine, insoluble, chalk (powder) particles. The USDA definition for chalky is "A tactual type of flavor lacking in characteristic milk flavor." The chalky off-flavor is more of an objectionable mouthfeel sensation than it is an off-taste. The chalky defect frequently tends to manifest itself as a delayed mouthfeel – an aftertaste response of the evaluator.

Cooked Cooked has an odor and flavor resembling that of milk that has been heated to 73.8 °C (164.8 °F) or higher. The USDA definition for cooked flavor in dry milk products is "Similar to a custard flavor and imparts a smooth aftertaste."

Feed A milk off-flavor that is usually characteristic of the roughage (feeds) consumed by milk cows is simply referred to as a feed defect. Several USDA definitions state “Feed flavors (such as alfalfa, sweet clover, silage, or similar feed) in milk carried through into the nonfat dry milk.”

Flat The descriptor flat implies a lack of fullness of flavor; this flavor defect is suggestive of added water. It is not detectable by odor perception. The listed USDA definition for flat is “Insipid, practically devoid of any characteristic reconstituted nonfat dry milk flavor.”

Fermented The following definition for fermented is taken from the USDA standards for dry whey: “Flavors, such as fruity or yeasty, produced through unwanted chemical changes brought about by microorganisms or their enzyme systems.”

Foreign Foreign refers to any atypical or objectionable off-flavor that is not ordinarily associated with good-quality milk; sometimes a chemical- or medicinal-like off-flavor may have occurred. This flavor defect usually stems from the fluid milk used as a raw material to produce the dry milk and may relate to the presence of residual sanitizer and/or cleaning agents in the product.

Metallic The off-flavor, metallic, is quite suggestive of the presence of copper or iron in the raw material used to produce the dried product. Metallic is usually regarded as a phase of oxidized (metal-induced) off-flavor.

Neutralizer The neutralizer off-flavor is an alkaline taste generally derived from alkaline substances used to neutralize any developed acidity in milk. The USDA has made provisions for the pH adjustment of dry whey using “safe and suitable pH adjusting ingredients,” but acid neutralization of most other dry products is not permitted.

Oxidized Milkfat oxidation is the cause of the defect described by the term oxidized in many dairy foods, including dry milk products. The perceived sensation in an oxidized off-flavor resembles wet cardboard, oily substances, or aged beef tallow, depending on the defect intensity. The USDA definition also includes the term cappy, which refers to the bygone days when paperboard “caps” were placed on milk containers, imparting a type of “wet cardboard” aroma.

Rancid Rancidity in dry milk products usually exhibits a strong, pungent odor that may be accompanied by a soapy aftertaste. These sensory properties are primarily due to the generation of small, short-chain fatty acids resulting from the hydrolysis of milk triglyceride.

Salty A salty taste defect in dry milk products is simply a perceived primary taste of salt or a salt solution; it resembles a milk product that contains excessive amounts of salt. Perception of a salty taste on the front tip and sides of the tongue is relatively rapid, compared to other experienced taste sensations.

Scorched This flavor defect is produced when milk powder has been subjected to excessive heat in the drier or other heat-exchange processes; it is generally suggestive of burnt protein. The USDA definition for scorched is "A more intensified flavor than cooked," plus an additional statement that this flavor defect is generally characterized by having a burnt aftertaste.

Stale Stale generally implies a lack of product freshness. This flavor sensation in dried milk products is ordinarily associated with deterioration of milk protein rather than milkfat. Some dairy product evaluators tend to use the descriptor "lacks freshness" in lieu of the term "stale," while other evaluators use both of the aforementioned descriptors interchangeably. The terms "stale" or "lacks freshness" are commonly applied when the flavor is not as refreshing as expected by the evaluator.

There is an apparent anomaly in use of the terms "stale" and "storage" as flavor descriptors. The USDA provides guidelines for various intensities of both stale and storage off-flavors, but their singular definition treats them as one and introduces some element of confusion for product evaluators (i.e., "Stale, storage. Lacking in freshness and imparting a 'rough' aftertaste"). Such discrepancies suggest that more mainstream sensory techniques should be applied to develop a more accurate terminology.

The author notes that a logical argument can be made for the acceptance of separate meanings of the terms "stale" and "storage." It is true that a stale off-flavor in dry milk can develop during storage but so can the oxidized off-flavor. Analogous to the oxidized off-flavor, stale is a distinctively recognizable off-flavor that typically develops over the course of storage. Unfortunately, thus far, research has not conclusively pinpointed the chemical precursor or the actual chemical entity that is responsible for the stale off-flavor. The precursor could be any of the following: (1) a protein, (2) a product of the Maillard reaction, or (3) some compound(s) derived from milkfat. The chemical compound(s) produced from potential precursor(s) may require that the substance(s) undergo oxidation to eventually produce the stale off-flavor. The salient point is that the stale off-flavor is a distinct entity, whereas the designation "storage off-flavor" is somewhat more generic. Hence, the descriptor "storage" more appropriately encompasses a range of off-flavors that dry milk products may acquire during a period of storage. These shortcomings may range from absorbed off-flavors (from the storage environment) to flavor defects that develop from slow, gradual chemical reactions in the product, which can be appropriately designated as a "lacks freshness" and/or "storage" off-flavor.

Unclean (Utensil) Typically, the unclean flavor defect in dry milks refers to an unpleasant odor and lingering aftertaste that is suggestive of organic decomposition products. The sensation of "uncleanliness" may vary from an odor that resembles barny or barnyard-like, to that of spoiled feed or the decay of organic matter. These objectionable sensory characteristics are usually due to proteolytic or lipolytic activity by spoilage bacteria in milk. The unpleasant aftertaste is often dirty-like, persistent, and generally objectionable, if not obnoxious.

The USDA definition is somewhat more general and only relies on the antiquated term "utensil." Hence, unclean (utensil) is described by USDA terminology thus, "A flavor that is suggestive of improper or inadequate washing and sanitation of milking machines, utensils, or manufacturing equipment." Due to its questionable relevance, the term utensil should probably no longer be used in describing this off-flavor, yet it still exists in the standards. The activity of spoilage microorganisms (e.g., psychrotrophs) in residual milk soils that remain on the equipment is responsible for the defect, not the equipment and/or utensils themselves.

Undesirable The USDA uses the term undesirable to describe certain off-flavors that are in excess of the permitted intensity in specific grades of dried milk products or for those miscellaneous off-flavors that are not otherwise listed.

Weedy Weedy is a flavor characteristic of certain weeds that may be consumed by cows that produced some of the raw material used for manufacture of the dried product. See the dry whey grading standard (USDA, AMS, 2001).

11.28 Terms Describing the Appearance of Dry Products

The reader is advised to review Table 11.11 for a suggested scoring scheme for physical appearance characteristics of dry milks. USDA grading literature also provides the following intensity definitions:

Practically Free
Present only upon very critical examination.

Reasonably Free
Present only upon critical examination.

Table 11.11 Suggested scoring guide for the physical appearance characteristics of dry milk

	Scores for a given intensity				
Defect	Slight	Moderate	Definite	Strong	Pronounced
Dry:					
Caked	2	1	0	0	0
Dark particles	3	2	1	0	0
Lumpy	4	3	2	1	0
Unnatural color	4	3	2	1	0
Color not uniform	4	3	2	1	0
Reconstituted:					
Churned particles	3	2	1	0	0
Dark particles	3	2	1	0	0
Grainy	3	2	1	0	0
Undispersed lumps	3	2	1	0	0

"No criticism" is assigned a score of "5." Normal range is 1–5 for a salable product where 5 represents a product of ideal appearance character. A score of "0" (zero) is assigned if the product is determined to be unsalable

Moderately Free
Discernible upon careful examination.

Caked Caked means a hardened mass of powder that results from lactose crystallization. It usually disintegrates into small hard chunks, which are practically undispersible in water.

Lumpy Lumpy refers to a nonhomogeneous appearance of dry milk, which is due to sizeable lumps of agglomerated powder particles. The USDA definition for lumpy is "Loss of powdery consistency but not caked into hard chunks."

Reasonably Free Flowing This refers to the ability of the product to flow, in powder form. USDA language is as follows: "Pours in a fairly constant, uniform stream from the open end of a tilted container or scoop."

Unnatural/Natural Color Unnatural color refers to an abnormal or atypical color of the product due to either caramelization of lactose, nonenzymatic browning, or added color. The USDA defines unnatural color for dry whole milk and nonfat dry milk as follows: "A color that is more intense than light cream and is brownish, dull or grey-like." Conversely, *natural color* is defined as "A color that is white to light cream."

Visible Dark Particles Scorched powder particles or visible extraneous matter is termed "visible dark particles." A similar definition is offered by the USDA: "The presence of scorched or discolored specks." The American Dairy Products Institute (see https://www.adpi.org/DairyProducts/tabid/62/Default.aspx) provides publicly available standards for such particles for a variety of common dried dairy ingredients.

11.29 Terms Describing the Appearance of Reconstituted Product

Churned Particles Masses of coalesced fat and/or coagulated protein that may float to the surface (and eventually adhere to the side wall of the container) are generally called "churned particles."

Grainy Grainy refers to visible insoluble particles in reconstituted milk products that distinctly appear granular. This is the only appearance term defined by the USDA for reconstituted dry products. The USDA definition reads "Minute particles of undissolved powder appearing in a thin film on the surface of a glass or tumbler."

Pressure This term refers to the dissolution of lumps as the product is rehydrated and blended, similar to what will occur during manufacture, and is defined as follows: "*Very slight pressure*. Lumps fall apart with only light touch," "*Slight pres-*

sure. Only sufficient pressure to disintegrate the lumps readily," and "*Moderate pressure*. Only sufficient pressure to disintegrate the lumps easily." Intuitively, the term "undispersed lumps" refers to masses of caked or lumpy powder that do not readily dissolve in water.

11.30 Terms to Describe Packaging Defects

The product package is not a defined criterion in the USDA grading system. Documents included in 7 CFR 42 provide general requirements for the condition of food-grade packaging. The US Dairy Export Council provides some description and convention regarding adequate packaging design and application for dried dairy ingredients in their publication, "Reference Manual for U.S. Milk Powders, 2005 revision." A suggested guide for scoring the package integrity of dry milk products is illustrated in Table 11.12.

Ruptured Vapor Barrier Any visible mechanical opening in the product package is referred to as a "ruptured vapor barrier."

Soiled The unsightly appearance of the package exterior due to adherence of dried product or any foreign substance is simply called "soiled."

Unsealed Unsealed refers to a closure that is not secured in such a manner to guarantee that access to the product is impossible without breaking or tearing a visible seal on the product container.

11.31 Laboratory Tests of Dry Dairy Products

Certain laboratory tests are indispensable in helping to assess the quality parameters of dry dairy products. Analyses provide objective, quantitative measures of hygienic quality, product composition, rehydration characteristics, possible acidity development (as well as evidence of neutralization of excessive acidity), compliance with minimum pasteurization requirements, and potential keeping-quality

Table 11.12 A suggested scoring guide for the packaging of dry milk

Parameter	Score range
Soiled package, graded and scored proportional to the nature and quantity of soil	0–5
Unsealed package and/or ruptured or defective vapor barrier	0
Any packaging that fails to meet the requirements of regulatory agencies	0

A score of zero ("0") is assigned if the defect is so serious (or pronounced in intensity) as to render the product unsalable characteristics. Descriptions and procedures used for conducting such assays are included in several well-recognized resources, listed below for reference.

AOAC, International. (2019) Official Methods of Analysis 21st Ed. Revision 1. AOAC International, Arlington VA. See www.aoac.org

Standard Methods for the Examination of Dairy Products 17th Ed. (2004) H. M. Wehr and J.F. Frank eds. American Public Health Association, Inc., Washington D.C. See www.apha.org

From the U.S. Dairy Export Council (See www.usdec.org).

Reference Manual for U.S. Milk Powders
Reference Manual for U.S. Whey and Lactose Products

From the American Dairy Products institute (See www.adpi.org).

Dry Milks
Concentrated milk
Whey products

The International Dairy Federation (See www.fil-idf.org).

11.32 Methods of Reconstituting Dry Dairy Products for Flavor Examinations

Limited quantities of reconstituted dry milk and whey products are used as beverage products in the USA. However, even if they are used only as ingredients in dairy products or other foods, the sensory properties of reconstituted dry dairy ingredients must meet desired standards and favorably contribute to the desired quality criteria of finished product(s). Therefore, a standardized procedure should be devised by each user for evaluating dry dairy products for determining their suitability as a food product ingredient. For example, if a poor-quality (off-flavored) NDM is used in ice cream manufacture, the off-flavor(s) will most likely carry through into the ice cream. On the other hand, a slightly off-flavor NDM may sometimes be incorporated into highly flavored products with little negative impact.

Two types of test situations may arise with dry dairy products to be consumed as a beverage. In acceptability testing using a consumer panel, the product should be reconstituted in exactly the same manner as the consumer is instructed to do by the user directions on the container. The temperature at which the reconstituted product is served in the test should be the typical consumption temperature for the product. In grading or quality evaluation (discrimination) by trained evaluators or panelists, conditions are chosen and defined in order to optimize detection of off-flavors but not exaggerate their intensity; such assessments may include the incorporation of the ingredient into an authentic dairy food (Lloyd et al., 2004; Caudle et al., 2005; Drake et al., 2003). Since the perceived intensity of flavor characteristics varies with temperature, comparative judgments should be made with reconstituted samples at the same temperature. In most instances, USDA dairy product grading standards require that products be evaluated within a specific temperature range. However, a study using trained evaluators and Cheddar cheeses showed that serving temperature had no impact on panelist or panel performance (Drake et al., 2005).

Normally, grading or quality evaluation should be performed on dry dairy products that are intended as ingredients for other foods. The odor perceived immediately after the containers are opened should be carefully noted, since it provides an immediate clue to a possible flavor problem. Precautions should be taken to avoid inhaling powder. The powder should be reconstituted and evaluated under standardized conditions, including a specified ratio of powder to water, source of water, manner of mixing, temperatures and time interval between reconstitution, and actual testing. The re-liquefied product should be evaluated in practically the same manner as its fluid counterpart. The evaluators should know, learn, and "fix-in-mind" the desirable flavor characteristics of whey, sweet cream, buttermilk, nonfat milk, etc., to which they must mentally compare the flavor of the reconstituted product.

Distilled water is commonly used for reconstituting dry dairy ingredients for flavor evaluation, even though tap water is more likely to be used in the home, as well as in the plant. Since tap water varies in hardness and flavor in different locations, there is a rationale for specifying distilled water. However, since distilled water may also vary in sensory properties (depending on residual impurities), a good precaution is to ensure that the water is relatively tasteless and odorless.

Directions for determining the taste and odor of products derived from reconstituted milk were prescribed by the USDA as follows:

> Reconstitute with an electric mixer 6.5 g of whey, 10 g of nonfat dry milk, or 13 g of dry whole milk in 100 ml of distilled water. Allow samples to stand 1 hour, stir thoroughly, and taste at room temperature. Observe odor and taste in a room free of disturbance and off-odors. Report the flavor as satisfactory or report the off-flavor in accordance with the appropriate US grade standards.

A directory of Codex Standards for the evaluation of dairy ingredients in found in the document Codex Stan 234-1999 wherein the sampling method allows an adjustment based on milkfat content (see IDF 50C and 113A).

11.33 Conclusion

With the ability to provide high nutrition, quality, and functionality, dry dairy ingredients continue to be a strong component of the dairy foods industry, growing in both volume and diversity. Coupled with the advent of improved manufacturing technologies as well as novel technologies such as membrane separation systems, dry dairy ingredients see applications as novel ingredients in a growing number of food systems. In almost every case, however, dried dairy ingredients remain complex both physically and chemically, requiring a sound, science-based understanding of their properties to maintain the value of these ingredients in an increasingly competitive market. Sensory assessments continue to provide a frontline of information detailing the chemical, microbial, and physical properties of dry dairy ingredients. Routine grading practices as well as formally defined consumer and trained descriptive methods each have roles in the maintenance and understanding of manufacturing dry dairy ingredients with desirable flavor and functional properties.

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Chapter 12
Pasteurized Process Cheeses

Stephanie Clark

12.1 Introduction

While natural cheeses tend to form free fat and moisture in cooking applications, pasteurized process cheeses (often called processed cheese or American cheese) are made to have smooth, uniform flow when melting occurs. The cooking stage of process cheese manufacture tends to stop natural cheese aging, thereby extending the flavor properties of mild- or medium-aged cheeses throughout a much longer shelf life than would be the case of the natural cheeses from which they are made. Further processing of natural cheeses affords manufacturers the ability to select melting properties that range from free-flowing to partially restricted, to full melt restriction. A free-flowing melt is desirable for hamburgers and in cooking applications such as macaroni and cheese. Partial melt restriction is typically desired for cordon bleu applications where some ingredient flow is desired, but the cheese should not just melt and flow away from the center of the plated item. Full melt restriction is useful for cheese inclusions within further processed foods, e.g., hot dogs or sausages. Process cheese products also allow for combinations of flavors, e.g., American, Swiss, and other cheese blends.

Process cheeses tend to be versatile, and with appropriate control of ingredient inputs, predictable and consistent for both flavor and texture attributes. These favorable characteristics justify the extensive popularity of process cheese foods in the food service industry. The lower cost compared to natural cheese is another

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appealing factor. The retail price of American processed cheese in the USA from 1995 to 2020 has remained very close to $4 per pound ($1.80/kg) (Statista, 2021). Retail sales of process cheese are not as robust as in food service. US retail process cheese sales were $2.8 billion during the 52 weeks ending January 26, 2020 (a 1.5% drop from 2019); natural cheese dollar sales exceeded $13.2 billion in the same period (a 2.1% rise) (Canning, 2020). The USDA Economic Research Service reported that total processed cheese consumption in the USA dropped to 7.0 lb. per capita in 2019 (4.7 for processed cheese; 2.4 for cold pack, cheese foods, and other processed foods and spreads), while natural cheese per capita consumption reached 38.6 lb.

Much knowledge and manufacture technology about process cheese formulation and development has historically been proprietary. Hence, much less information has been published in this product category compared to the more popular varieties of natural cheese. An excellent review of applicable patents and the proprietary history involved in the development of the process cheese industry was provided by Zehren and Nusbaum (1992). Fox et al. (2000) present a comprehensive overview of process cheese ingredients functionality and their interactions during the manufacturing process.

Process cheese manufacture typically involves grinding natural cheese and melting it with the aid of an emulsifying salt, which interacts with casein. Hydrophobic regions of casein are unfolded and surround fat droplets, holding them in a stable process cheese matrix. Emulsifying salts are salts of organic or inorganic acids (e.g., sodium phosphates or trisodium citrate); they are not typical oil-in-water interface compounds (such as lecithin) or other surface active agents that are used to emulsify margarines. The function of these emulsifying salts in process cheese manufacture is to exchange sodium ions for calcium and thus facilitate the unfolding of casein, such that the respective hydrophobic and hydrophilic regions of casein may interact with additional water and milkfat to form a stable emulsion.

12.2 Product Definitions

Pasteurized process cheese is defined within Title 21 of the Code of Federal Regulations (CFR, USDHHS, 2021) under three main product categories:

1. Pasteurized Process Cheese (21 CFR133.169)
2. Pasteurized Process Cheese Food (21 CFR133.173)
3. Pasteurized Process Cheese Spread (21 CFR133.179)

These definitions address acceptable/allowed ingredients and final composition of the cheese. For example, pasteurized process cheeses (process cheeses) are a mixture of natural cheeses, heated with the aid of an emulsifying agent. Generally, process cheeses must conform to the composition of the natural cheeses from which they are made, with allowance made for an additional 1% moisture, typically derived from steam condensate incorporated during the heating step.

Pasteurized process cheese foods (cheese foods) must contain ≥51% natural cheeses by weight and are allowed to incorporate milk, skim milk, buttermilk, and/or cheese whey. These optional dairy ingredients may be added to cheese foods by hydration of their powder forms to produce a slurry for ease of ingredients metering. Cheese foods are allowed to contain ≤44% moisture and must contain >23% fat.

Pasteurized process cheese spreads (cheese spreads) are allowed to contain all of the dairy ingredients found in cheese foods, plus functional gums and sweeteners. Cheese spreads also must contain as an ingredient ≥51% natural cheeses by weight. US regulations allow cheese spreads to contain between 44% and 60% moisture, and milkfat must be ≥20%.

The CFR defines many additional types of pasteurized process cheese options, including but not limited to:

- Pasteurized process cheese with fruits, vegetables, or meats (21 CFR133.170). They contain one or any mixture of two or more of any properly prepared cooked, canned, or dried fruit, vegetable, or meat.
- Pasteurized process pimento cheese (21 CFR133.171). They conform to the identity of pasteurized process cheese with fruits, vegetables, or meats, except that pimentos, and only pimentos, make up not less than 0.2% of the finished product weight.
- Pasteurized process cheese food with fruits, vegetables, or meats (21 CFR133.174).
- Pasteurized cheese spread (21 CFR133.175). The product differs from pasteurized process cheese spread only in that no emulsifying agent is allowed.
- Pasteurized process cheese spread with fruits, vegetables, or meats (21 CFR133.180).

For products containing fruits, vegetables, or meats, as with any flavored product, the distributions of condiments must be homogenous, and flavorings, colorings, and textures should not detract from the quality of the underlying cheese.

An important product category that is not defined in the CFR is pasteurized process cheese product. Pasteurized process cheese products may have associated fanciful names (e.g., “style,” “loaf,” or “block”). This product category typically falls outside of existing standards of identity due to the use of ingredients targeting functionality (e.g., starches and/or gums), which are not specifically listed within definitions of pasteurized process cheese or pasteurized process cheese food. Also, pasteurized cheese products may be so named because they utilize protein sources such as milk protein concentrates. Cheese analogues made by using vegetable oil and/or vegetable proteins as an ingredient may sometimes be labeled as a cheese “product.”

Cold-pack and club cheese (21 CFR133.123), cold-pack cheese food (21 CFR133.124), and Cold-pack cheese food with fruits, vegetables, or meats (21 CFR133.125) are entirely different from pasteurized process cheeses, spreads, and products in that they are not pasteurized, do not contain emulsifying salts, and may contain acidifying agents as long as the pH does not drop below 4.5. These products are "prepared by comminuting, without the aid of heat, one or more cheeses of the same or two or more varieties, except cream cheese, neufchatel cheese, cottage cheese, low-fat cottage cheese, cottage cheese dry curd, hard grating cheese, semi-soft part-skim cheese, part-skim spiced cheese and skim milk cheese for manufacturing, into a homogeneous plastic mass" (21 CFR133.123). Variations on the them include "pub cheese," "spreadable cheese," and "cheese spread," which are not defined by the CFR. In addition to plain, Port wine-flavored cold-pack cheeses and spreads can readily be found in the market (Figs. 12.1 and 12.2).

Fig. 12.1 A variety of cheese spreads, cheese dips, and pasteurized process cheese products. (S. Clark image)

Fig. 12.2 A variety of spreadable cheeses and cold pack cheeses. (S. Clark image)

12.3 Sensory Evaluation

The application of sensory evaluation to ingredients and in-process stage changes is an important element of process cheese manufacture. Cheeses (the primary raw materials) are graded in a selection process when assembling various cheese blends for subsequent reprocessing. Although the intended use of finished process cheese products may have nothing to do with USDA regulations or guidelines, the standards for cheese grades published by the USDA (7 CFR 58.735; USDHHS, 2021) are frequently implemented in evaluating the raw materials. These quality assessment grades are based on ratings for flavor, aroma, body, and texture. In addition, a sensory evaluation of the body and texture properties (i.e., "smear" or "breakdown" characteristics) of representative cheese samples between the thumb and forefinger is commonly used to predict the function and performance of selected cheeses within a blend. Sometimes the objective is to blend out or minimize shortcomings of certain natural cheese stocks in order to produce flawless process cheese. It is common industry practice to blend so-called broken down, flavorful natural cheeses with sources of minimally aged (younger) cheese that typically exhibit a more solid texture, in order to manufacture a process cheese having sliceable texture with good flavor characteristics. Young Cheddar or American cheese varieties are most often chosen as the backbone of US process cheese varieties.

12.3.1 Grading of Raw Materials

Sources of natural cheese for use in process cheese manufacture include a young variety to serve as a source of intact casein to provide structure in the finished product. In the USA, this source is often granular cheese (21 CFR 133.144; USDHHS, 2021), often referred to as "barrel Cheddar." Cheese flavor may be provided by older cheese, e.g., aged Cheddar block or from cheese trim coming from cut and wrap operations that convert block natural cheeses to retail chunk or slices. Trim or "scrap" from these operations may be very useful sources of flavor when manufacturing process cheeses. The natural cheese selected for processing is graded by using USDA standards for grades, which are primarily sensory tests. For example, 21 CFR 58.711 describes the characteristics of Cheddar cheese to be used in pasteurized process cheese manufacture as follows: "Cheese, used in the manufacture of pasteurized process cheese products should possess a pleasing and desirable taste and odor consistent with the age of the cheese; should have body and texture characteristics which will impart the desired body and texture characteristics in the finished product; and should possess finish and appearance characteristics which will permit removal of all packaging material and surface defects."

Other dairy ingredients such as nonfat dry milk, butteroil, and buttermilk powder are graded on a similar basis by using standards defined in Part 58 of 7 CFR. Other raw materials such as nonfat dry milk and anhydrous milkfat can impart desirable or undesirable flavors to finished products when using these dairy ingredients. It is prudent to know and assess their flavor characteristics before given lots of such ingredients are used in process cheese manufacture. Potential off-flavors can become an issue as certain sources of whey fractions are used as product ingredients. Whey protein interactions with casein may also result in unpredictable and/or unwanted texture changes in process cheeses. The use of old or extended storage dairy powder ingredients (nonfat dry milk, whey, whey protein concentrate, milk protein concentrate) often invites stale, storage, cardboard-like, and/or oxidized off-flavors. The reader is directed to Chap. 11 for a comprehensive overview of the sensory evaluation of various concentrated and dry milk products. In addition to typical milk off-flavors, e.g., feed, rancid, or oxidized (see Chap. 5), dry dairy ingredients have their own associated flavors such as cooked, scorched, and lacks freshness (stale). Intense off-flavors derived from these added ingredients may not be masked in process cheeses; occasionally these flavor defects may become more pronounced in the finished product.

High-fat ingredients (e.g., anhydrous milkfat, plastic cream, dry whole milk, or dry cream) may impart oxidized or definitive feed off-flavors. Raw materials used for the manufacture of the aforementioned ingredients, as well as adverse storage conditions and handling practices, can diminish their sensory properties in ways that may be detectable in process cheeses. Flavor assessment of all these ingredients should be conducted prior to use in process cheese manufacture. Flavor assessment of AMF and plastic cream could be conducted similarly to methods described in Chap. 5 for whipping cream and/or half-and-half; the dry whole milk and dry creams may be evaluated by first rehydrating the given dry ingredient with good-quality water at a ratio back to the approximate moisture content of the original high-fat ingredient.

There are certain off-flavors specific to process cheeses that may arise from the addition of emulsifying salts or other inclusions. For example, phosphate-emulsifying salts may contribute to subtle "emulsifier burn" or pronounced "soapy" flavor defects. Phosphate emulsifiers, especially those having a trisodium phosphate component, will raise the pH of process cheeses from typical natural cheese near pH 5.1 to pH 5.8 or higher. As the pH nears or exceeds 6.0, a definite alkaline flavor will become apparent and, in the extreme, can taste of detergent or soap. These particular sensory characteristics tend to not be observed in those process cheeses emulsified with citrates. Process cheese emulsified with trisodium citrate is typically in the pH 5.4 range.

Acids used for flavor and/or pH adjustment of process cheeses may suffice to contribute either desirable or undesirable sensory properties. Up to 0.25% of acetic acid may mimic flavors typical of "sharp" natural cheeses; however, acetic acid used in excess may impart vinegar-like flavors to process cheese. Lactic acid is naturally occurring in cheeses used for the manufacture of process cheeses but may contribute metallic off-flavors if added in excess of 0.25–0.30%. Lactic acid and acetic acid may be used in combination to adjust pH and to drive desirable acidic flavors but should not exceed 0.40% of typical process cheese formulas.

Sugars or maltodextrin may be used in process cheese spread manufacture to balance the sensory properties of added acids. Sugars, obviously, may also impart atypical sweet taste notes. Excessive lactose from whey powders may crystallize within a process cheese matrix. Unfortunately, consumers have been known to perceive formed lactose crystals as bits or shards of glass, thus potentially leading to market withdrawals and most adverse publicity. Maltodextrin imparts less sweetness than either sugars or corn syrup solids; however, maltodextrin may contribute a slightly sweet flavor to process cheeses.

The addition of starter culture distillate to process cheese can impart fresh cheese or buttery flavor notes, but if added in excess, the finished product may seem artificial and/or popcorn-like. Certain yeast extracts may provide flavor notes that simulate aged natural cheese, but they may also impart an undesirable flavor or an aftertaste.

Added colorants do not typically provide flavor but are often diluted in a vegetable oil carrier. Vitamins and food coloring are often diluted in vegetable oil to facilitate adding small quantities to batches of process cheeses. The sensory properties of some vegetable oils may adversely influence sensory properties of process cheeses. Cardboard-like, oxidized, and other lipolytic vegetable oil off-flavors are undesirable. The sensory attributes of any vegetable oil used as a product ingredient may adversely affect process cheese flavor. Oxidized off-flavors in process cheeses may also be derived from the vegetable oil source used either as a colorant or as a vitamin carrier. Vegetable oil vitamin carriers may also be perceived as imparting grassy flavor to process cheeses.

Sorbic or propionic acids may be incorporated as antimycotics on consumer cuts (sliced, diced, shredded) of process cheeses. These mold preservatives may contribute to undesirable acidic or mouthfeel "burning" sensory characteristics.

"Non-standard of identity" ingredients, such as enzyme-modified cheese (EMC), are evaluated by appearance and aroma. Some EMC sources may have a profound effect on process cheese flavor. EMC aroma may be monitored, but the associated flavor characteristics are typically so intense that it is impractical to try to evaluate directly. Employing EMC as an ingredient in processed cheese creates a need for closely monitoring all finished products for flavor character contributions derived from the EMC. Enzymatic breakdown of natural cheese protein and lipids to intentionally create pronounced cheese-like flavors leads to the ability to use small quantities of EMC to lend natural cheese flavor to process cheeses made from mild natural cheeses which may otherwise not provide much flavor.

12.3.2 Evaluation of Finished Product

Evaluation of quality attributes of the finished products is essential to guarantee consistency from batch to batch. The USDA has issued guidelines for evaluation of the quality attributes of pasteurized process cheeses (7 CFR 58.736; USDHHS, 2021). These guidelines include flavor, body and texture, color, finish, and appearance. Zehren and Nusbaum (1992) make reference to sensory evaluation of process cheese with the following observation: "The organoleptic properties are specified in the agreed upon standards between the process cheesemaker and his customer. The customer usually has specific requirements or the process cheesemaker has specific quality requirements to distinguish his brand. One customer may desire a high flavored, high melt, softer bodied cheese while another may desire a bland flavored low melting firm resilient body or in contrast a cheese that is hard and brittle. For that reason, there is not a single unique quality standard for judging process cheeses. The product needs to be judged against its standard."

When establishing a "gold standard" or reference formulas, processors must be attentive to the tendency for ingredient characteristics to change. As natural cheese manufacturers adapt their processes to increase cheese yield and gain production efficiency in their facilities, the performance and flavor characteristics of natural cheese sources may change. The young Cheddar cheese sourced from a given plant several years ago may be quite different from the same young Cheddar obtained from that plant today.

Some detailed sensory testing methods for evaluating process cheese are given in *Process Cheese Manufacture*; a JOHA™ Guide; edited by Prof. Dr. H. Klostermeyer (1998). These tests are pertinent to process cheese manufactured for European markets. The testing methods are applicable to process cheese manufactured anywhere, even though the targets or goals for specific attributes may be different in the USA from those in Europe. Guidance is also provided by M. A. Thomas (1977) in *The Processed Cheese Industry* for product evaluation and quality control protocols; however, these guidelines are somewhat generic. In addition, various instruments for measuring finished product firmness, crumbliness, and stickiness have been developed or adapted for process cheese manufacture. Although these instruments serve to add some degree of enhanced objectivity to measurement of these body and texture attributes, the contemporary process cheese industry tends to make these particular evaluations by subjective observation.

The sensory attributes of the cheese sources being processed (see Chaps. 9 and 14) should be somewhat evident in pasteurized process cheese. Process Swiss cheese should exhibit flavors characteristic of natural Swiss cheese. Process Monterey Jack may be difficult to distinguish from typical American process cheese (other than shade of color), but there should be some element of acidity and moderate salty taste typical of the natural cheese from which it was made. Stated in other words – you do not necessarily need a whole new set of flavor descriptor terms specific to process cheeses.

One of the appealing things about process cheese is the ability to "set" or lock in the flavor of a natural cheese while terminating the aging or ripening process. At the same time, common defects or quality shortcomings of natural cheeses may possibly become sensory attributes of process cheese. The use of too much natural cheese having a distinct bitter taste will result in a bitter-tasting process cheese. Use of a highly acidic natural cheese typically results in a most acidic-tasting process cheese with associated texture defects such as too firm and/or brittle. Process blue cheese should taste like blue, not like a shoe.

When evaluating the sensory properties of pasteurized process cheeses, it is useful to develop a sensory language or lexicon or vocabulary list and to use that sensory language to provide the clients or colleagues common and accepted flavor, texture, and mouthfeel definitions. Without an agreed-upon lexicon, cheese processors risk carrying on endless product development cycles in an attempt to reach sensory attributes the two parties have not clearly defined. Dealing with numerous lots of rework is a costly aspect of product development. Sensory lexicons have been published for a wide variety of foods, e.g., Indian cuisine (Uhl, 2000), olive oil (Frank, 2000), dried dairy ingredients (Drake et al., 2003), chocolate milk (Thompson et al., 2004), and cheeses (Drake et al., 2001, 2005, 2010). The reader is referred to Chap. 17, which provides an overview of lexicon development and applications to many cheeses and dairy products. Table 12.1 offers a lexicon of sensory attributes focused on process cheeses. Included are descriptions of defined attributes and recommendations for mimicking suggested flavor or aroma attributes of processed cheese via standards that can help focus product development and quality assurance endeavors.

Texture is a key component of the sensory evaluation of process cheeses. Simple manipulation of a process cheese sample with the fingers can reveal a great deal of information regarding breakdown and smear characteristics. These characteristics may also be identified with a targeted lexicon of texture attributes, and those attributes in turn may be linked to objective measurements of process cheese firmness, e.g., texture analyzer force readings. Lexicon definitions should be tied as closely as possible to expected process cheese usage or customer expectations for flavor and performance. Further objective tests based upon customer use of process cheese should be clearly identified in written standard operating procedures (SOP).

Process cheese sensory scorecards are useful tools for use in sensory evaluation. Scorecards may clearly define expected flavor and texture characteristics using a company's lexicon or may be more free-flowing with suggested attributes for evaluators to use to guide their sensory comments. It is also possible to create a sensory scorecard typical of those used in collegiate dairy product evaluation competitions. These scorecards include a lexicon and suggested scores to be assigned for each sensory attribute when identified at slight, definite, or pronounced intensity (Table 12.2).

12.4 Applications Testing

12.4.1 Sauces

When a processor realizes that a specific form of process cheese is used as a primary ingredient in an application such as sauces, then it is customary to evaluate sensory properties in that particular application. When making sauces from process cheese, the quality assurance entity needs to define standard operating procedures (SOP) for

Table 12.1 Terms used to describe sensory attributes commonly observed in process cheese

Attribute	Description	Reference
Aged cheese; sulfur	Sulfurous aromatic typically associated with aged Cheddar cheese, hard boiled eggs, and struck matches	Natural Cheddar cheese aged 9 or more months; sulfur may be simulated using mashed boiled egg
Browned/toasted	Sweet, browned aromatics associated with slight overheating	Browned, melted cheese; or toasted bread
Burnt	Harsh aromatic associated with overheating	Burnt toast
Diacetyl (buttery)	Aromatic associated with the chemical compound diacetyl	Diacetyl, 20 ppm
Cardboardy (oxidized)	Aromatics reminiscent of wet cardboard, also described as flat or stale	Wet piece of cardboard or brown paper sack, old nonfat dry milk or old milk protein concentrate
Milkfat (creamy)	Sweet aromatics associated with milkfat and lactone compounds found in milkfat	Fresh whipping cream, delta octalactone, 100 ppm
Sour aromatic	Sour aromatics reminiscent of the fermentation of milk products	Cultured sour cream
Unclean (dirty socks)	Sharp, sweaty, aromatics that also generally provide a lingering unpleasant aftertaste	Kasseri or gruyere cheeses
Fruity	Nonspecific fruity aromatic reminiscent of ripe fruit	Fresh pineapple or canned pineapple juice
Free fatty acid (rancid)	Aromatic associated with short-chain free fatty acids primarily butyric acid. At low concentrations, this is often perceived as a delayed response after swallowing or expectorating	Feta or Romano cheese; butyric acid, 200 ppm
Methyl ketone	Sweet aromatic or flavor suggestive of methyl ketones, typical of blue cheese	Blue cheese, 2-octanone, 50 ppm
Musty	Earthy aromatic reminiscent of a poorly ventilated cellar, musty hay or mold	Potting soil, geosmin, 10 ppb
Old oil (rancid-like)	Flat, stale, rancid oil flavor, and aroma	Aldehyde (C9; nonanal) or aldehyde (C10; decanal) or old margarine
Soapy	Phosphate flavor characteristic of oxidized fats and long-chain fatty acids	EMC powder with a lauric acid component, or lauric acid, 500 ppm
Yeasty	Aroma and flavor of fermented bread dough	Brewer's yeast
Acetaldehyde	Pungent, penetrating aroma, and taste of green apple	1% acetaldehyde in water; fresh plain yogurt; fresh asiago cheese
Brothy	Aromatics associated with boiled meat or vegetable soup stock	Canned potatoes; beef broth cubes, methional, 10 ppm
Cooked	Aromatics of cooked milk	Skim or 2% milk heated to 85 °C for 30 min

(continued)

Table 12.1 (continued)

Attribute	Description	Reference
Nutty	Aromatics typically associated with nuts	Lightly toasted unsalted hazelnuts or walnuts; wheat germ, 2/3-methyl butanal, 500 ppm
Whey (whey taint)	Aroma and flavor of cheese whey	Fresh cheddar whey
Sweet taste	Like sugar; basic taste which triggers taste receptors	Sucrose solution (80 g/1000 ml)
Sour taste (acidic)	Basic taste which triggers taste receptors. Sharply acidic vinegary or tart	Citric acid solution (0.88 g/1000 ml)
Salty taste	Salty taste at an intensity beyond expectation	Salt water solution (7 g/1000 ml)
Bitter	A basic taste sensation (somewhat delayed) similar to strong black coffee, quinine, or tonic water	Caffeine (0.44 g/500 ml)
Umami	Basic taste associated with nucleotides and monosodium glutamate	Monosodium glutamate (5% solution)
Astringent	Mouthfeel sensation, elicits a drying, puckering sensation of the oral tissues	Alum in water (0.3 g/100 ml)

Source: Adapted from Drake et al. (2001, 2003, 2005)

(1) the pertinent dilution factor and (2) the relative quality of the diluent(s) used. Hard water or water that contains iron or sulfur may adversely impact sauce sensory properties. The quality of milk used and whether it is fat-free, whole, fresh, a concentrated form, or reconstituted milk may also suffice to markedly influence sauce sensory properties. For some applications, the end product user may wish to include typical condiments (e.g., green chili peppers), but this will complicate efforts to evaluate the sensory properties of the process cheese used to form the sauce. Appropriate communications with marketing and the sales force help to define typical product use conditions. Perhaps a process cheese sauce will be boiled, then cooled either slowly or rapidly, and conceivably be used immediately or over an extended period of time. Responsible QA entities will want to write their SOP protocols to be as predictive and as relevant as possible of what all product customers will see and experience during typical process cheese usages.

12.4.2 Cast Slices

Process cheeses earmarked for cast slices are typically made with sodium citrate or a blend of sodium citrate and sodium phosphate. This form of process cheese forms a band on a wide moving belt that is cooled from the opposite side (Klostermeyer, 1998). Cheese is cooled most rapidly compared to block process cheeses. Cooled bands of cheese are formed with a knife, then layered, cut, and packaged. To avoid

Table 12.2 Examples of process cheese evaluation scorecard

	Slight	Definite	Pronounced
Appearance criticisms			
Browning	4	2	1
Gassy	4	2	1
Greasy	3	2	1
Matte	4	3	1
Pinking	3	2	1
Body and texture criticisms			
Chalky	4	2	1
Pasty	3	2	1
Sandy	3	2	1
Short/brittle	3	2	1
Too firm	4	2	1
Too soft	4	2	1
Flavor criticisms			
Bitter	9	7	4
Fermented, fruity	8	6	5
Flat, lacks flavor	9	8	7
Garlic, onion, weedy	6	4	1
Heated, cooked	9	8	7
High acid, sour	9	7	5
Malty	8	7	6
Metallic	7	5	3
Moldy, musty	7	5	3
Rancid, lipase, putrid	6	4	1
Sulfide, skunky	9	7	4
Unclean, dirty	8	6	5
Whey taint, sour whey	8	7	5
Yeasty	6	4	1
Barny	8	6	5
Brothy	8	6	5
Brown or toasted	9	8	7
Burnt	6	4	1
Cultured	9	8	6
Dairy sweet	9	8	7
Emulsifier burn	7	5	3
Goaty	5	3	1
Milkfat (lactone)	9	8	7
Nutty	9	8	7

Modeled after Table 9.3 Sensory Evaluation of Cheddar Cheese

air holes and subsequent weak places in the band of cheese or difficulty achieving target weight for a stack of slices, a vacuum chamber is often included within the processing line for manufacturing cast slices. Loss of moisture may be calculated, and adjustments then made so that finished product meets composition targets. Vacuum treatment will also remove some volatile flavor components. In some situations, this may be an end product quality advantage, but this product treatment can also result in a blander flavor of cast slices.

Enzyme-modified cheeses (EMC) or a small quantity of aged cheese may be incorporated into cast slice formulas to compensate for the vacuum effect upon flavor intensity reduction. The use of aged cheese is limited in this application since the use of young cheese is necessary to achieve ribbon texture. Enzyme-modified cheeses may present flavor challenges of their own. Technologies for EMC making and commercial EMC options have improved dramatically in recent years; however, cast slice manufacturers must still be alert to excessive lipolysis or proteolysis and associated rancid, soapy, or bitter off-flavors. A light coating of vegetable lecithin – typically in refined, bleached, and deodorized vegetable oil – is applied to one surface of cast slices to prevent or limit sticking. However, a mild vegetable oil flavor may be detectable if cheese age and EMC use do not compensate for this process treatment.

Flavor of cast slices may be evaluated at the same time as visual color evaluation, surface appearance, stickiness/slice separation, "roll" test for resilience, and ribbon uniformity are being conducted, typically at scheduled intervals throughout manufacture. Slice aroma and flavor may be evaluated in an adjacent, designated laboratory area separate from the manufacturing line in order to not violate the obligatory "no eating" good manufacturing practice. The "roll" test involves rolling up a slice in the direction it was cast and also rolling a slice in the direction opposite casting. Slices should be resilient and should roll and unroll in each direction without cracking or breaking. Slice separation is evaluated at this time, as well, and provides a first indication of whether lecithin spray is effective or cheese texture is correct, so that foodservice operations working with loaves of cast slices can easily separate slices for application to burgers or other sandwich-like applications.

The more or less objective melt test is supplemented by the visual appraisal of the appearance of the melted product including smooth or rough surface and degree of browning. Excessive bubbling may indicate that the process cheese emulsion contains water that is not tightly bound. Browning during the melt test may suggest

Fig. 12.3 Bulk "American Cheese" cast slices or "singles". (S. Clark image)

Fig. 12.4 Examples of some of the options available in the market, including pasteurized process cheese products, pasteurized process cheese spread with peppers, pasteurized prepared cheese products, imitation process cheese foods, and reduced fat pasteurized prepared cheese products. (S. Clark image)

excessive lactose. Appearance information from the melt test may therefore lead formulators to examine choice and quantity of emulsifying agents, lactose level, or total moisture. Melt properties should be evaluated with as much understanding of customer expectations as possible so the result can help in creating robust formulas (Figs. 12.3 and 12.4).

12.4.3 Package Conformation and Integrity

Five-pound net weight rectangular loaves of process cheeses are evaluated for uniformity and conformity of rectangle dimensions. While not typically hermetically sealed, there will be some evaluation of seal integrity as well as ease of opening and removing the packaging film. Unless the process cheese is of high moisture, e.g., spread, the liner should not stick to the cheese surface nor should process cheese break off with the packaging upon opening. When the package is removed, the cheese surface should be smooth and glossy. Air pockets at one surface are common, but should not be pronounced. Five-pound loaves of process cheese are typically sliced for retail sale in subunits of 0.5- or 1-pound net weight. Finished product evaluation will include some measure of how well the cheese slices, whether there is smearing on the slicer blade and whether slices tend to stick together after slicing.

Aroma and flavor should be typical of the natural cheese variety from which loaf process cheese is made.

Cast slices in 5-pound loaf format should have good package conformity. If the package appears squashed or slumped, this is a quick indication of lack of body. The formula may need emulsifier adjustment or a shift toward younger natural cheese. The package should not force out at the sides under gravity but should retain rectangular conformity. Upon opening, cast slices should appear glossy and smooth. There should not be any mottling from uncooked curd particles or burnt particles. Cast slices rolled between the fingers should be resilient rather than brittle. Cast slices should separate easily and should not feel tacky to the touch. These are often applied to sandwiches in restaurant settings, so functionality evaluations should be approached from the intended use point of view. The aroma and flavor of cast process cheese slices should be typical of the natural cheese variety from which they are made.

12.5 Conclusion

Process cheeses continue to be a large and important segment of the total cheese market in the USA. Process cheeses offer the whole range of natural cheese flavor possibilities with improved hot flow properties and targeted texture characteristics. Flavor evolution, e.g., mild to medium to sharp Cheddar cheese, does not take place in process cheeses. Mild Cheddar process cheese will remain mild throughout its expected life. Texture may be selected across a broad range from soft and easily spread to firm enough to slice or cube. Flow when heated is more uniform in process than natural cheeses and can be targeted to free-flowing or completely restricted from flow depending upon customer performance requirements.

Title 21 of the Code of Federal Regulations (CFR) contains standard of identity definitions for pasteurized process cheese, pasteurized process cheese food, and pasteurized process cheese spread. CFR standards provide moisture maxima and minimum fat percentages for each category. In addition to these defined categories, process cheese "product" includes styles that do not meet CFR definitions due to the use of milk protein concentrates, vegetable fats or which fall outside the fat, or moisture ranges of the CFR categories.

Sensory evaluation of the natural cheeses used to manufacture process cheeses is critical to achieving flavor and texture targets. Flavorful cheese may be combined with mild cheese to achieve an intermediate level of cheese flavor. Additionally, blending young cheese with older cheese provides a backbone of intact casein which is useful in developing process cheese texture. Generally speaking, natural cheese should have a pleasing flavor typical of the variety represented. In addition to natural cheese, other dairy ingredients affect the sensory properties of process cheeses and cheese products.

Sensory evaluation of process cheeses often involves creation of a target or "gold standard". Differences in raw material age and sensory characteristics may make this challenging. Another useful tool for the sensory evaluation of process cheeses is creation of a lexicon of terms to be used in evaluating process cheese samples.

Process cheeses, cheese foods, cheese spreads, and cheese products provide consumers a wide variety of ways to enjoy the flavor of natural cheese varieties with enhanced flavor stability and targeted texture characteristics. By applying sensory evaluation practices from this text and those targeted to process cheeses in this chapter, manufacturers can help to assure that their process cheese items deliver sustainability to their enterprise by consistently meeting or exceeding customer expectations.

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Chapter 13
Cultured Cream Products

Stephanie Clark

13.1 Introduction

Archeologists place the time of the earliest use of milk fermentation at approximately 8000 BC. Until the European Middle Ages, the so-called let-it-be method of milk fermentation was interfered with minimally. An early publication of the US Department of Agriculture surprisingly recommended souring cream at the farmstead by permitting unpasteurized cream to incubate at room temperature "until it thickens, assumes a glossy appearance, and is mildly sour." The same publication emphasized that a safer, more consistent product would result from cream pasteurization and cooling, followed by inoculation with a starter culture (White, 1917). In many contemporary parts of the world, milk fermentation is still entrusted to wild species of microflora.

Historically, every human culture that has produced and consumed dairy products has developed its own traditional fermented milk products. Typically, locally produced fermented dairy products become closely identified with that region of the world from which they derived. Interestingly, fermented foods carry a disproportionate share of a given culture's identity. The wines, cheeses, breads, sausages, and other fermented meat products, fish, and fermented vegetables tend to become central elements of a given region's or nation's uniqueness and/or distinctiveness. Fermented or cultured milks and cream-based products are a frequent or common product category.

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This chapter will focus on spoonable cultured cream products, namely, cultured sour cream, crema Mexicana agria (Mexican-style sour cream), crème fraîche, mascarpone, and cream cheese, and their reduced fat versions (light, lite, low fat, nonfat). Cultured butter is covered in the chapter about butter.

The goal of this chapter is to (1) review manufacturing procedures as well as faults that may yield less than satisfactory sour cream and other fermented milk products; (2) provide the reader with a list of sensory characteristics found in the preferred or "ideal" sour cream and related cultured milk products; and (3) provide a vocabulary that will assist in communicating sensory attributes that a quality assurance manager might convey to the production supervisor and/or manufacturing team.

One form of a popular cultured cream product that recurs under different names but in slightly different forms globally is known in the USA by the simple descriptor "sour cream." Variations from the US version are primarily in milkfat content and local preferences as to the ideal level of acidity (sourness) and/or viscosity. In addition, the product's final use or food application varies from country to country. Hence, the consistency and the stability of cultured creams vary accordingly. Cultured sour cream in the USA is commonly used as a convenient flavorful topping, plain or flavored chip dips, baked desserts and pies ingredient, cake topping component, and/or as a key ingredient in various warm or hot foods such as casseroles and stroganoff (Kosikowski & Mistry, 1997). The French counterpart, crème fraîche, is typically used as a cold topping for fruit or cakes or as a foundation for sauces (Meunier-Goddik, 2004). The Italian soft cream product often used in dessert applications (e.g., Tiramisu), mascarpone, is not a cultured cream product but thermal-acid-coagulated cream product. The popular firm version of cultured cream, cream cheese, is available in blocks. Modified, lower-fat versions, "cream cheese spread," "whipped cream cheese spread," and various flavored versions, are available in tubs throughout the USA. The reduced fat version (1/3 less fat), Neufchatel, is also available in blocks and tubs. Classic cheesecake is made with cream cheese but can also be made with Neufchatel.

Wherever it is manufactured and whatever its precise composition, cultured creams represent an example of dairy food processors taking advantage of and ultimately exerting aesthetic control over processes that would occur naturally – creaming and souring. Once dairy manufacturers learned to exert measures of control over cream fermentation processes, they commenced to create more consistent products that satisfied the sensory and functional requirements of consumers and food-service users.

13.2 Standards of Identity

Sour Cream

The US Code of Federal Regulations (CFR, USFDA, 2022c) Sec. 131.160, 2019 defines "sour cream" or "cultured sour cream" as the food that "results from the souring, by lactic acid producing bacteria, of pasteurized cream. Sour cream contains not less than 18% milkfat; except that when the food is characterized by the addition of nutritive sweeteners or bulky flavoring ingredients, the weight of the milkfat is not less than 18% of the remainder obtained by subtracting the weight of such optional ingredients from the weight of the food; but in no case does the food contain less than 14.4% milkfat. Sour cream has a titratable acidity of not less than 0.5%, calculated as lactic acid."

Optional ingredients for sour cream products include:

1. Safe and suitable ingredients that improve or enhance body and texture, prevent syneresis (water separation), impact flavor, or extend the shelf life of the product.
2. Sodium citrate in an amount not more than 0.1% may be added to the product base prior to culturing as an aroma compound (diacetyl) precursor.
3. Rennet (optionally for potential body and texture enhancement).
4. Safe and suitable nutritive sweeteners (limited use in North America).
5. Salt (to potentiate flavor).
6. Possible flavoring ingredients, with or without safe and suitable coloring, as follows:
   (i) Fruit and fruit juice (including concentrated fruit and fruit juice)
   (ii) Safe and suitable natural and artificial food flavoring

Additionally, reduced fat, light, lite, and fat-free sour creams are manufactured and must meet the following criteria. In order to be labeled "reduced fat sour cream," the final product must contain a minimum 25% reduction in fat content and contain "13.5% or less of total fat when compared to sour cream meeting minimum compositional requirements for fat" (USDA, 2000). To be labeled "light" or "lite," the sour cream product must deliver at least a 50% reduction in fat and contain "9.0% or less of total fat when compared to sour cream meeting minimum compositional requirements for fat" (USDA, 2000). Finally, so-called nonfat sour cream is permitted to contain "less than 0.5 g of fat per 50 g of product and less than 1.0% total fat" (USDA, 2000).

Standards for the minimum titratable acidity remain consistent for all sour cream products – namely, ≧0.5%. Whatever the specific final milkfat content, the product quality goal of the sour cream manufacturer should be achievement of a "relatively heavy, smooth appearing, viscous product, that exhibits a glossy sheen and should possess a pleasant acidic taste, and a buttery-like (diacetyl) aroma" (Bodyfelt, 1981; Connolly et al., 1984).

Acidified sour cream, also defined in the CFR (USFDA, 2022c; Sec. 131.162), differs from sour cream in that lactic acid bacteria are not required for its production. A suitable acidifying agent may be used instead.

Sour cream in the USA is typically marketed in wide-mouthed polypropylene tubs. Consumer-sized packaging will range from 228 to 455 g (8 to 16 oz), with food-service containers weighing as much as 1362 g (3 lb) (Fig. 13.1).

Fig. 13.1 A variety of sour cream brands, sizes, container styles, and fat contents are available in the marketplace. (S. Clark images)

Fig. 13.2 Crema Mexicana (table cream) and Crema Mexicana agria (sour cream) are sold by multiple producers, in multiple packaging formats. (S. Clark images)

Crema Mexicana Agria

Crema Mexicana agria, or Mexican sour cream, is not defined in the US Code of Federal Regulations. Crema Mexicana agria should not be confused with Crema Mexicana (table cream) (Fig. 13.2). Crema is made essentially the same way as sour cream, but the fat content tends to be higher (20–30%, depending on brand). Salt is sometimes added.

Crème Fraîche

Crème fraîche, the French equivalent of cultured sour cream, is not defined in the US CFR. It is distinguished from the American product primarily in its fat content, the absence of stabilizers, and by its milder (less sour) flavor (Meunier-Goddik, 2004). Crème fraîche, or more correctly, crème fraîche épaisse fermentée, possesses a fat content between 30% and 45%.

Mascarpone

Mascarpone is not defined in the US CFR. Although similar in flavor, body, and texture to crème fraîche, mascarpone is not cultured and is produced in a different fashion. Fat content ranges widely in the marketplace, from about 27% to about 43%. Retail packaging is typically stout 8-ounce polypropylene tubs (Fig. 13.3).

Cream Cheese

The US CFR (USFDA, 2022a; Sec 133.133) defines cream cheese as the soft, uncured cheese prepared from pasteurized milk, nonfat milk, or cream, cultured with lactic acid bacteria, used alone or in combination, and clotting enzymes of animal, plant, or microbial origin, with or without optional ingredients (e.g., salt, whey, stabilizers (≤0.5%)). The final product must have a minimum fat content of 33% by weight and maximum moisture of 55% by weight.

Neufchatel cheese, the reduced fat version of cream cheese, is very similar to cream cheese. The milkfat content is not less than 20% but less than 33% by weight (1/3 less fat than cream cheese); moisture content is 65% by weight (USFDA, 2022b; CFR Sec. 133.162). Instead of using the name Neufchatel, sometimes cream cheese is marketed as reduced fat cream cheese (1/3 less fat than regular cream cheese) (Fig. 13.4).

Fig. 13.3 A variety of plain and flavored mascarpone products. (S. Clark image)

Fig. 13.4 A variety of reduced fat cream cheese products displaying a range of fat content from 0% to 16%. (S. Clark images)

The CFR (Sec. 133.134) defines "cream cheese with other foods" as cream cheese mixed with one or a mixture of two or more types of foods (except other cheeses). The maximum moisture must not exceed 60% by weight, and milkfat must not be less than 27% of the finished food. Stabilizers must not exceed 0.8%. Such foods must be called "cream cheese with ___" or "cream cheese and ___" with the blank indicating the name of the food(s) in order of predominance by weight. Additionally, "pasteurized Neufchatel cheese spread with other foods" is specified (Sec. 133.178) to not exceed 65% in water content and not be less than 20% fat by weight of the finished food. Commercial products should be called "pasteurized Neufchatel cheese spread with ___" (where the blank contains the common names of the food(s) added).

Fig. 13.5 Flavored, whipped, and flavored whipped cream cheese spreads, reflecting a range in fat composition from 15% to 33% fat and a variety of flavors from sweet to savory. (S. Clark images)

Other variations of cream cheese include "cream cheese spreads" (e.g., plain, strawberry, honey pecan, chive and onion, etc.), "whipped cream cheese spread," as well as "Greek cream cheese" or "Greek cream cheese spread" (Figs. 13.5 and 13.6). The composition of these products is not specified in the CFR, and fat composition among commercial brands ranges from 13 to 35%. The "Greek" varieties tout the extra protein (three to four times) compared to regular cream cheese.

Cream cheeses are marketed in a multitude of packaging options, including food-service tubs, plastic, foil, and single-serve polypropylene cups, as well as consumer foil-sealed and 8-oz polypropylene tubs.

Fig. 13.6 Greek cream cheese, prominently displaying fat and protein content in comparison to regular cream cheese. (S. Clark image)

13.3 Manufacturing Methods

The following discussion describes a typical process for making cultured cream products. There are certainly variations to the methods described that may be utilized to yield products that serve niche markets, but most products found commercially are manufactured by a process closely resembling those described here.

Achieving the subtle flavors that are expected of cultured cream products requires the highest quality cream and a metabolic collaboration between homofermentative and heterofermentative lactic acid bacteria. The necessity for selection of only high-quality cream cannot be overstated. Cultured cream products will only be as "good" as the quality of the cream used to manufacture them. The cream must be separated from fresh milk, collected from healthy cows, properly cooled, agitated, and maintained at or below 7C for less than 48 hours. The fresh cream must be devoid of any off-aromas or off-flavors, as any defect will become pronounced in the final product. The reader is encouraged to read the chapter about fluid milk products to review typical milk off-flavors.

The homofermentative bacteria generate primarily lactic acid from the fermentation of lactose. These species contribute little other than acid to the flavor of fermented dairy products. Heterofermentative bacterial fermentation yields lactic acid as its primary metabolite but also yields technologically significant quantities of flavor compounds such as diacetyl, acetic acid, acetaldehyde, and sometimes carbon dioxide (Kosikowski & Mistry, 1997; Morgan et al., 1966). Kneifel et al. (1992) screened commercially available US mesophilic starter cultures for their respective biochemical, sensory, and microbiological properties for the successful propagation of various cultured dairy foods, including sour cream and cream cheese. These authors found a wide disparity in the production of diacetyl, acetaldehyde, and carbon dioxide among the cultures tested. Only those cultures that yielded a very low diacetyl concentration were judged as low in odor and mild in flavor, and none were judged as "green" even when the ratio of diacetyl to acetaldehyde favored acetaldehyde. In addition, the authors reported that CO_2 helped potentiate diacetyl perception, probably by facilitating volatilization (Kneifel et al., 1992).

Mesophilic starter culture species and strains that contribute to the sensory quality of final products include both acid and aroma producers. Acid producers include *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris* (Meunier-Goddik, 2004; Hutkins, 2006). The aroma-producing species include *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis* (Meunier-Goddik, 2004), *Leuconostoc lactis*, and *Leuconostoc mesenteroides* subsp. *dextranicum* (Hutkins, 2006).

The primary desirable aroma compound in cultured cream products is diacetyl (2,3 di-butanone). The so-called buttery note derives from diacetyl production via citrate metabolism by citrate-fermenting (cit+) lactic acid bacteria. Without the presence of this buttery-like aroma, most discriminatory consumers would most likely find cultured cream products disappointingly "flat," whereas experienced dairy products judges would be inclined to declare that such a product "lacks cultured flavor." Lactic acid bacteria that produce diacetyl are often described as citrate fermenters, or in shorthand, cit+. The cit + species and strains require either citric acid or sodium citrate as a substrate if they are to produce diacetyl.

To gain and preserve the diacetyl, a number of conditions must be satisfied. First, there must be adequate citrate in the cream prior to fermentation. For Cit + lactic acid bacteria, citrate is an obligatory substrate for diacetyl production. The naturally occurring citric acid content of milk (or cream) is largely influenced by diet. The milk from cows fed on pasture will contain more citric acid than those fed rations (Davies, 1939). To enhance flavor development, federal regulations permit supplementing the sour cream base with up to 0.1% sodium citrate prior to fermentation.

Care must be taken to ensure that fermentation is arrested, while residual citrate remains or shortly after exhaustion, as these species can rapidly reduce diacetyl to the odorless compound, acetoin (acetyl methyl carbinol), once citric acid is exhausted (Monnet et al., 1996). Incubation temperature and rate of acid production must be controlled, as both of these factors influence the evolution of diacetyl. Incubation temperatures above 24 °C (75 °F) will favor the growth of homolactic species, and too much lactic acid will be produced, resulting in the inhibition of citrate fermenters. A fermentation temperature that is too low (<20 °C [<68 °F]) will yield a cultured cream products that lacks acidity.

The citrate transport system requires some acid to be present, and diacetyl development proceeds most rapidly when the pH is between 5.0 and 5.5. Once diacetyl is produced, additional acid production helps protect the diacetyl that has already been produced, as the pathway that reduces diacetyl to acetoin and 2,3 butanediol (both odorless compounds) is inhibited by acidic conditions (Hutkins, 2006).

Sour Cream

Sour cream production involves ingredient blending, pasteurization, homogenization (typically), cooling, culturing, coagulum breakage with cooling, and packaging.

A critical aspect of cultured sour cream manufacture is the requisite need for fastidious pre- and post-process sanitation protocols, inasmuch as the presence of numerous Gram-negative (i.e., psychrotrophs) bacteria produce vast quantities of diacetyl reductase, which readily reduces diacetyl to the flavorless reduction end product, acetyl methyl carbinol (Seitz et al., 1963; Bennett et al., 1964).

In order to satisfy a number of consumer and food-service user demands for functionality and certain aesthetics in sour cream, stabilizers and/or emulsifiers may be added, although they are not required. Generally, low concentrations (<0.5%) of gelatin or other hydrocolloids provide satisfactory results yielding a sour cream that does not separate when used as a topping on a wide range of foods, has a pleasant mouthfeel, and possesses the level of viscosity and homogenous appearance expected by most consumers. A food-service customer might prefer a highly stabilized product that will keep its form when placed on a baked potato long before serving. However, caution should be employed when using gelatin, as even slightly overusing it will yield a body so stiff that it cannot be stirred with a lightweight plastic spoon without breaking the spoon handle. More commonly, proprietary blends of stabilizer/emulsifier will also yield sour cream that generally satisfy consumer expectations.Use of excessive levels (>0.75%) of certain stabilizer/emulsifier blends in sour cream can lead to undesirable, overly thick, and excessively viscous finished products. Furthermore, the use of several different common stabilizer and emulsifier agents in a model dairy system (simulating sour cream) was observed to markedly reduce head space-available diacetyl (Rankin & Bodyfelt, 1995, 1996; Chen et al., 1999).

Another variation of cultured sour cream sometimes employed by manufacturers is the incorporation of additional skim milk powder into the formulation. By dramatically increasing the milk solids nonfat fraction, the manufacturer can more effectively bind water and inhibit whey expulsion (syneresis) in the container. Precautions should be taken relative to the freshness of the skim milk powder used since sour cream is a delicately flavored product and off-flavors or storage-related defects in milk powder will carry through into the sour cream (Caudle et al., 2005). “Squeezable” forms of sour cream are less viscous and are sold in a package similar to a small ketchup bottle, with a flip top lid-dispenser that delivers sour cream easily when squeezed. To achieve this “weak” or less firm form of body, the manufacturer may prefer to employ xanthan gum and/or carboxymethylcellulose (CMC) as body stabilizers.

As is the case with yogurt, the cream base used for sour cream must be pasteurized under high temperatures to partially denature the whey proteins. This extent of denaturation enables incorporation of the whey proteins into the curd mass, which improves the important water-binding capacity and viscosity of the curd. Since minimum legal cream pasteurization temperatures are not adequate to fully denature the whey proteins, vat pasteurization at >82 °C (180 °F) for >30 min or HTST at >85 °C (185 °F) for 25–60 s are typically utilized, although temperatures as high as 95 °C (203 °F) for 5 min may be used (Lyck et al., 2006).

Pasteurization is typically followed by a single-stage homogenization (not required by the CFR) at 14–21 KPa (2000–3000 psi), at a temperature between 40° and 85 °C (104–185 °F), though this can vary depending upon the fat content and stabilizers used (Lyck et al., 2006). These researchers recommended a homogenization pressure of 15–20 KPa (2150–2900 psi) for 10% fat, 12–17 KPa (1700–2400 psi) for 18% fat, and 3–5 KPa (430–714 psi) for 38% fat cream. The use of single-stage homogenization (as opposed to two stage) suffices to optimize the desired viscosity properties of sour cream products.

A widely adopted processing variation includes a dual homogenization procedure initially developed by Dr. Guthrie of Cornell University (Kosikowski & Mistry, 1997). He discovered that double homogenization of the cream yielded an extremely thick, almost gelatinous sour cream that would hold its shape when cut with a knife. L. J. Manus of Washington State University advocated a “double homogenization” process for optimizing sour cream (and cottage cheese dressing) viscosity, without the use of any added stabilizers or emulsifiers (Manus, 1957). The initial homogenization step was undertaken at pasteurization temperature, and then the sour cream base was cooled to the range of 43–46 °C (110–115 °F) and homogenized a second time. In the aforementioned processing protocol, only single (first)-stage pressure was applied. Currently, the vast majority of pasteurized sour cream bases in the USA are produced with the application of only the first-stage valve to maximize product viscosity and surface sheen (Kosikowski & Mistry, 1997). Single-pass homogenization facilitates the re-agglomeration of homogenized milkfat globules, which tends to markedly enhance sour cream base viscosity, as opposed to the cream undergoing two-stage homogenization (Manus, 1957; Bodyfelt, 1981; Kosikowski & Mistry, 1997).

The cream base is then cooled to about 21–22 °C (70–74 °F) and inoculated with both acid- and aroma-producing lactic cultures and allowed to ferment. The choice of culture sources and the incubation conditions are critical to the consistent production of a high-quality sour cream.

Once the ideal pH is achieved, the sour cream is packaged with minimal agitation and coagulum breakage and cooled as rapidly as possible (with gentle and intermittent agitation). The finished product must come into direct contact with cold surfaces of the incubation vessel within 30–45 min in order to stop bacterial activity at a fairly precise pH endpoint (Meunier-Goddik, 2004).

Crema Mexicana Agria

Crema Mexicana agria is made essentially the same way as sour cream, but the range in fat content may be higher (18–30%, depending on brand). Stabilizers are not as commonly used, which leads to a weaker body and free whey. Salt is sometimes added to the product. Screw-topped PET jars are common.

Crème Fraîche

Crème fraiche is also made similarly to and with similar cultures (*L. cremoris*, *L. lactis*, *L. lactis* biovar *diacetylactis*) as sour cream, but the fat content is higher (30–45%). Full fat crème fraîche is a stable gel that will not separate in most applications. Reduced fat crème fraîche (~15% fat), on the other hand, destabilizes when heated. It could be made stable with the inclusion of commercial food grade stabilizers; however, European Union legislation forbids the use of stabilizers in crème fraîche. Like sour cream, an ideal crème fraîche is a viscous product. Since its pH is often higher than sour cream, its flavor profile derives primarily from its aroma-producing starter cultures. Crème fraîche is not yet a common product on US grocery shelves and is usually much more expensive than sour cream. One can make an acceptable crème fraîche at home by simply inoculating heavy cream with a tablespoon of aromatic high-quality buttermilk and permitting it to ferment at room temperature for 16–24 h.

Mascarpone

Macarpone is not a cultured cream product. Production begins with gradually heating cream to 85–95 °C and adding an acidifying agent (e.g., acetic, citric, tartaric, or lactic acid, vinegar, or lemon juice) to drop the pH from 6.6 to 5.7 (Capozzi et al., 2020; Zade & Ghosh, 2018). Draining commences for approximately 20 hours, and the end product has 44–50% moisture and 40–45% fat. Although made similarly to ricotta, mascarpone is more smooth (less grainy) in body and texture; it has a mild, creamy, sweet flavor.

Cream Cheese

Cream cheese, Neufchatel, and cream cheese spreads are manufactured from standardized pasteurized and homogenized milk and/or cream (approximately 8–14% fat or 5% fat, respectively) (Schulz-Collins & Senge, 2004). The total solids may be increased to greater than 20% with powders (Brighenti et al., 2008). To increase firmness, either a preheat treatment or chymosin may be used (Gutierrez-Mendez et al., 2019). The standardized cream is inoculated with mesophilic starter cultures and incubated until pH 4.5–4.8 is attained, after which point the curd is heat treated to facilitate syneresis (Fox et al., 2000; Lucey, 2002). Whey is drained to attain proper moisture (approximately 50–55% (cream cheese) or 60–65% (Neufchatel)), mixed and/or homogenized, and additional ingredients (e.g., salt(s), hydrocolloid(s), flavor(s), color(s)) are added, while the curd is heated (>70 °C) (Brighenti et al., 2020; Guinee et al., 1993). Products are typically hot-filled, then cooled (Brighenti et al., 2020).

Greek cream cheese spreads may be attained by using a centrifugal curd separator to more extensively reduce moisture content and increase protein or by using additional solids (e.g., whey protein concentrate, nonfat dry milk) in the formulation. Whipped cream cheese products require incorporation of air into the cheese body, commonly coupled with the use of a strong stabilization system to maintain air cell structure (e.g., gelatin, modified food starch). Fat-free cream cheese manufacture begins with concentrated skim milk (~25% nonfat solids), and fermentation to a higher pH (i.e., 4.8 to 5.0), the use of emulisifer salts (e.g., sodium citrate), bulking agents (e.g., buttermilk solids, corn syrup solids), and stabilizers (e.g., xanthan gum, locust bean gum, guar gum) (Brighenti et al., 2008). Brighenti et al. (2020) demonstrated that stabilizers affect cream cheese rheology differentially across the temperature ranges of cream cheese production and utilization.

13.4 Sensory Evaluation

All cultured cream products must begin with high-quality cream, or the resulting products will suffer defects. A summary of appearance, body, texture, and flavor defects for cultured cream products is included in Tables 13.1 and 13.2.

Table 13.1 Body and texture, and appearance defects in cultured cream products, their characteristics, and possible causes

Defect	Characteristic	Cause
Atypical color	Excess yellowish color, translucense, or the absence of a cream-like color	Excess carotenoid levels in the cream will yield a darker than expected yellow color. Low-fat or fat-free sour cream analogs will often appear unnaturally white, dull, or translucent
Curdy	Exhibits nonhomogeneous mouthfeel and/or contains lumps of firm curd	Untimely agitation of a weak coagulum in the late stages of incubation. Nonhomogeneous distribution of the culture inoculum Incomplete hydration of any or all of added dry ingredients
Free whey	The appearance of a hazy or greenish-yellow liquid exudate on the surface or around the edges of the sour cream in the container	Product improperly stabilized or inadequately heat-treated cream. Whey may also appear in a product as it approaches the product sell-by-date
Gassy	Small effervescing or entrained CO_2 bubbles	Use of CO_2-producing cultures or product base post-pasteurization contamination by gas-producing bacterial contaminants
Grainy	Small, persistent particles in body of curd	Incomplete rehydration of dry ingredients, irreversibly denatured proteins, or final product pH too close to the isoelectric point of casein
Gel-like	Gelatin consistency; product is stiff, with sharp edges when spooned. When stirring the product with a small lightweight plastic spoon may readily break	Excessive use of or incorrect stabilizer
Over-stabilized	An unnaturally slimy or "slick" smoothness – Almost a greasy sensation within the mouth	Excess stabilizer or an inappropriate choice of stabilizer
Too firm	High or excessive viscosity. When stirring the product with a small lightweight plastic spoon, it may almost break	Excessive inclusion of milk solids, or excessive heat treatment of the product base, or over-stabilization
Weak	Low viscosity	Low milk solids levels and/or insufficient heat treatment of the product base

13.4.1 Product Packaging

The first sensory consideration when evaluating any product is package integrity. Not only does a package provide customers information about product content, but it influences their first impression regarding product identity and quality. Clean, intact packaging is essential to quality and safety.

Table 13.2 Some flavor defects found in cultured cream, their brief description, and possible causes

Defect	Description	Cause
Bitter	A basic taste, typically detected on the back of the tongue	The most common cause of bitterness is proteolysis by bacterial contamination. Typically occurs when cream is either aged or stored at elevated temperatures (>7.2 °F). Bitterness can also result from prolonged storage as the lactic acid bacteria will hydrolyze β-lactoglobulin to bitter peptides
Cheesy	Reminiscent of Cheddar or other moderate to strong flavored cheese	Can result from using contaminated lactic culture, any direct contact with unclean/unsanitized processing equipment, or possibly using old (aged) cream
Cooked	Cooked milk, custard, or hard-boiled egg aroma, flavor, and/or aftertaste	Excessive temperature treatment or re-pasteurization
Feed (weed)	Suggestive of roughage feed (e.g., silage, alfalfa, other hays, brewer's or cannery by-products, certain grasses)	A consequence of herd milking without withdrawing feed from the cows for a suitable interval (~3 h prior to milking) or feeding cows a particularly pungent feed or silage
Foreign	Atypical off-flavor and/or often objectionable (e.g., cleansers, sanitizers, vitamins or minerals, stabilizers or emulsifiers)	An atypical off-flavor may derive from leaked lubricants (most common), accidental contamination with cleaning chemicals, or residual sanitizers
High acid	A tart (sour) taste sensation (has a range of intensities), usually quickly perceived via the taste buds on the sides of the tongue	The fermentation temperature was either (1) too high, (2) the fermentation proceeded too long, (3) excessively long product-storage period, or (4) temperature abuse after packaging
Lacks cultured flavor (flat)	Lacks creamy taste and/or lactic cultured aroma (i.e., diacetyl, acetic acid, and other aromatics)	Too low citrate concentration (<0.2%) in the cream base, improper selection, or performance of an aromatic (heterofermentative) lactic culture; or possible water dilution of product base during processing
Lacks freshness (stale)	A stale aroma and/or flavor	Product has been stored too long; code date was not properly established
Low acid	Product lacks characteristic subtle to moderate sour (acid) taste	The product was under inoculated, incubated at too low of temperature, or the fermentation was arrested too early (too high pH (>5.5)
Old ingredient	Stale aroma and/or flavor with long-lasting unpleasant aftertaste. Some stabilizers or emulsifiers develop a unique type of "oxidized/chemical-like" off-taste sensation	Use of aged dry ingredients, (e.g., milk and/or whey powder). Stabilizer and/or emulsifier (many emulsifiers contain elevated levels of unsaturated fatty acids, which are vulnerable to auto-oxidation
Oxidized (metallic)	Oxidized aroma, flavor, or aftertaste (i.e., copper penny, painty, fishy); possibly with associated puckery mouthfeel	Exposure of the milk or cream to transition metal surfaces (i.e., copper, iron, and/or manganese) or their ions deposited on equipment surfaces

(continued)

Table 13.2 (continued)

Defect	Description	Cause
Oxidized (light activated)	Oxidized aroma, flavor or aftertaste (i.e., wet cardboard or cabbage-like "burnt hair or feathers"). A light-oxidized fat-free product will taste different from a light-oxidized full fat product	Exposure of cream to light, in particular fluorescent light or direct exposure to the sun
Rancid (lipolytic)	The odor is suggestive of Romano, kasseri or blue cheese or baby vomit, accompanied typically with a somewhat delayed bitter aftertaste	Hydrolysis of triglycerides by contaminating bacteria Rough treatment (i.e., over agitation, air leaks, freezing) of the raw milk that facilitates endogenous lipase activity due to fractured fat globule membranes
Yeasty	Smells like rising bread dough. Flavor possesses bread-like notes. Product may exhibit gas or panelist may sense effervescence	Failure to maintain the milk or cream at a sufficiently low temperature, combined with the exposure of processing lines and equipment to yeast

A manufacturer who wishes to attain a premium price for their product(s) must remind the consumer of a familiar brand name and should have artwork commensurate with the quality promised within. On the other hand, manufacturers seeking to carve out a niche within the community of the economy-minded might consider a plain package that conveys the message that the lower price reflects savings achieved in part by eschewing needless ornamentation and advertising and then passing those savings on to the consumer.

The next component of packaging that deserves consideration is the tamper-evident seal under the tub's lid. This plastic seal should adhere tightly to the lip of the tub. Such seals frequently bear an inscription describing themselves as consumer confidence seals. Quite the opposite effect from instilling confidence results when the seal is so loosely attached that it comes off when the container lid is removed. The consumer must be able to discern if the seal came off when they opened the package or if the seal had been tampered with prior to purchase (Fig. 13.7). Cream cheese products must also exhibit clean, tamper-evident boxes, foils, or overwraps (Fig. 13.7).

13.4.2 Appearance and Color

Upon opening the carton, the examiner should observe an opaque, glossy to semi-glossy surface with a uniform color that may range from snow-white to a slight straw-yellow color (Fig. 13.8). The consumer should expect to find an opaque product, with no translucency. This can present a challenge in low and fat-free cultured cream products. No "shrunken" (pulling in) should be evident in cups, and "free

Fig. 13.7 Sour cream and cream cheese displaying tamper-evident seals. (S. Clark images)

Fig. 13.8 Sour cream displaying appropriate gloss, smoothness, and white color (left), straw color, shrunken, and free whey (middle), and shrunken, free whey, and grainy appearance (right). (S. Clark images)

whey" should not be visible either on the surface or in a space between the curd and the sidewall of the tub or foil wrap (Fig. 13.8). Free whey is often the result of either an un-stabilized cultured cream product or one that would have benefited from a higher heat treatment. This is often a particular problem with low-fat and nonfat versions. Free whey in cream cheese may be suggestive of temperature abuse post-packaging.

13.4.3 Body and Texture

Upon stirring, sour cream products should smoothly mound up on the spoon (Fig. 13.9) rather than crack (too firm) or splash (weak). For cream cheese, greater resistance is expected, even with whipped products, and smooth spreadability is of utmost importance.

Removing a spoonful from the original package and observing at eye level (Fig. 13.10) or placing in a petri dish or plate can reveal body and texture defects. An example of sour cream exhibiting an overly firm and grainy-like body and

Fig. 13.9 Freshly stirred sour cream displaying typical mounding up on spoon. (S. Clark image)

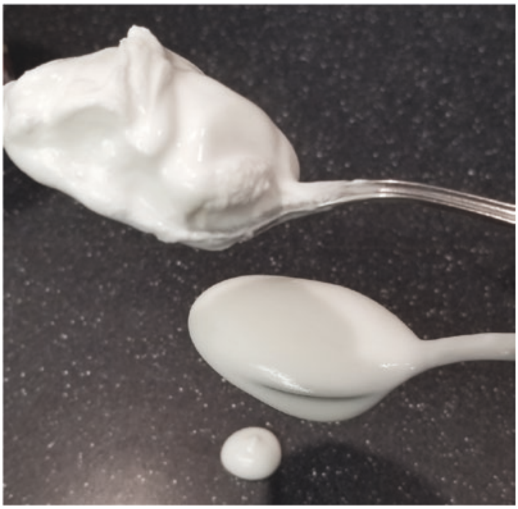

Fig. 13.10 Two sour cream samples displaying firm (top) and weak (bottom) body on spoons. (S. Clark image)

texture (Fig. 13.11). The sample shown in Fig. 13.12 is a low-fat organic sour cream. It exhibits both translucency and free whey. The sample shown in Fig. 13.13 is an improperly stabilized sour cream that expelled a hazy whey "halo" within a short time after spooning into a petri dish.

Fig. 13.11 Sour cream exhibiting dull surface, firm body, and grainy texture. (Costello, 2009 image)

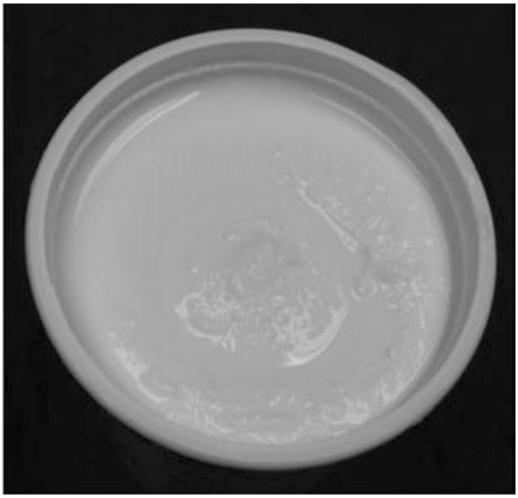

Fig. 13.12 Grainy texture and free whey appearing in a freshly opened cup. (Costello, 2009 image)

A dull surface appearance (one that lacks gloss) can result from the use of chymosin (rennet) to coagulate reduced fat cultured cream products. Free whey on the surface is another potential consequence of chymosin usage (Lee & White, 1993). Excessive usage of skim milk powder to increase sour cream viscosity may result in a dull appearing surface, as will the inadequate rehydration of added dry ingredients.

Translucency commonly occurs commonly in light and fat-free sour cream products, which gives away the product's reduced fat composition. Some product manufacturers may include titanium dioxide as a trace ingredient to impart an enhanced opacity that attempts to better emulate the appearance of full fat sour creams.

Within the mouth, the texture of cultured cream products should be reasonably or perfectly smooth, but without the mouthfeel of slime-like (e.g., slimy) or salve-like (salvy). A fairly common texture defect of cultured cream products is grainy (or

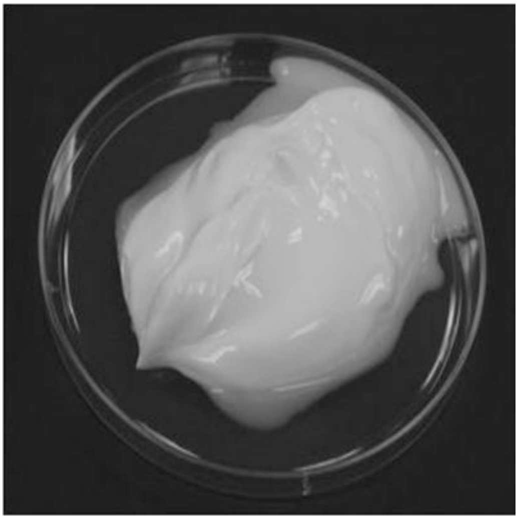

Fig. 13.13 Sour cream displaying a free whey "halo". (Costello, 2009 image)

grittiness – depending on particle size); it is characterized by the persistence of small, firm particles within the mouth.

A grainy texture can result from a number of manufacturing oversights or shortcomings. One source of grainy texture that sour cream shares with other dairy products is inadequate rehydration of dry ingredients. Skim milk powder added via improper usage of a powder funnel can predictably produce cultured cream products with grainy texture. Even skim milk powder incorporated using a liquefier may yield a grainy product if the liquefier level is too low or too full, since fill level affects turbulence. Empirically, the ideal level for full hydration is between 2/3 and ¾ capacity (Infanger, 2006, personal communication).

The occasional presence of residual acid cleanser residues (such as peroxyacetic acid) on processing equipment and piping can irreversibly denature proteins on contact (Infanger, 2006), which is another potential source of a grainy texture. Another cause of a grainy-textured product is a final product pH that resides too close to the isoelectric point of casein (Meunier-Goddik, 2004). Reduced fat sour cream products that are coagulated by using chymosin may also exhibit a texture described as "grainy/gritty," "too firm," and/or "lumpy" (Lee & White, 1993).

One variable that needs to be considered when seeking to achieve an "ideal" body and texture is the fermentation temperature and the rate of acid production. The microstructure of the acid gel formed during fermentation is influenced by the temperature, as gels form by different mechanisms when the temperature is above 30 °C or below 20 °C. Above 30 °C, the stability of the casein micelles is overcome by collisions between micelles. These relatively high-energy collisions collapse the "hairy" κ-casein surface layer. Below 20 °C, it is believed that the acidic conditions solubilize the micellar casein (Hunt & Maynes, 1997). As the temperatures at which sour cream is fermented fall between these ranges, the gel is formed through a blend of these mechanisms, and small changes in fermentation temperature can alter the mix gel "alloy" formed, and therefore, the functional characteristics might be predicted to change accordingly (Hunt & Maynes, 1997). A weak body or low viscosity can result from low-fat content, low milk solids nonfat, improper homogenization or heat treatment of the product base, incubation at too low a temperature, and inadequate acid development (Bodyfelt, 1981). A weak body may also result from excessive curd disruption during pumping and packaging (Meunier-Goddik, 2004).

Another texture defect occasionally encountered in cultured cream products is "gassy" due to CO_2 formation. The gassy defect is a consequence of either a CO_2-producing lactic culture or a microbial contaminant that produces a gaseous fermentation. The latter is usually a consequence of poor plant sanitation. Selection of inappropriate starter cultures that produce CO_2 must be avoided as well, although minute amounts of CO_2 may impart a pleasant effervescence or "zip" on the tongue (Bodyfelt, 1981).

An additional characteristic that should be considered when it comes to cream cheese products is the expectation of spreadability. Desired smooth, easy spreadability is displayed in Fig. 13.14. If the cream cheese curd lacks moisture, the curd can flake and require excessive force to spread.

13.4.4 Flavor

The characteristic flavor of high-quality cultured cream products should include a subtle to moderate lactic acid note and a buttery (diacetyl) aroma. Achieving the ideal balance of flavor requires proper culture selection, close control of the lactic acid development, along with the proper composition (fat content, milk solids not fat, and citric acid concentration), and quality of the cream (free of hydrolytic rancidity and auto-oxidation defects).

Fig. 13.14 Cream cheese on a typical carrier (a bagel), exhibiting expected smooth, easy spreading characteristics. (S. Clark image)

Controlled manufacture of cultured cream products should impart delicate flavors. As such, flavor defects originating in the raw materials will not be masked in the products' production. Hence, it is essential that the cream used for manufacture be relatively free of flavor defects. Additionally, utmost care must be taken during the manufacturing stages to protect it from development of any off-flavors. The trend for cultured cream products in recent years has been toward a less acidic flavor (Meunier-Goddik, 2004). Table 13.2 lists the most common flavor defects and their origins.

Oxidation, rancidity, bitterness, and other objectionable defects that result from the mishandling of dairy ingredients and finished products should be entirely absent from marketable cultured cream products.

Certain contaminating microorganisms can contribute to a "flat" (lacks culture aroma) cultured cream products. *Pseudomonas fluorescens* and *Enterobacter aerogenes* possess acetoin dehydrogenase activity; hence, the unfortunate contamination by these particular psychrotrophic microorganisms usually yields a distinct flat-flavored product (Monnet et al., 1996). Prolonged storage may also yield a flat flavor as aromatic compounds diffuse through the packaging material (Lyck et al., 2006). Flavor attributes that are also affected by storage include acidity, acetaldehyde odor (green apple), acetic acid odor, bitterness, and a prickly (carbonated) mouthfeel (Folkenberg & Skriver, 2001). Incubating the cream at too high a temperature will also inhibit the growth and metabolism of flavor-producing organisms. The flavor-producing organisms that thrive when cream is incubated at 22 °C will vanish at 27 °C, yielding a relatively flavorless cultured cream product (Hutkins, 2006).

With higher fat, the creamy flavor of crema Mexicana agria is more pronounced, and acidity less pronounced, as a result. Additionally, some crema Mexicana agria brands taste more salty because they contain more sodium than US sour cream.

The acidity of crème fraîche is lower than is typically found in sour cream, and other flavor elements are more subtle as well. The flavors derived from fermentation should be so delicate as to barely mask the fatty flavor of the cream. Because the flavors are so delicate, only the highest quality cream is suitable for use in crème fraîche fermentation.

Though typically more sweet and not as complex, because of the lack of fermentation by-products, Capozzi et al. (2020) identified 27 volatile organic compounds in 12 mascarpone cheeses. Nine aromatic compounds predominated, particularly 2-heptanone and 2-pentanone, which have been described as sweet, fruity, orange peel and herbaceous.

13.5 Reduced Fat Cultured Cream Products

Health concerns motivate some American consumers to seek reduced fat products. Nevertheless, consumers demand that reduced fat products possess sensory attributes that approximate the traditional, full fat versions of familiar foods.

Manufacturers have responded to this demand with uneven success. As a rule, reduced fat products simply do not elicit an equivalent sensory response to full fat versions of the same food. Most consumers rank reduced fat products below the original or full fat versions. Until reduced fat foods yield hedonic results similar to full fat foods, there will be incentives to improve reduced fat foods.

Cultured cream products fall into the category of a relatively higher fat product with a nutritional label that undoubtedly discourages some purchases. As such, manufacturers have experimented with a variety of strategies to produce a product that consumers will seek out for sensory attributes as well as lower fat content. The perceived sensory deficiencies of reduced fat cultured cream products are both in flavor and in body and texture.

The body and texture of reduced fat cultured cream products are often less creamy-like than the full fat counterparts. Upon opening the container of a reduced fat product, the consumer's first view may more likely include surface free whey. Additionally, the product may tend to exhibit a somewhat translucent character. The flavor of some brands of reduced or fat-free sour cream can best be described as flat or unbalanced. However, some contemporary manufacturers are producing reduced fat cultured cream products either comparable or even superior to cultured cream products with prudent formulation and modified manufacturing processes (Durbin, 1996).

Characterization of rheological, textural, and sensory properties of 18 commercial US cream cheese products with different fat contents (Brighenti et al., 2008) revealed that full-fat cream cheeses were firmer, more cohesive, more difficult to dissolve and spread, and less sticky than Neufchatel and fat-free cream cheese products.

13.6 Flavored Cultured Cream Products

Consumers desiring variety often seek products with different styles and flavors – manufacturers have answered the call with a multitude of flavor-added cultured cream products. Of utmost importance is to acquire high-quality flavoring and coloring ingredients. Fruits, nuts, meats, herbs, and colorings must communicate the product identity successfully but should also not overpower the underlying clean, fresh, and delicate dairy product flavors of cultured cream products.

Additionally, in recent decades, clean labels (labels with simple and natural ingredients) are preferred by many consumers. Food science skills are put to the test when manufacturers are forced to modify established formulations. Proper selection of ingredients, manufacturing practices, and code dates is essential to ensure flavor and color consistency across lots and during storage.

13.7 Cultured Buttermilk

Although not a cultured cream product, cultured buttermilk was originally a by-product of the cultured butter-making process, so deserves mention here. As a "throwback" to a visual component of hand-made cultured buttermilk of the past, a modest amount of contemporary commercial buttermilks may contain added butter flakes to emulate or reproduce the appearance of the earlier period. Interestingly, today's cultured buttermilk has never seen a churn but retains the historical name of buttermilk.

Cultured buttermilks may be made from whole milk, low-fat, or fat-free milk that has been either pasteurized or ultrapasteurized; then cooled to optimum incubation temperature; and carefully inoculated with specifically selected acid and aroma-producing lactic starter cultures. Typically, the cultures used are the same as those used in sour cream manufacture. The fermentation conditions, the substrate requirements, and the ultimate flavor profiles are the same or quite similar. An exception is the manufacture of Bulgarian-style buttermilk, which is traditionally made with whole milk and is inoculated with a *Lactobacillus* sp. and/or *Streptococcus thermophilus* (Bodyfelt et al., 1988), and is generally more acidic (often ≧1.0% titratable acidity).

Whatever the specific composition or the lactic culture utilized, the consumer generally expects a smooth and viscous product with a moderate to distinct acidity and preferably a delicate, buttery aroma.

Since the body and texture of buttermilk are derived primarily from the acid precipitation of casein, the vast majority of the defects that one would predict from such a process may occur when the process goes astray of the manufacturers' best intention – a common event when we trust to the providence of microbiology.

When a buttermilk's texture is relatively nonuniform, this defect is described as "curdy." The curds are easily discerned by pouring the product slowly. Curdy buttermilk often results from low milk solids, disturbance of the coagulum during incubation, or the use of an inappropriate culture (Bodyfelt et al., 1988).

Most consumers prefer a buttermilk that is not overly viscous. Heavy bodied is the descriptive term for a product whose viscosity exceeds the normal range. Heavy-bodied buttermilk will pour only slowly from the container and may even be difficult to drink. Potential sources of an overly viscous buttermilk include the use of lactic cultures known to yield a higher viscosity, a base product too high in solids, excessive heat treatment of the product base, entrained air, or over-stabilization of the buttermilk (Bodyfelt et al., 1988).

As one would predict, a thin-bodied buttermilk suffers from the opposite defect as a heavy-bodied buttermilk. The thin-bodied buttermilk lacks the viscosity expected by most consumers. Low solids, insufficient heat treatment, an inactive or slow culture, or a culture with too little proteolytic activity are all potential causes of a thin-bodied buttermilk. Since weak starter activity is a common cause of a thin-bodied buttermilk, this defect is frequently correlated with a flat flavor and/or aroma (Bodyfelt et al., 1988).

Wheying-off, or syneresis, is characterized by the presence of free whey, usually near the surface, but occasionally occurring anywhere in the container. Wheying-off, when caused by entrapped gas, is a result of an abnormal fermentation and frequently manifests itself by the appearance of syneresis on the surface. Syneresis attributable to excess buoyancy of the curd reveals itself as free whey in the mid-levels or at the bottom of the container and may be a consequence of milkfat trapped within the curd (Bodyfelt et al., 1988). In most cases, the solution to wheying-off is adequate heat treatment of the milk prior to inoculation and fermentation, proper culture selection, and the practice of good sanitation (Bodyfelt et al., 1988).

Departures from the ideal buttermilk (or lactic culture flavor) include such unfavorable off-flavors as astringent (chalky), coarse (harsh), cooked (heated), foreign, excess diacetyl, fruity/fermented, green (acetaldehyde), low acid, lacks freshness (stale), oxidized/metallic, rancid, sauerkraut-like, stabilizer, unclean, and/or yeasty (Bodyfelt et al., 1988).

Properly made, modern cultured buttermilk is a refreshing, healthful drink that so far has not enjoyed the surge in popularity experienced by other cultured dairy products. This may be a consequence of the passing of those generations who grew up consuming traditionally made buttermilk. The generations that have followed have not yet been introduced to this delightful dairy product, the health benefits of which are similar to those credited to yogurt, which has seen rapid sales growth over the past 30 years (Nauth, 2004). During this same period, buttermilk consumption dropped by 50% between 1963 and 1993 (Kosikowski & Mistry, 1997). Compared with traditional or former buttermilk direct from the churn, contemporary cultured buttermilk is a much more consistent product and possesses the potential to enjoy the same surge in popularity that yogurt has seen. But health benefits are not always enough to ensure good sales. The product must be pleasing to the consumer. As such, buttermilk, if it does gain the popularity of yogurt, will have to be manufactured in a manner that guarantees that the consumer will enjoy buttermilk for its sensory experience as much as for its health benefits.

13.8 Conclusion

Cultured cream variations occur around the world, and the expectations for ideal sensory quality vary according to local tastes, customs, raw material sources, and quality as well as the final use for which the product was intended. In most western cultures, achieving the ideal cultured cream requires using only raw materials of the highest quality, as the delicate flavors of the final product will conceal no defects.

Additionally, numerous and detailed manufacturing details must be closely monitored as is the case with any fermented food product. The functional microorganisms incorporated for producing flavorful, aromatic end products tend to “behave” or “misbehave” strictly according to the fermentation conditions and the relative freshness and quality of the milk product substrates provided.

High-quality cultured cream products are largely defined by the consumers who purchase them and who, more importantly, purchase them again if their first sampling satisfies their needs and expectations. Keeping customers requires strict attention to detail, since product consistency and flavor predictability seem to be the most important sensory characteristics that processors can impart upon any dairy product.

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Chapter 14
Cheeses with Eyes

Vaishnavi Sankarlal and Stephanie Clark

14.1 Introduction

Cheeses with eyes include those manufactured in Switzerland (Emmentaler or Swiss), the Netherlands (Gouda and Edam), Italy (Fontina, Provolone and Asiago), Norway (Jarlsberg), Denmark (Havarti), and the United States (Brick, Swiss block and Baby Swiss) (Steffen et al., 1993). Swiss-type cheeses trace their origins to the Emmen valley in Switzerland. Emmentaler, the most popular Swiss cheese, is a large, round wheel, usually weighing about 100 kg (220 lb). Each wheel is about 112 cm (44 in.) in diameter and 15–23 cm (6–9 in.) thick, with a smooth, cream-colored to yellowish rind. Emmentaler is simply called "Swiss cheese" in the United States and is a rindless block (Jenkins, 1996).

In Swiss-style cheeses, the main characteristic feature is the propionic acid fermentation, resulting in the production of CO_2 in the cheese, usually by propionic acid-forming bacteria. Eyes (CO_2-formed openings) are expected and contribute to the cheese's visual appeal (Fig. 14.1). The number, size, shape, and surface luster of eyes are characteristic for each type of cheese. Microorganisms intentionally used in the making of cheeses with eyes include (1) *Streptococcus thermophilus* (produce lactic acid early in the cheese vat and the press), (2) *Lactobacillus delbrueckii* ssp. *bulgaricus* (produce lactic acid at a greater rate later in the pressing stage rather than in the vat), and (3) *Lactobacillus helveticus* (grow slowly and use up residual lactose and galactose – which is necessary to minimize browning and provide desired body and texture characteristics to cheese through proteolysis). Of particular importance

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Fig. 14.1 The eyes in Swiss-style cheeses contribute to their aesthetic appeal

is *Propionibacterium freudenreichii* ssp. *shermanii* (4), which plays a sequential role in development of a key flavor element, propionic acid, and the production of CO_2, for characteristic eye formation. *P. shermanii* reproduce in the cheese but not in the vat and require a temperature of >21 °C (70 °F). Extremes in eyes appearance reflect adversely on workmanship and/or on milk quality.

The main visual characteristic features of Swiss cheese are:

(a) Natural, attractive, uniform ivory to light yellow color
(b) Mild, pleasing, characteristic sweet hazelnut-like flavor
(c) Round or slightly oval-shaped eyes that are relatively uniform in size (1–2 cm [3/8–13/16 in.] in diameter) and distribution
(d) Uniform, firm, smooth texture, and slightly elastic body

Other related type bacteria that produce CO_2 in cheese include *Leuconostoc mesenteroides* ssp. *cremoris* and/or citrate-positive *Lactococcus lactis* ssp. *lactis*. In some Scandinavian-ripened cheeses, *Leuconostoc mesenteroides* ssp. *cremoris* and/or citrate-positive *Lactococcus lactis* ssp. *lactis* generate sufficient CO_2 to form characteristic small round eyes.

Gas holes in cheeses outside the Swiss-type, Dutch Goudas, and Danish Havartis are generally considered undesirable because they often indicate the presence of undesirable lactic, spoilage, and/or pathogenic microorganisms (*Escherichia coli* and *Clostridia*). Fermentation by *Clostridia* especially the spores of *Clostridium tyrobuturicum* has the ability to germinate during the cheese production and transform lactic acid into butyric, acetic, and gas commonly known as butyric fermentation. Unintended excessive gas formation in cheeses in the form of either CO_2, H_2, and/or H_2S is typically accompanied by several texture defects (slits, cracks, irregular eyes) and an unclean-like off-flavor during the late stages of cheese ripening. This late blowing leads to enoromous losses to cheese manufacturers as cheese cannot be sold due to poor quality and flavor.

14.2 Composition of Swiss-Type Cheeses

US federal standards of identity for Swiss cheese require at least 43% fat on a dry basis and not more than 41% moisture (21 CFR 133.195 and FDA, 2006). The finished product typically contains 27–28% fat, 26–28% protein, and 1–1.6% salt on a wet weight basis. The composition of other related cheeses with eyes is compared to Swiss and Cheddar in Table 14.1.

The basic characteristics of cheese structure are mainly determined by the acid production in the vat. The given pH of whey at the time of draining from the curd is the key for determining the final pH range of any basic cheese category and the properties of the curd in the young and subsequently aged cheese. The pH of whey at draining dictates the solubility of calcium ions into whey and thus the loss of calcium phosphate from the curd. The amount of loss affects the extent to which the casein submicelles that were originally in the milk will be disrupted and consequently determines the basic structure of the cheese. For instance, little latic acid is produced in Swiss cheese manufacture before the whey is drained, thus yielding a higher calcium content that yields the characteristic elasticity observed in Swiss cheeses (Lawrence et al., 1984). Curd washing for final pH control is key for most varieties of cheeses with eyes.

Table 14.1 Typical composition of Swiss, Cheddar, and common cheeses with eyes (Kosikowski & Mistry, 1997; Fox et al., 2000)

	Fat	Fat on dry basis	Total solids	Total protein	Salt	Ash	pH
Asiago	31	42	73	31	3.6	6.6	5.3
Brick	30	50	60	23	1.9	4.4	6.4
Cheddar	32	51	63	25	1.5	4.1	5.5
Edam	24	44	57	26	2.0	3.0	5.7
Emmentaler/Swiss	31	45	65	28	1.2	3.5	5.6
Fontina	26	46	57	24	1.2	3.3	5.6
Gouda	29	47	59	27	2.0	3.0	5.8
Gruyere	30	45	67	30	1.1	4.1	5.7
Havarti	27	47	57	25	2.2	2.8	5.9
Provolone	27	47	58	25	3.0	4.0	5.4

Gruyere cheese, made in France and Switzerland, is similar to Emmentaler but is smaller (about 55 kg [121 lb]) and displays eyes no larger than a cherry. Gruyere exhibits a smooth, easy-to-slice body and presents a significantly more intense flavor than Emmentaler, with an abundance of sweet–saline beefiness and an undertone of fruit (apples, pears) and hickory nuts (Jenkins, 1996). While Gruyere is made with propionic acid bacteria in combination with regular Swiss cheese lactic cultures, its flavor is mainly influenced by the growth of the surface microflora during aging. Surface ripening begins with the growth of yeasts (e.g., *Debaryomyces hansenii*) that utilize lactate and increase the surface pH of the cheese. When the pH increases above 6.0, *Brevibacterium linens*, other coryneform bacteria and staphylococci begin to grow and evolve the final characteristic flavors of Gruyere cheese (Brennan et al., 2004).

Cheeses with eyes that originated in the Netherlands include Gouda and Edam. Gouda and Edam range from semisoft to hard in body and are sweet-curd cheeses (pH range of 5.7–5.9) made from cow milk. While Gouda is made with whole milk, milk used for making Edam is typically skimmed to contain 2.5% milkfat. Both cheeses have a pleasant, mild, clean, somewhat nutty flavor and a sweet and salty taste. The body of aged Gouda and Edam is rather firm and crumbly, with or without a small number of shiny eyes, while young variants of these cheeses are rather pliant and rubbery-like. Gouda and Edam cheeses are generally ball shaped or somewhat flattened ball shaped and are coated in either orange or red wax or plastic coatings (USDA, 1978). The eyes in Edam and Gouda are typically smaller than those of Swiss and Gruyere. These eyes result from citrate metabolism by citrate-positive lactic cultures (Fox et al., 2000). Jarlsberg is a Norwegian cheese similar to Emmentaler but softer in body. It typically has numerous large eyes, produced by propionic bacteria. This cheese is light to medium yellow in color and may or may not have a formed rind.

Cheeses with eyes that originated in Italy include Fontina, Provolone, and Asiago. Fontina is a whole milk, semisoft to hard, slightly yellow cheese with a nutty flavor and pleasing aroma. It is similar to Gouda but has a more robust or intense flavor. It is made from either ewe (Italy) or cow (the United States) milk. Fontina is round and flat and weighs between 12 and 35 kg (26 and 77 lb) and may have a few small, round eyes. Provolone is an Italian pasta filata cheese, meaning that the curd is stretched, much like Mozzarella. Provolone is light in color, mellow, smooth, cuts without crumbling and has a pleasing mellow flavor. Typically, Provolone is pear shaped or oblong and weighs anywhere from 3 to 90 kg (7–198 lb). Provolone can be most easily distinguished from Mozzarella in flavor by its piquant or rancid flavor (derived from the addition of lipase in the make procedure). The presence of eyes is another common feature that distinguishes Provolone from Mozzarella. Asiago was originally made from ewe milk but is now made from cow milk. It is a sweet curd, semicooked grana-type cheese (dry and firm which lends it to grating) with a pungent or rancid aroma. It is round and flat and generally weighs between 7 and 10 kg (15 and 22 lb) (USDA, 1978).

Havarti is a cheese that is made from partially skimmed or full fat pasteurized cow milk. It is soft to semisoft and presents many irregular openings. Havarti, like Limburger and Muenster, is traditionally a surface-ripened cheese. The flavor of fully ripened Havarti is reminiscent of fully matured Camembert, Muenster, and/or Limburger (aromatically pungent and distinctly unclean-like flavor). The body should be smooth and pliable and display eyes and/or openings (Kosikowski & Mistry, 1997). Rindless Havarti, since it does not undergo surface ripening by *Bacterium linens*, has a distinctly milder flavor (in both aroma and taste) than traditional Havarti cheese.

Brick, Maasdam, and Baby Swiss are US-developed cheeses with eyes. Brick is a brick-shaped cheese with an open texture and numerous round and irregular-shaped eyes. Brick cheese is a sweet curd, semisoft cow milk cheese with a pungent, and sweet taste driven largely by the surface-ripening microorganisms. Brick cheese is more closely related/comparable to aged Muenster, Havarti, mild Limburger, Breakfast, Schloss, or aged Camembert, than Cheddar, and spans the range from mild/young to extra sharp. The body of Brick cheese is softer than Cheddar but firmer than Limburger, is elastic, and slices well without crumbling. The US version of Swiss, Baby Swiss, may be made in a similar fashion to Swiss cheese or in a highly automated fashion. Baby Swiss eyes are relatively smaller in size than aged Swiss cheese and Dutch Maasdam. The distinctive small eyes in Baby Swiss reflect a shorter curing time versus a longer time for block- or wheel-sized Swiss, thus making it a milder cheese. Since the CO_2 is produced more rapidly than in traditional Swiss, the critical pressure for bubble formation is quickly attained and results in numerous smaller-sized holes. Of critical difference is that Baby Swiss is made from pasteurized milk, due to its age, whereas Swiss can be made from pasteurized, thermalized, or raw milk. The cooking temperature of Baby Swiss is also around 39 °C, instead of 54 °C in traditional Swiss. During the cooking step, some of the whey may be washed out with hot water to remove lactose and increase the curd temperature (Kosikowski & Mistry, 1997). Baby Swiss is generally higher in moisture and milkfat content; hence, it exhibits a softer or weaker body and a milder flavor than traditional Swiss cheese. Baby Swiss may be produced in block or wheel and weighs typically from 1 to 2 kg (2–4 lb) (Bodyfelt, 1988).

14.3 Swiss Cheese Production

Swiss cheese is one of the most challenging cheeses to make well due to the complexity of microorganisms, unique cooking process, and aging parameters that must be balanced to consistently produce high-quality cheese (USDA, 1978). The processing steps are diagramed in Fig. 14.2.

Traditional Swiss cheeses are large, round, wheel-shaped cheeses that usually weigh about 100 kg (220.5 lb). Traditional Swiss cheese possesses a rind that is

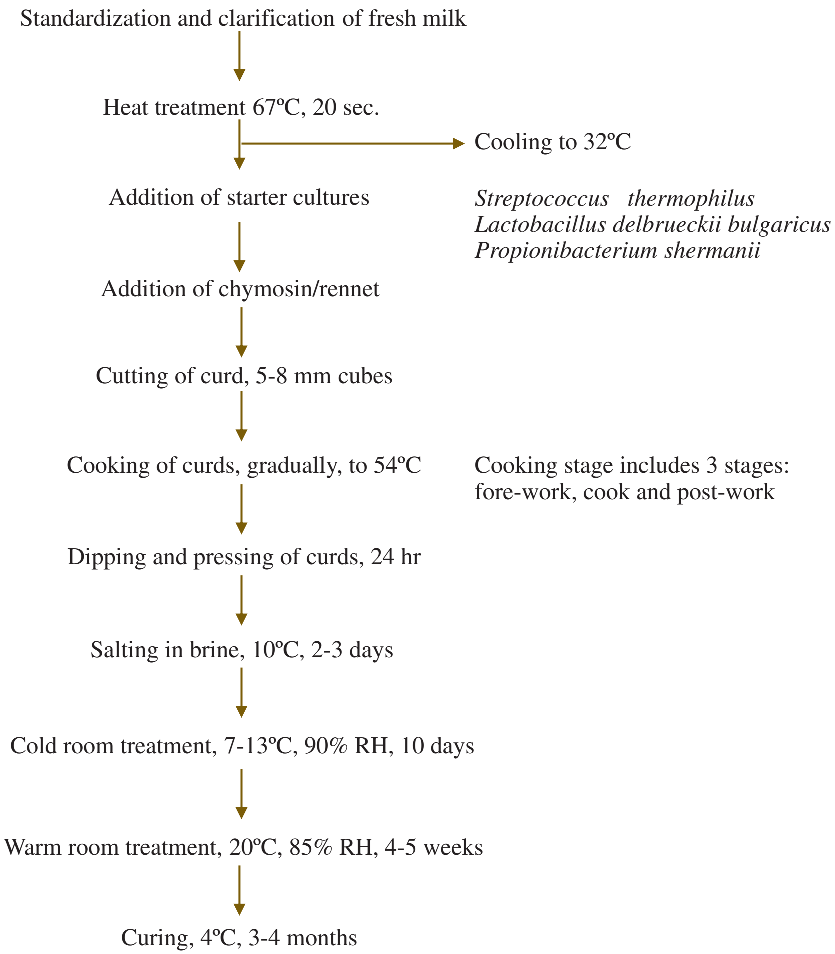

Fig. 14.2 Flow diagram of Swiss cheese production (Adapted from Kosikowski & Mistry, 1997)

"sufficient to protect the interior of the cheese" (USDA, 2001). However, traditional Swiss cheese manufacturing methods have changed with large-scale mechanization; hence, rindless varieties have become more common. Most of today's US production of Swiss cheese (over 90%) is in the rindless block form. Rindless cheeses are "properly enclosed in a wrapper or covering which will not impart any objectionable flavor or color to the cheese" (USDA, 2001). Ongoing differences in the treatment of cheesemilk, the extent of mechanization, and methods of finished cheese handling have sufficed to modify cheese weight, shape, ripening time, and shelf life of the original Swiss cheese. Rindless block Swiss has a more flexible, softer body and is less aromatic, tends to exhibit a sweeter flavor, and has more uniformly distributed eyes that are typically closer to the surface. Rindless Swiss is considered to be more suitable for sandwiches because of its easily sliceable body. Generally, it is lower in salt, higher in moisture, and ripened for a shorter time period than traditional Swiss cheese. The US federal standard of identity requirement for the moisture and fat content of rindless block is the same as round wheel Swiss; however, the rindless form generally contains slightly more fat (Kosikowski & Mistry, 1997).

The milk used in Swiss cheese manufacturing should be clarified, standardized, and generally heat treated before pumping into the vat. Centrifugal clarification of milk generally improves development and distribution of eyes in Swiss cheese. The clarification step prevents excess eye formation by removing potential nuclei like somatic cells, chaff, and other insoluble particles (Kosikowski & Mistry, 1997). Following clarification, the milk is standardized to 3% fat content. According to 21 CFR 133.195, Swiss cheese may be made from either raw, heat-treated (must be aged for at least 60 days) or pasteurized milk. Traditional Swiss cheese produced in Europe is manufactured from raw milk. For US Swiss cheese production, cheesemilk is typically heat treated (thermalized) to 67 °C (152 °F) for 20 s for partial destruction of undesirable flora and cooled down to 32 °C. Swiss cheesemakers prefer not to employ full pasteurization protocols, inasmuch because it has been presumed that superior Swiss cheese is produced with thermalized milk as opposed to cheesemilk pasteurization (Reinbold, 1972). Optionally, one or more approved dairy ingredients may be added to Swiss cheesemilk (benzyl peroxide as a cheesemilk bleaching compound and hydrogen peroxide/catalase for inhibition of coliforms in cheesemilk). The milk is then inoculated with lactic acid-producing and propionic acid-producing cultures. A milk clotting enzyme (chymosin or other rennet) is typically used in the production of Swiss cheese.

Starter cultures, *S. thermophilus* and *L. delbrueckii* subsp. *Bulgaricus*, are added to provide a relatively slow development of lactic acid throughout the curd-making process. *S. thermophilus* hydrolyzes lactose to glucose and galactose but further metabolizes only the glucose moiety to lactic acid. The galactose moiety is metabolized subsequently, relatively slowly, by *L. delbrueckii* subsp. *Bulgaricus*. The extent of fermentation of residual galactose to lactic acid largely determines the final pH of the curd. Swiss cheese is more anaerobic in its fermentation than Cheddar cheese, and there is considerably less lactic acid development before the cheese is pressed. The pH of 1-day Cheddar cheese may range from 5.3 down to 4.9, while the pH of 1-day Swiss cheese should be 5.3 for desired eye development (Lawrence et al., 1984). Selected propionic acid bacteria of the species *P. freudenreichii* are added to obtain characteristic eyes and nutty flavor.

Approximately 30 min after rennet is added, a curd is formed. The coagulum is randomly cut into fine-sized curds (~0.65 cm [1/4 in.]) with a curd harp and cooked to 54 °C (129 °F) to remove whey. The cooking process is divided into three-time periods, namely, forework, cooking, and postwork. The foreworking stage involves slow agitation of the newly formed curds, without heat, for approximately 40 min. During agitation, the curd particles tighten (curd gains firmness), expel whey, and shrink in size. The pH drops to slightly less than 6.5 with the rapid growth of the *S. thermophilus* and lactic streptococci cultures. In the cooking stage, curds are cooked to a temperature of up to 54 °C (129 °F) for approximately 40 min to remove whey and firm the curds (Kosikowski & Mistry, 1997). The use of high cooking temperature is responsible for the development of the springy, elastic curd of Swiss cheese. The higher cooking temperature, in addition to acid development and gentle stirring, drives whey out of the curd, which causes calcium-casein molecules to fuse together to form continuous strands. This is necessary for the characteristic elastic body of the Swiss cheese. The cooking rate should be managed carefully to control the moisture and acid development. Rapid cooking results in case-hardening, where the outside of the cheese becomes firm and dry while the inside remains high in moisture and acid. Cooking too slowly leads to formation of curds that are too dry or even too high in acidity. Initially, the temperature should be raised gradually, followed by rapid heating (Reinbold, 1972). Finally, in the postwork stage, the curds are agitated for an additional 45–60 min until the proper moisture level, curd firmness, pH, and acidity are reached. The rate and amount of acid development at this stage must be observed carefully. Curds high in acidity do not knit or drain readily and acquire serious eye defects. The typical whey removal pH at the end of cooking is 5.2–5.3. If acid development is insufficient (pH > 5.3), prolonged stirring is applied.

The curds are dipped into metal hoops and pressed under vacuum for 20 min and then pressed overnight at about 20 °C (68 °F). The cheeses are removed from the press and placed into saturated (23%) NaCl and $CaCl_2$ brine solution for 2–3 days. Since propionic acid bacteria are sensitive to salt, brining is less intensive than for other cheese varieties (Frohlich-Wyder & Bachmann, 2004). To avoid rind rot or development of weak, soft surfaces during curing, cheese blocks should be dried before wrapping. The drying process is performed through a heated, ventilated drying tunnel or by storage at 80% relative humidity and 12 °C (54 °F) for 24 h. Wrapping is a very important step in rindless block Swiss manufacturing. The wrapping material enclosing the cheese block should be sufficiently extensible to allow the cheese to freely expand in all directions during eye formation to maintain the desired shape. Covering should be sufficiently impermeable to oxygen transfer to prevent mold growth while permitting the release of excessive CO_2. Several applications, including prefabricated, double-wound bags, heat-shrinkable plastic pouches, or water-/air-resistant sheet films are in common usage (Reinbold, 1972).

The aging process for Swiss cheese is essential to proper eye development. An initial cool room treatment of 7–13 °C (45–55 °F) at 90% relative humidity for up to 10 days is applied to stabilize the physicochemical, enzymatic, and microbiological activities within the curd. During the precooling stage, the cheese loses most of the residual lactose as the starter bacteria, and *Lactobacillus helveticus* use up residual lactose and galactose to form lactic acid. The pH decreases one or two-tenths of a unit and the body of the cheese firms. Following the cool room treatment, Swiss blocks are transported to a warm room at 20–24 °C (68–75 °F) and 80–95% relative humidity for an additional 33–54 days for desired eye development. Propionic acid fermentation begins with the ripening of cheese at warm room temperatures.

Propionic acid bacteria convert residual lactate into propionic acid, acetic acid, and carbon dioxide. These metabolites contribute to the distinctive flavor and eyes of Swiss cheese.

Production, spacing, and size of eyes are governed by the classical laws of gas physics and the solubility and behavior of the gas within a gel structure (which leads to saturation level). Gas generation must occur at an optimum rate, temperature, and at the correct stage of aging. A critical gas pressure is created, which enables the gas to evolve from solution as a small bubble or to become part of another bubble in a favorable sector of the cheese. Gas generated in nearby areas tends to move to the initial eye and expands in size rather than creating another bubble, because it is physically easier to increase the size of a gas hole already present than to originate a new one (Kosikowski & Mistry, 1997).

The pressure, P, which creates and maintains the roundness effect of the gas bubble suspended in a gel, is based on $P = (2S/a)$, where S is the surface tension and a the radius of the bubble. A gas bubble in a cheese with a greater radius (2 (1/4) = ½) requires less pressure to become larger than a smaller bubble or a new starting bubble (2 (1/2) = 1). Thus, depending upon the rate of gas generation and the presence and pattern of distribution of nuclei, Swiss eyes of large uniform size can be produced for a given area and be spaced uniformly apart (Kosikowski & Mistry, 1997). The presence of unwanted somatic cells, soil, and/or other possible debris could serve as a type of "object foci" for precipitating irregular and randomly spaced "nuclei" and cause unintended eye formation. Clarification of milk prior to manufacturing helps to remove unwanted nuclei and thus contributes to uniform size and even distribution of the eyes.

When gas is produced too slowly, a saturated gaseous state does not develop; hence, few or no eyes are produced. When it is generated too fast, the gas does not have enough time to migrate to a favorable point where nuclei for deposition are situated. Critical pressures for bubble formation are quickly attained under these circumstances, and the result is too many small holes. A gas (CO_2) generation rate that proceeds excessively fast tends to break down the cheese structure, and thus, the gas forms large pockets, or the pockets may flow together to create a large blowhole (Kosikowski & Mistry, 1997).

The ability of propionic acid cultures to utilize aspartate greatly affects the final characteristics of Swiss cheese. Strong aspartase activity is generally coupled with a high growth rate of propionic cultures, resulting in higher concentrations of propionate, acetate, and CO_2. Cheeses made with cultures having strong aspartase activity contain a greater number of eyes and larger eyes, due to increased CO_2 release. The intensity of taste, odor, and aroma is also more pronounced due to high concentrations of free short-chain acids produced through fermentation as well as the free fatty acids, *n*-butyric, and *n*-caproic acids, released by lipolytic activity of propionic acid bacteria. Such cheeses may require shorter ripening time in the warm room since they are more likely to exhibit late fermentation during maturation (Frohlich-Wyder & Bachmann, 2004).

As soon as a sufficient number and size of eyes are formed, the propionic acid fermentation is slowed down by transferring the Swiss cheese blocks to a curing room at 4 °C (40 °F). The purposes of cold room treatment are to limit eye development to the proper size, to inhibit bacterial growth, to firm the cheese for easier handling, and to prevent the onset of body and flavor defects. Curing is the last step prior to cheese distribution and sale (Reinbold, 1972).

14.3.1 Flavor Formation

The predominate factors that affect flavor quality of Swiss cheese are raw milk quality, starter cultures, processing technology, and ripening conditions. Typical Swiss-type cheese has a characteristic nut-like, sweet flavor, due to free fatty acids, peptides, amino acids, carbonyls, or interactions among these compounds. The volatile flavor compounds produced by glycolysis, proteolysis, and lipolysis are the most important ones responsible for Swiss-type cheeses flavor (Noel et al., 1999). The volatile short-chain fatty acids, primary and secondary alcohols, methyl ketones, aldehydes, esters lactones, alkanes, and aromatic hydrocarbons are the principal volatile flavor compounds identified in Swiss cheese (Bosset et al., 1993). However, the characteristic flavor of Swiss-type cheeses is caused primarily by acetic, propionic, *n*-butyric, isovaleric, and *n*-caproic acids (Bosset et al., 1993; Beuvier et al., 1997; Rychlik & Bosset, 2001). Proteolysis of free amino acids (FAA) also influences the development of Swiss-type cheese flavor. FAAs are converted into volatile flavor components by peptidases and other amino acid-converting enzymes. Plasmin, a native milk protease, affects flavor perception. Plasmin activity is known to be higher in Swiss-type cheese (Ollikainen & Nyberg, 1988), as the higher cooking temperatures inactivate chymosin and other rennets (Garnot & Molle, 1987) allowing the plasmin activity to contribute to the flavor development in Swiss cheese. Bastian et al. (1997) reported that increased plasmin activity resulted in rapid hydrolysis of β-casein during 12 weeks of ripening and increased perception of propionic acid and overall flavor. Generally, raw milk cheese develops a more intense flavor than pasteurized milk cheese due, in part, to higher concentrations of amino acids, fatty acids, or volatile compounds (Beuvier et al., 1997). The intensity of odor, aroma, saltiness, and sourness increases during ripening due to complex enzymatic and microbial processes.

Ji et al. (2004) suggested that it is necessary to keep Swiss-type cheese in the warm room for at least 3 weeks to develop enough FFA and amino acids that are required for typical Swiss cheese flavor. The release of FFA in the warm room occurs simultaneously with the growth of propionic acid cultures. Thierry et al. (2004) stated that *P. freudenreichii* is the organism responsible for the conversion of branched chain amino acids, leucine, and isoleucine to isovaleric acid in Swiss-type cheese. Other thermophilic starter cultures, especially *L. delbrueckii* subsp. *lactis*, play a major role in flavor development because they have the enzymatic potential to produce potent and varied aroma compounds from amino acids (Helinck et al., 2004). Strain selection, make procedure, and ripening time can all have a large impact on flavor. Ripening temperature in the warm room and acid production in the vat at whey drainage influence the "nutty" and "sweet" flavors of the final product (Lawlor et al., 2003). Compared to traditional Swiss cheeses produced in Europe, commercially available Swiss-type cheeses in the United States have lower intensities of flavor characteristics. In a study conducted on flavor attributes of Swiss cheese, 15 commercial Swiss-type cheeses in the United States (10 Swiss cheeses, 4 baby Swiss cheeses, and 1 Swiss Emmenthal) were assessed by a trained panel for flavor characteristics. It was reported that most Swiss cheeses were characterized by low flavor intensities. Nutty flavor was only detected in 2 of 15 Swiss-type cheeses in an appreciable amount (Liggett et al., 2008).

14.3.2 Body and Texture Formation

Soft and elastic texture is the main requirement for desired eye formation in Swiss cheese. The elasticity of texture is controlled by ensuring that the mineral content of the curd is relatively high after lactic acid fermentation. The amount of acid produced before the whey is drained off should be correspondingly small (Lawrence et al., 1984). Proteolysis control is essential for the development of desired texture characteristics of Swiss cheese. Indigenous milk proteinase and proteolytic enzymes of lactic acid bacteria are generally responsible for protein breakdown. Insufficient proteolysis may lead to flat flavor and "long" texture consistency. Uneven openings may also be observed. Contrarily, high levels of proteolysis, accompanied by intense propionic acid fermentation, may lead to late fermentation, where additional or excessive gas is produced after the desired fermentation has been completed. The resulting texture will be low in elasticity, and the cheese can develop cracks that are similar to those observed with either excessive and/or rapid CO_2 production (Frohlich-Wyder & Bachmann, 2004).

14.3.3 Appearance/Eye Formation

The shape, size, and distribution of the "eyes" are most important as a point of emphasis in sensory evaluation. Cheese with eyes should have well-developed round or slightly oval-shaped eyes that are relatively uniform in size, shape, and distribution. The eyes should exhibit a glossy and velvety surface appearance, with smooth and even walls. The majority of the eyes in Swiss cheese should be 1–2 cm (3/8–13/16 in.) in diameter (Fig. 14.3), though other cheeses with eyes may have smaller eyes. The eyes should be uniformly distributed throughout the cheese matrix. The distribution of eyes at the center of the cheese tends to be more "ideal." If the Swiss cheese eyes are so large and/or so numerous as to "predominate" a plug or a slice of the cheese sample, then such a cheese would be criticized severely (Bodyfelt, 1988).

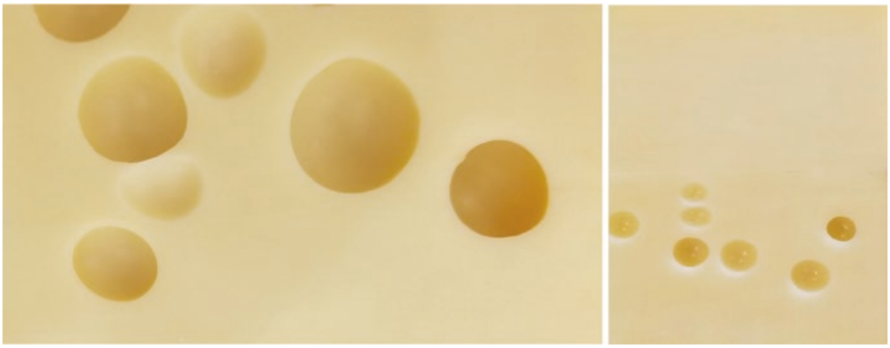

Fig. 14.3 Swiss cheeses exhibiting ideal (left) and small (right) eye size, with uneven distribution

Eye formation is a desirable result of carbon dioxide production through propionic acid fermentation. Eye development depends upon (a) time, quantity, and intensity of CO_2 production; (b) the number and size of the areas of future eye formation; (c) CO_2 pressure and diffusion rates; and (d) body, texture, and temperature of the given cheese (Steffen et al., 1993). However, if spoilage microorganisms like *Escherichia coli*, *Acetobacter aerogenes*, and/or *Clostridia* grow in the cheese, hydrogen (H_2) and hydrogen sulfide (H_2S) are produced in addition to CO_2. The resultant eyes are either too small, too numerous, or may grow excessively large. Generally, the formation of such atypical gas-formed holes is accompanied by unclean, atypical, or otherwise undesirable off-flavor(s).

14.3.4 Sensory Attributes of Cheeses with Eyes

Swiss cheese may be the most recognizable cheese available in the marketplace. Its distinct appearance makes it a common feature in advertisements and clip art. As a result, defects in appearance are readily recognizable to even the average or casual Swiss-type cheese consumer. US Standards for Swiss cheese or Emmentaler cheese include US Grade A, US Grade B, and US Grade C. The grading system differentiates cheeses based on established quality criteria outlined in the US Standards for Grades of Swiss Cheese, Emmentaler Cheese, established by the USDA Agricultural Marketing Service Dairy Programs (USDA, 2001). Regular evaluation of Swiss cheeses conducted by well-trained plant personnel, who use the guidelines described in the following pages, suffice to serve well the product quality efforts of Swiss-type cheese.

The first step in Swiss cheese evaluation is the training of personnel to recognize the established quality standards. Becoming aware of the "ideal" sensory attributes of Swiss cheeses enables product evaluators (cheese graders) to recognize deviations from those ideal features. Grade A Swiss cheese flavor is expected to possess the pleasing and desirable characteristic Swiss cheese flavor (nutty-like), consistent with the age of the given cheese (more profound with advanced age), and needs to be free from undesirable flavors (described later). The cheese body is expected to be uniform, firm, and smooth. The cheese should be properly set, such that it possesses well-developed round or slightly oval-shaped eyes that are relatively uniform in size and distribution. The majority of eyes are expected to be 1–2 cm (3/8–13/16 in.) in diameter. Swiss cheese rind, if present, should be sound, firm, and smooth, providing good protection to the cheese. Rindless Swiss should be reasonably uniform in size and well shaped, and the flexible wrapper needs to adequately and securely envelop the cheese, be neat, unbroken, and fully protect the surface of the cheese but may be slightly wrinkled. Cheese color is expected to be white to light yellow and natural appearing, attractive, and uniform (USDA, 2001).

Grade A Swiss cheese by USDA standards must be devoid of almost all the defects listed in Tables 14.2, 14.3, 14.4, 14.5, and 14.6. Exceptions are given for "eyes and texture" attributes and "finish and appearance" attributes, which may be noted at slight levels in Grade A Swiss cheese. On the other hand, Grade C Swiss cheese should conform to the same requirements as Grades B and A; however, the cheese "may possess the following off-flavors to a slight degree: fruity, metallic, old milk, onion, rancid, sour, weedy, whey-taint, and yeasty; and the following to a definite degree: acid, bitter, feed, flat and utensil (USDA, 2001)." The guidelines also specify particular "body, eyes and texture, finish and appearance and color" attributes that are considered acceptable for Grade A, B, and C Swiss cheeses. Swiss cheese will not be assigned a US grade if it (a) fails to meet or exceed the requirement for US Grade C; (b) fails to meet composition, minimum age, or other requirements of the FDA; or (c) is produced in a plant found upon inspection to be using unsatisfactory manufacturing practices, equipment, or facilities or to be operating

Table 14.2 Classification of flavor of Swiss cheese by United States Standards for Grades of Swiss Cheese, Emmentaler Cheese (USDA, 2001)

Identification of flavor characteristics	US Grade A	US Grade B	US Grade C
Acid	–	S	D
Bitter	–	S	D
Feed	–	S	D
Flat	–	S	D
Fruity	–	–	S
Metallic	–	–	S
Old milk	–	–	S
Onion	–	–	S
Rancid	–	–	S
Sour	–	–	S
Utensil	–	S	D
Weedy	–	–	S
Whey taint	–	–	S
Yeasty	–	–	S

S slight, *D* definite, – not defined

Table 14.3 Classification of body of Swiss cheese by United States Standards for Grades of Swiss Cheese, Emmentaler Cheese (USDA, 2001)

Identification of body characteristics	US Grade A	US Grade B	US Grade C
Coarse	–	–	S
Pasty	–	–	S
Short	–	–	S
Weak	–	S	D

S slight, *D* definite, – not defined

Table 14.4 Classification of eyes and texture (cut surfaces) of Swiss cheese by United States Standards for Grades of Swiss cheese, Emmentaler cheese (USDA, 2001)

Identification of eyes and texture characteristics	US Grade A	US Grade B	US Grade C
Afterset	–	–	S
Cabbage	–	–	S
Checks	VS	S	D
Collapsed	–	–	S
Dead	–	VS	S
Dull	VS	S	D
Frog mouth	–	S	D
Gassy	–	–	S
Irregular	–	–	S
Large eyes	–	–	S
Nesty	–	VS	S
One sided	–	S	D
Overset	–	S	D
Picks	VS	S	D
Rough	VS	S	D
Shell	VS	S	D
Small eyes	–	–	S
Splits	–	–	S
Streuble	VS	S	D
Underset	–	S	D
Uneven	–	S	D

VS very slight, *S* slight, *D* definite, – not defined

under unsanitary plant conditions. The following section elaborates on the attributes that may be realized in finished Swiss cheese.

14.3.5 Preparation of Cheese for Evaluation

Evaluation of any lots of cheeses with eyes should be conducted on representative samples. The rating of each quality factor must be established on the basis of characteristics present in a randomly selected sample that represents a given vat of cheese. In the instance of institutional-size cuts (i.e., multi-pound, wrapped cheese

Table 14.5 Classification of finish and appearance of Swiss cheese by United States Standards for Grades of Swiss Cheese, Emmentaler Cheese (USDA, 2001)

Identification of finish and appearance characteristics	US Grade A	US Grade B	US Grade C
Checked rind	–	–	S
Huffed	–	S	D
Mold on rind surface	VS	S	D
Mold under wrapper or covering	VS	S	D
Soft spots	–	–	S
Soiled surface (rind)	–	S	D
Soiled surface (rindless)	–	–	VS
Uneven	–	S	D
Wet rind	–	S	D
Wet surface (rindless)	–	S	D

VS very slight, *S* slight, *D* definite, – not defined

Table 14.6 Classification of color of Swiss cheese by United States Standards for Grades of Swiss Cheese, Emmentaler Cheese (USDA, 2001)

Identification of color characteristics	US Grade A	US Grade B	US Grade C
Acid cut	–	–	S
Bleached surface	–	S	D
Colored spots	–	–	S
Dull or faded	–	–	S
Mottled	–	–	S
Pink ring	–	–	S

S slight, *D* definite, – not defined

portions, typically cut from a larger piece and product that is intended for use by various foodservices), the designated samples may be selected on a lot basis. Cheeses in their original, uncut form should be evaluated following appropriate tempering (21 °C [70 °F]) for approximately 1–2 h depending on cheese size and ambient temperatures. For determination of "flavor" and "body" characteristics, the grader needs to examine a full trier plug of cheese withdrawn from the approximate center of one of the largest flat surfaces of the given sample. Smaller portions of a cheese plug are allowed if the samples are of insufficient size for a full plug (USDA, 2001). In order to best determine the "eyes and texture" and "color" characteristics, the wheel or block should be divided approximately into two halves, thus exposing two cut surfaces for facilitating examination (USDA, 2001).

Summaries of defects that may be encountered in cheeses are given for "color, finish and appearance" (Table 14.7), "eyes and texture" (Table 14.8), "flavor" (Table 14.9), and "body" (Table 14.10). Some terms have been combined in these tables due to similarities among the attributes described. For greater understanding, individual terms are explained in detail in the following pages, as defined based upon US Standards for Grades of Swiss Cheese, Emmentaler Cheese, as produced by USDA Agricultural Marketing Service Dairy Programs (2001).

Table 14.7 Common color and finish and appearance defects in cheeses with eyes, identification, and their probable causes

Appearance Color	Identification	Probable cause
Acid cut or bleached surface	Bleached or faded appearance that may extend into cheese	Excessive acid development during whey drainage, overdressing and salting, nonuniform moisture distribution in the cheese, incomplete drying before wrapping
Colored spots, mottled or pink ring	Colored areas, irregular blotches, or other unsightly color variability	Spoilage bacteria growth (pigmented propionibacter or lactobacilli), poor quality milk, high moisture cheese and/or high pH cheese, mixed curd from different vats, poor drainage of whey
Dull or faded	A color condition lacking in luster	Excess fat in milk and curd
Finish and appearance		
Checked rind	Numerous small cracks or breaks in the rind	Poor workmanship during ripening of cheese, lack of elasticity in relation to proteolysis, improper dressing during pressing
Huffed	Cheese is rounded or oval in shape instead of flat	Presence of late blowing activity of spoilage bacteria including clostridia, poor quality milk, grass silage, and/or inadequate milking practices
Mold on rind or under wrapper	Mold growth on surface or under wrapper	Exposure to mold spores in the presence of oxygen, low-quality wrapping material
Soft spots	Spots are soft to the touch, may be faded, may be moist	Poor workmanship during pressing and ripening of cheese, poor whey drainage
Soiled surface	Milkstone, rust spots, grease, or other discoloration on the surface of the cheese	Exposure of cheese to contaminants
Uneven	One side of the cheese is higher than the other	Improper molding or jostling of molded cheese during press
Wet rind or surface	Moisture adheres to the surface of the rind and may or may not soften the rind or cause discoloration	Poor drainage of whey

The extensive number of available score cards that have been employed over the decades for Swiss cheese grading may seem overwhelming to the uninitiated processing plant evaluators. Thus, the abbreviated score card presented as Table 14.11 provides an alternative to the multiple score cards shown in Tables 14.2, 14.3, 14.4, 14.5 and 14.6. Essentially, every cheese plant may determine and evaluate cheese quality based upon the methodology appropriate to the setting.

Table 14.8 Common eye and texture defects in cheeses with eyes, identification, and their probable causes

Appearance	Identification	Probable cause
Blind/ underset	Little or no eye formation present	Lack of propionic acid fermentation; too acidic milk; complete removal of particles serving as nuclei
Checks/picks/ splits	Range from small to sizable, irregular cracks or ragged openings within the body	Excessive proteolysis and acid production
Dull/dead eyes	Eyes lack a bright shiny luster or have completely lost their glossy or velvety appearance	Excess fat in milk and curd; improper pH; poor whey drainage; large block size; poor quality milk
Frog mouth	Eyes which have developed into a lenticular or spindle-shaped opening	High acid milk; over-ripening; overuse of starter cultures; too high cooking temperature
Irregular eyes/collapsed	Eyes that have not formed properly and do not appear round or slightly oval, distorted, somewhat elongated, walnut-shaped eyes	Spontaneous fermentation, variations in moisture within blocks; presence of *Clostridia* species; increased moisture or low pH
Nesty/streuble	An overabundance of small eyes in a localized area, or just under the surface of the cheese	Abnormal gassy fermentation; lack of surface knitting of curd particles; reincorporation of chilled curd during initial pressing
Overset/ cabbage/ blowhole	Excessive number of irregular eyes within the major part of the cheese causing overcrowding, leaving only a paper-thin layer of cheese between the eyes, giving a cabbage appearance	Late gas blowing caused by activity of Clostridia bacteria, poor pressing of the curds, allowing formation of large weak areas
Rough or shell	Eyes that do not have smooth, even walls; rough, nutshell appearance on walls	Insufficient rate and amount of whey drainage; low pH
Small eyes or afterset	Spherical and glossy eyes less than 1 cm in diameter, or small eyes caused by secondary fermentation	Excess gas generation or air inclusion; afterset specifies secondary fermentation, indicating poor quality milk
Uneven or one-sided eyes	Overabundance of small eyes, reasonably developed in some areas and underdeveloped in others (or one side)	Mishandling of cheese, temperature gradient in the curd during pressing; high acid curd; improper knitting; inadequate pressing

14.3.6 Finish and Appearance

The first thing one will notice upon approaching a cheese with eyes is the external surface or finish and appearance. With respect to finish and appearance, “very slight” means the defect is detected upon most critical examination. “Slight” defect intensity is detected upon moderately critical examination, while “definite” is not a particularly intense defect level but is certainly detectable by an astute observer.

Table 14.9 Common flavor defects in cheeses with eyes, identification, and their probable causes

Flavor	Identification	Probable cause
Acid	Sharp and puckery to the taste, characteristic of lactic acid	Excess lactic acid, the use of high acid milk
Bitter	A basic taste similar to quinine or caffeine	Proteolytic starter culture, microbial contamination
Feed/weed	Feed flavors (such as alfalfa, sweet clover, silage, or similar feed)	Feeding cow strongly flavored feeds before milking
Flat/lack of flavor	Insipid, practically devoid of characteristic sweet hazelnut, typical flavor for the cheese	Contamination with other bacteria, inadequate fermentation, and proteolysis
Fruity	A sweet fruit-like flavor resembling pineapple, apple, or pears	*Pseudomonas fragi* growth
Garlic/onion	This flavor is recognized by the peculiar taste and odor suggestive of its name	Feeding of onions/garlic or leeks
Metallic	A flavor having qualities suggestive of metal, imparting a puckery sensation	Oxidation of ingredients (milk)
Old milk	Lacks freshness	Old milk
Rancid	A butyric acid flavor sometimes associated with bitterness. Formation of volatile fatty acids (C_4 through C_{12})	Mishandling of cheese milk, milk lipolysis, or microbial lipase activity
Sulfide	Odor of hydrogen sulfide or spoiled eggs	An abnormal fermentation
Unclean (dirty aftertaste)	An undesirable, persistent, aromatic aftertaste	Undesirable microbial growth
Unnatural (atypical)	Generally has a relatively clean flavor, but the overall sensory perception is atypical for the given cheese	May be chemical, enzymatic, or bacteriological in origin
Whey taint	A slightly acid taste and odor characteristic of fermented whey	Too slow expulsion of whey from the curd
Yeasty	A flavor indicating yeast fermentation	Contamination by yeast and mold, poor packaging

Table 14.10 Common body defects in cheeses with eyes, identification, and probable causes

Body/texture	Identification	Probable cause
Coarse	Rough, mealy, and sandy feeling	Overcooking of curds
Crumbly	Falls apart while working	Low moisture retention
Firm/rubbery/ corky	Resistance to mastication or manipulation between thumb and fingers	Excess use of chymosin; too high cooking temperature and/or time; low moisture; lack of proteolysis
Pasty	Sticky and smeary when rubbed between the thumb and fingers	Excessive acid production; high moisture content, poor drainage of whey; excessive proteolysis
Short	No elasticity to the plug when rubbed between the thumb and fingers	Excess proteolysis and acid production
Weak	Requires little pressure to crush, is soft but is not necessarily sticky like pasty cheese	High moisture; excessive proteolysis

Table 14.11 Proposed score card for the evaluation of cheeses with eyes

Defects (Unofficial; modify scores accordingly)	Slight	Definite	Pronounced
Flavor			
Acid/sour	8	6	4
Bitter	9	8	6
Feed/weedy	9	8	6
Flat/lack of typical flavor	9	8	6
Fruity	8	6	4
Metallic	6	4	1
Old milk	6	4	1
Onion/garlic	5	3	1
Rancid	6	4	1
Sulfide	6	4	1
Unclean (dirty aftertaste)	8	6	4
Unnatural (atypical)	6	4	1
Whey taint	8	6	4
Yeasty	5	3	1
Body and texture			
Coarse	3	2	1
Crumbly	4	2	1
Firm/rubbery/corky	4	3	2
Pasty	3	2	1
Short	4	3	2
Weak	4	2	1
Appearance			
Blind/underset	4	2	1
Checks/picks/splits	3	2	1
Color defects	3	2	1
Dull/dead eye	3	2	1
Frog mouth	3	2	1
Irregular eyes/collapsed	4	2	1
Nesty/streuble	4	2	1
Overset/cabbage/blowhole	3	2	1
Small eyes	4	3	2
Uneven/one-sided eyes	3	2	1

Checked rind describes numerous small cracks and/or breaks in the cheese rind. This defect may allow the intrusion of mold to the body of the cheese. Surface cracks most usually result from improper dressing during pressing and rough handling.

Huffed describes a cheese that has become somewhat rounded or oval in shape instead of exhibiting the distinctly preferred symmetrically flat top and bottom surfaces.

Mold on rind surface is self-explanatory; unwanted and unappealing mold growth has occurred.

Mold under wrapper or covering. Broken or torn wrappers result from rough handling, improper wrapping, and used of inferior materials for wrapping and curing, which permits oxygen to enter and growth of mold on the surface.

Soft spots are cheese surfaces that appear/feel soft to the touch and generally appear faded and may feel moist.

Soiled surface describes formation of potential milkstone, rust spots, grease, or other unusual and undesirable discoloration areas on the surface of the cheese.

Uneven is a term used when one side of the cheese obviously appears higher than the other (i.e., misshapen).

Wet rind describes when moisture adheres to the surface of the rind and may or may not soften the rind or cause discoloration.

Wet surface is a term used to describe a rindless cheese when moisture appears between the wrapper and the cheese surface.

14.3.7 Cheese Color

Upon trying or slicing into a cheese, the color will be readily noted. With respect to color, the term "slight" refers to attributes that are only detectable upon careful and critical examination, while the presence of a "definite" quality defect is not intense but is nonetheless readily detectable under close examination. Color defects of eyed cheeses include the following:

Acid cut is defined as a bleached or faded appearance that sometimes varies throughout the cheese.

Bleached surface describes a type of faded coloring, beginning at the surface and extending inward a short distance. The main reason for this defect is high acid resulting from improper whey drainage. When the salt concentration in the brine has fallen dramatically low, the outer portions of the block become soft and white. Improper dressing and salting may enhance bleaching by permitting the surface to remain wet. Incomplete drying before wrapping will cause the color change on the outer surface.

Colored spots are brightly colored areas (ranging from pink to brick red or gray to black) of atypical bacteria growing as readily discernible colonies, randomly distributed throughout the cheese. They are found mostly in winter cheese, low-acid cheese, and cheese made from poor bacterial quality milk.

Dull or faded describes a color condition that is lacking in the expected level of luster.

Mottled indicates irregular-shaped spots or blotches in which certain portions are light colored and others are more highly colored. Also, an unevenness of color due to the combination of curd from two different vats is sometimes referred to as "mixed curd." A mottled or wavy condition may result from exceedingly poor technique in filling the molding vat and incomplete pressing.

Pink ring suggests a unique color condition, which usually appears pink to brownish red and occurs as a uniform varied color band near the cheese surface and which may also follow or accompany eye formation. The definite ring of color rapidly disappears when a freshly cut cheese surface is exposed to air, which indicates an association with changes in oxidation reduction potential. This defect is rarely seen in young cheese but may appear in cheese 4 months of age and older. Pink ring should not be confused with the many pigmented bacteria, yeast, and mold that may grow on the surfaces of improperly dried and wrapped cheese blocks.

14.3.8 Cheese Eyes and Texture

The defects related to eye and texture formation can be classified according to distribution, number, size, shape, and interior condition (Fig. 14.4).

14.3.8.1 Eye Distribution

One sided refers to cheese that is reasonably developed with eyes on one side and underdeveloped eyes on the opposite side. This defect is more commonly related to rindless blocks due to lower salt and higher moisture content. One possible reason

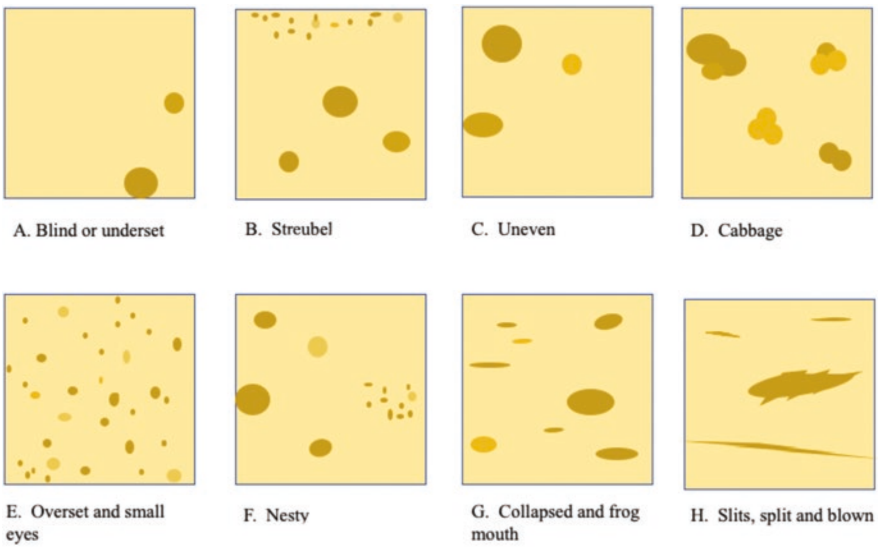

Fig. 14.4 Diagrams of cheese slices exhibiting a variety of eye defects

for the one-sided defect is a temperature difference between the surface and inside of the curd at the press. The occurrence of one-sidedness can be reduced by preventing the press temperature from dropping below 24 °C. “Slight” means eyes are evenly distributed throughout at least 90% of the total cheese area, while “definite” means eyes are evenly distributed throughout at least 75% but less than 90% of the total cheese area.

Gassy describes variously scattered gas holes of various sizes, shape, and appearance that may be due to the unwanted development of atypical microbial gas formations. A “slight” intensity is defined as no more than three occurrences per any given 13 cm^2 (2 $in.^2$) of internal cheese surface.

Nesty refers to an overabundance of small eyes in a localized area (Fig. 14.5). The occurrence of nesty is related to the disturbance of the curd during knitting. Small nests are most frequently found on the outer top edge of cheese blocks due to incomplete pressing of the top side or reincorporation of the curd that escapes between the press plate and molding vat wall during initial pressing. The curd should not be disturbed after it has started to knit in order to prevent the occurrence of this defect. “Very slight” means occurrence is limited to no more than 5% of the exposed cut area of the cheese. “Slight” means occurrence in more than 5%, but less than 10%, of the exposed cut area of the cheese, and “definite” means occurrence in more than 10%, but less than 20%, of the exposed cut area of the cheese.

Streuble refers to an overabundance of small eyes located just under the surface of the cheese. This defect can also be described as a surface nest. It is mostly found in wheel cheese where cheesemakers attempt to recover the remaining curd in the kettle after dipping. Already chilled curd does not knit to the wheel completely and causes streuble formation. The possible reasons for the occurrence of streuble in rindless block cheeses are lack of surface knit, too cool surfaces, air on the surface of the curd, and improper pressing or weight distribution. To prevent the formation of this defect, avoid improper knitting of the curd particles. “Very slight” extends no more than 0.3 cm (1/8 in.) into the body of the cheese. “Slight” extends 0.28 cm (>1/9 in.) or more but less than 0.6 cm (1/4 in.) into the body of the cheese. “Definite”

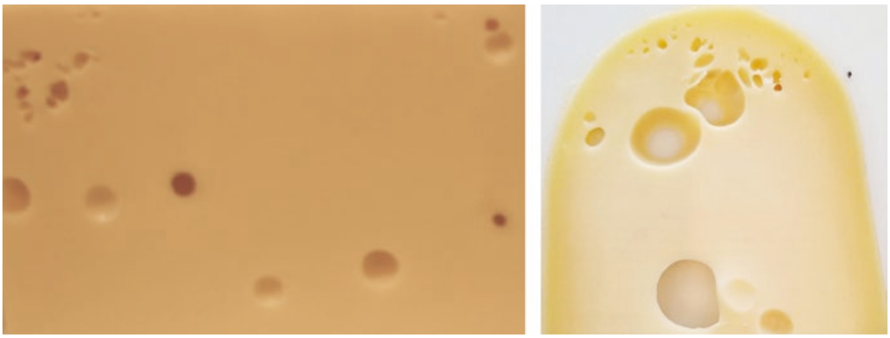

Fig. 14.5 Cheeses exhibiting nesty (left), streuble (right), and uneven eye distribution

extends 0.6 cm (>1/4 in.) or more but less than 1.3 cm (<1/2 in.) into the body of the cheese.

Uneven refers to cheese that is reasonably developed with eyes in some areas and underdeveloped in other areas. The possible reasons for this defect may be (a) incorporation of air in the curd mass during filling of the molding vat; (b) unequal filling of the molding vat; (c) major shifts of the curd mass during pressing; (d) high-acid curd, causing improper knitting; (e) temperature variation in the curd; (f) inadequate pressing of some portions of the curd mass; and (g) rupture of knitted curd during brining. "Slight" means eyes are evenly distributed throughout at least 90% of the total cheese area, while "definite" means eyes are evenly distributed throughout at least 75%, but less than 90% of the total cheese area.

14.3.8.2 Eye Number

Blind is a term that describes the absence of eyes in portions of or in an entire block of cheese. Any factor that prevents gas formation by propionic acid bacteria and complete removal of particles serving as nuclei for gas collection would result in blind cheese.

Underset describes when too few eyes are present. Similar factors that cause blind cheese also may lead to underset cheese. "Very slight" is used when the number of eyes present exceeds or falls short of the ideal by a limited amount. "Slight" indicates the number of eyes exceeds or falls short by a moderate amount (Fig. 14.6).

Overset describes an excessive number of eyes present within the cheese (Fig. 14.7). The overset condition may be seen throughout the cheese block uniformly or may be localized in specific areas such as across the top, through the middle, on one side, or at the edges. It is important to observe the location of the defect carefully to obtain an idea about the probable cause of the defect. The overgrowth of undesirable gas-forming bacteria, inadvertent incorporation of air in the curd mass before pressing, mishandling of the cheese during pressing, improper pH and moisture levels, presence of unwanted particles, and other factors that would

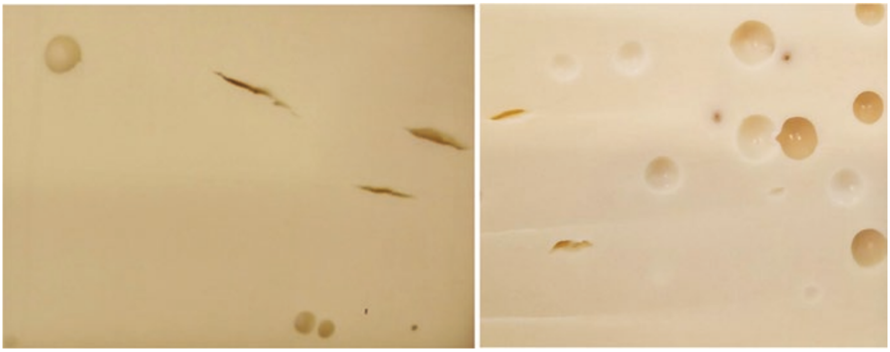

Fig. 14.6 Cheeses exhibiting slits and underset (left) and uneven eye distribution

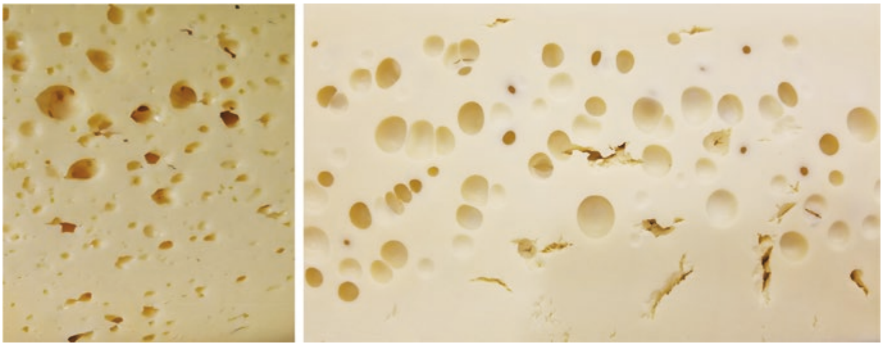

Fig. 14.7 Cheeses exhibiting overset, irregular eyes (left), uneven eye distribution, and slits (right)

Fig. 14.8 Swiss cheese exhibiting large eyes

prevent normal knitting of the curd before gas production by propionic acid bacteria would cause overset cheese. “Very slight” is used when the number of eyes present exceeds or falls short of the ideal by a limited amount. “Slight” indicates the number of eyes exceeds or falls short by a moderate amount.

14.3.8.3 Eye Size

Blowhole describes the presence of a large, overblown air sac (typically more than 12.5 cm (5 in.) in diameter) within the body of the cheese (Fig. 14.4). Externally, the cheese usually appears torn and deformed. One of the possible reasons for this defect could be the growth of *Clostridia*. However, the problem is not necessarily related to microbial activity only; it may also be caused by poor pressing of the cheese that allows formation of large, weak areas in the curd mass. The presence of unexpelled whey pockets is ideal for the formation of blowholes. Blowholes are encountered very rarely in plants using careful, proper pressing procedures.

Large eyes are called "slight" when the majority of the eyes are more than 2 cm (13/16 in.) but less than 2.5 cm (1 in.) in diameter (Fig. 14.8). The 0.6 cm (1/4 in.) size is ideal. Large eyes can be caused by high moisture content and high pH (over 5.4) of the curds. Improper circulation and block stacking both in the warm room and finished cooler may also contribute to the problem. Rapid and unimpeded cooling is necessary after warm room treatment to prevent further development of eyes.

Small eyes are called "slight" when the majority of the eyes are less than 0.95 cm (3/8 in.) but no more than 0.3 cm (1/8 in.) in diameter. The 0.6 cm (1/4 in.) size is ideal for a typical Swiss or Maasdam cheese (smaller for other cheeses with eyes).

Afterset describes small eyes caused by secondary fermentation, which is also known as late fermentation. This defect indicates a gaseous fermentation took place after the growth of propionic acid bacteria and generally occurs in the curing room. Poor-quality milk is one of the most common causes of the defect. "Very slight" is used as an intensity descriptor when the number of eyes present exceeds or falls short of the ideal by a limited amount. "Slight" indicates that the number of eyes exceeds or falls short by a moderate amount.

14.3.8.4 Eye Shape

Cabbage describes those eyed cheeses having eyes so numerous within the major part of the cheese that they crowd each other, leaving only a paper-thin layer of cheese between the eyes, thus causing the cheese to have a "cabbage-like" appearance and irregular-shaped eyes (Fig. 14.9). The most common causes are high moisture, soft body, low acidity, weak inactive starter, and inhibitory compounds.

Collapsed describes eyes that have not formed properly and do not appear either round or slightly oval but rather either flattened and/or appear to have collapsed

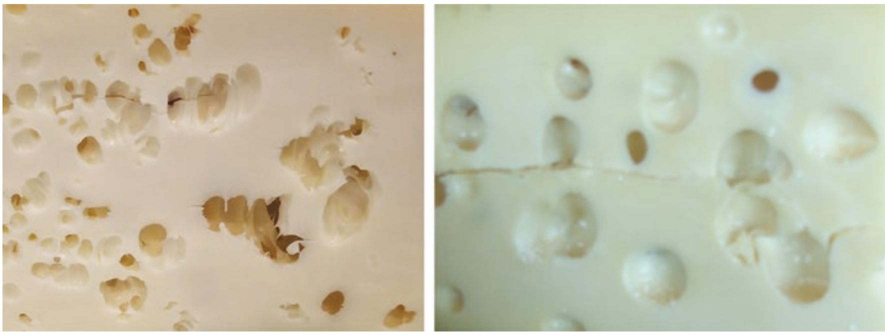

Fig. 14.9 Cheeses exhibiting slits (left), cabbage (both), and a split (right)

Fig. 14.10 Cheeses exhibiting irregular eyes, with frog mouth (left), and uneven eye distribution

Fig. 14.11 Cheeses exhibiting checks, splits and small, collapsed, and irregular eyes

(Fig. 14.10). Soft, pasty-bodied cheese cannot withstand pressure, and upon cooling after warm room treatment, the eyes fold in upon themselves.

Checks/picks/slits/splits are similar attributes. Checks are small, short cracks within the body of the cheese. Picks are small irregular or ragged openings within the body of the cheese. Slits may appear as straight or jagged breaks in the body. Splits are more sizable cracks, usually occurring in parallel layers and usually clean-cut, found within the body of the cheese (Fig. 14.11). "Very slight" infers infrequent occurrence (i.e., not more than 2.5 cm [1 in.] from the surface). "Slight" means limited occurrence, not more than 1 in. from the surface, while "definite" means limited occurrence throughout the cheese.

Frog mouth eyes have developed into lenticular or spindle-shaped openings (Fig. 14.10). Frog mouth can be seen if the cheese curd is not elastic enough to open normally under pressure to form a smooth, round eye. High-acid milk, overripening, overuse of starter cultures, too long firework, and too high cooking temperature are among the reasons for the formation of frog mouth.

Irregular eyes are eyes that have not formed properly and do not appear either round or slightly oval, and the shape (conformation) is not accurately described by other terms (Fig. 14.10). When the cheese body is soft and is not restrained during warm room treatment, the developing eyes tend to form along stress lines. Variations in moisture within blocks resulting from press temperature differences promote irregular eye formation. “Very slight” is used when the characteristic is exhibited in less than 5% of the eyes. “Slight” is used when the characteristic is exhibited in 5% or more, but less than 10% of the eyes. “Definite” is used when the characteristic is exhibited in more than 10% but less than 20% of the eyes.

14.3.8.5 Interior Condition

Dull/dead eyes are similar defects. Dead eyes are developed cheese openings but have completely lost their preferred glossy or velvety appearance (Fig. 14.12). Dull eyes have lost some of their bright shiny luster. The appearance of dull and dead eyes on the top and outer edge of blocks indicates a relationship between this defect and whey drainage. Other defects related to low pH, insufficient whey drainage, poor-quality milk, and poor manufacturing procedures may be observed along with dull and dead eyes.

Rough suggests that the cheese eyes simply do not exhibit the desired smooth appearing, even wall surfaces (Fig. 14.13). Rough eye is essentially an exaggeration of dull and dead eyes. Insufficient rate and amount of whey drainage are a common cause of defects. High moisture content leads to excessive acidity that causes the development of abnormal eyes attributable to the firm and short body.

Shell (like) describes a unique, rough “nutshell” appearance (multidimensional) on the wall surface of the Swiss eyes. The factors causing the formation of shell-like eyes are the same described for dull, dead, and rough eyes.

Fig. 14.12 Cheeses exhibiting slight slits and blown areas with some dull eyes

Fig. 14.13 Cheeses exhibiting pronounced slits and blown areas, with rough appearance

14.3.9 Cheese Flavor

While Swiss cheese should have a pleasing and desirable characteristic hazelnut-like flavor, all cheeses with eyes should exhibit their characteristic flavor, at an intensity consistent with the age of the given cheese, and be free from undesirable off-flavors. Swiss cheese industry experience has shown that there is a strong relationship between desirable flavor and proper eye formation. During manufacture and curing, the lactic acid bacteria transform lactose to lactic acid, and finally propionic acid bacteria produce some propionic and acetic acids, as well as carbon dioxide. Appropriate eye formation in Swiss cheese is considered a good indication of typical Swiss cheese flavor (Bodyfelt, 1988).

With respect to flavor, "slight" refers to detection only upon critical examination, while "definite" refers to a not intense but clearly identifiable level.

Acid is described as sharp and puckery to the taste, characteristic of lactic acid.

Bitter is a basic taste similar to quinine and, for many tasters, perceived after a momentary delay in perception.

Feed flavors include alfalfa, sweet clover, grass hay, silage, haylage (wilted and bagged grass), brewery wastes, and/or other similarly fed high-volume aromatic roughages, fed within the critical time period of 0.5–3.5 h prior to milking.

Flat is a term used to describe a cheese that lacks the typical intensity of characteristic cheese flavor for its presumed extent of aging.

Fruity provides a sweet fruit-like flavor (aroma) that resembles apples, pears, or other similar fruit.

Metallic describes a flavor character having qualities suggestive of metal (copper or tin-like) and also imparting a somewhat delayed puckery mouthfeel sensation.

Old milk describes a cheese that suggests the sensation of a product lacking freshness (i.e., a cheese made from less than the freshest milk [cheesemilk ≥4–6 days old]).

Onion/garlic is a distinctive cheese off-flavor that is recognized by the peculiar tastes and/or odors suggestive of the names of the “wild” plants consumed by milking cows (or goats) from foraging or from produced hays.

Rancid manifests the presence of butyric acid or other short-chain volatile fatty acids and their formed salts (soaps). It may be accompanied by unclean-like or otherwise objectionable odors and/or somewhat delayed bitter aftertastes as well.

Sour does not simply refer to an initial “acid” or sour taste but also to an accompanying pungent aroma resembling lactic acid and/or vinegar. The occurrence of sour milk generally implies inadequate cooling of raw farm milk, bulk transport operations, and/or inadequate milk temperature control at the cheese plant.

Utensil/psychrotrophic is a term used to describe a flavor suggestive of improper or inadequate washing and sanitizing of milking machines, utensils, and/or milk handling equipment. This off-flavor is primarily caused by the presence and outgrowth of psychotrophic Gram-negative spoilage bacteria (i.e., dirty, unclean, fruity/fermented flavor notes prevail).

Unclean (an unpleasant dirty-like and lingering aftertaste) is a succinct term that best describes this most objectionable and unpleasant and lingering off-flavor. The taste buds of the unfortunate taster frequently fail to “clean up” (clear up). Often an accompanying offensive, objectionable off-smell will prompt the more alert would-be taster to trust and rely on the focused sense of smell to determine the objectionable flavor profile of the “tagged” off-flavors of “unclean” and/or “utensil/psychrotrophic” off-flavors of milk.

Weedy is a flavor suggestive of aromatic weeds consumed by milking animals; “weed” off-flavors are much likened to “feed” off-flavors. In fact, garlic/onion off-aroma of milk supplies is nothing other than a variant of a weed (or feed) category of milk supply off-flavor.

Whey taint, as it occurs in cheeses with eyes, tends to exhibit a slightly acidic taste note and casts an odor characteristic of fermented whey (though sweeter than is the case for Cheddar and other more acidic cheeses). A pasty body may occasionally accompany the whey taint flavor character of eyed cheese varieties.

Yeasty is an occasional flavor character typically that indicates that yeast fermentation has occurred within the cheese; yeast-contaminated cheese starter cultures may be suspect.

14.3.10 Cheese Body and Texture

The body and texture of cheese plug samples withdrawn from Swiss cheese varieties should be reasonably firm, smooth, and moderately flexible when bent. Near the surface, where aged cheese is generally drier, the body may be slightly crumbly. A soft and pasty cheese body is often associated with high moisture or abnormal eye formation and may be accompanied by poor flavor development (Bodyfelt, 1988).

Body and texture defects assigned “slight” level of intensity infers detection only upon critical examination, while a “definite” degree is not intense but detectable.

The body properties can be examined by removing a plug from cheese and then working a small piece of the sample between the thumb, index, and middle fingers.

Coarse implies the cheese body feels rough, dry, and sandy between the fingers and/or in the mouth.

Firm, rubbery, or corky means the cheese is unusually resistant to efforts at compression; corky is the most dry in this progression of terms.

Pasty describes an unusually weak product body that, when worked between the fingers, atypically sticks to finger surfaces and readily smears.

Short body exhibits no elasticity when the plug is broken and worked between the fingers.

Weak cheese requires little pressure to compress or crush. It is soft (perhaps suggestive of higher moisture levels) but is not necessarily sticky like pasty cheese.

14.4 Modern Sensory Analysis of Swiss Cheese

Modern sensory analysis practices, detailed in Chap. 17, have worked effectively for the evaluation of Swiss cheese. Drake et al. (2007) utilized modern sensory practices to identify the compounds responsible for umami taste in Cheddar and Swiss cheeses. A trained sensory panel familiar with the Spectrum™ descriptive analysis method (Sensory Spectrum, New Providence, NJ) was utilized to select four Cheddar and four Swiss cheeses (two with low and two with high umami taste intensity for each type). The cheese flavor language included the basic taste umami, which was identified in the initial development of a lexicon (Drake et al., 2001). The compounds expected to contribute to umami taste (monosodium glutamate (MSG), disodium 5′-inosine monophosphate (IMP), disodium 5′-guanosine monophosphate (GMP), lactic acid, glutamic acid, proprionic acid, and succinic acid) were quantified by high-performance liquid chromatography (HPLC) on the four cheeses. Taste thresholds were determined for each compound (plus sodium chloride) using a modification of the ASTM procedure E679-9 (ASTM, 1992), an ascending forced choice method of limits. Comparison of analytical data and sensory thresholds indicated that glutamic acid contributed most profoundly to umami taste in Cheddar and Swiss cheeses; proprionic acid and succinic acid also contributed to umami taste in Swiss cheese.

Determination of free fatty acids (FFA) or nonesterified fatty acids (NEFA) in dairy products is often desirable because their presence can indicate quality and maturation and enable categorization by cheesemakers (Koca et al., 2007). However, determination of FFA is a challenge because FFA are often volatile, are found at low levels, and exist in a wide range of carbon chain lengths (Chavarri et al., 1997). The most common methodology for FFA quantification involves lipid extraction, isolation of FFA, and gas chromatographic quantification (de Jong & Badings, 1990). Koca et al. (2007) developed a rapid screening method to monitor the short-chain

FFA contents in Swiss cheese using Fourier transform infrared spectroscopy (FTIR). Forty-four Swiss cheese samples were evaluated by their methodology and with gas chromatography-flame ionization detection as a reference method. Infrared spectroscopy and chemometrics accurately and precisely predicted the short-chain free fatty acid (acetic, proprionic, and butyric acids) content in Swiss cheeses and in water-soluble fractions of the cheeses (Koca et al., 2007).

Proper eye formation and structural features have great importance on determining the commercial value and quality of Swiss-type cheeses. New emerging nondestructive methods have been developed for the detection of structural defects during the ripening of Swiss-type cheeses. Rosenberg et al. (1992) demonstrated that magnetic resonance imaging (MRI) is a potential technique for the evaluation of eye formation and structural quality. The MRI method was able to detect structural defects rapidly and nondestructively with high spatial resolution. Ultrasonic monitoring has been used for the evaluation of structural quality of Swiss cheese (Eskelinen et al., 2007). The method was capable of detecting and characterizing cheese eyes and cracks in ripened cheese. Such tools provide valuable information to improve and control the production process to obtain desirable structure in Swiss cheese.

The potential for additional advances in understanding Swiss flavor development and monitoring cheese quality is great with the numerous modern techniques available to the industry.

14.5 Conclusion

Swiss cheese and other cheeses with eyes have unique flavors and distinctive eye formation that differentiate them from other types of cheeses. The production of these cheeses requires careful orchestration of special cheese cultures, technical inputs, complex manufacturing steps, unique cheese making equipment, brining and aging strategies in order to consistently attain the desired characteristics, and consistent quality. There are numerous factors that contribute to variation of product quality such as processing/packaging methods and materials, as well as storage time and conditions. The training of cheesemakers to not only understand the sensory attributes described in these pages but also apply appropriate process control and how to recognize probable causes of quality shortcomings can suffice to lead to sound and improved cheese quality in the marketplace. Using the provided scorecards for the consistent evaluation of produced cheeses with eyes should enable processors to optimize product flavor, eye formation and uniformity, optimum texture properties, and appealing color and appearance in order to attract targeted consumers and simultaneously better monitor day-to-day product quality.

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Chapter 15
Mozzarella

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15.1 Introduction

Mozzarella is often referred to as a fresh cheese, as it is not deliberately aged to develop flavor. When eaten fresh, it tastes like the milk from which it is made but may have different intensities of buttery, salty, and acidic notes depending upon the style. Mozzarella, in all its forms, ranks number one as the most consumed cheese in the United States with 12.5 pounds eaten per person as of 2019. This accounts for approximately one-third of the United States' total cheese consumption (Dairy Farmers of Wisconsin, 2020, personal communication).

Mozzarella is not one cheese variety but rather a family of cheeses differentiated by composition and manufacturing protocol. The US Food and Drug Administration (Code of Federal Regulations (CFR), Title 21, Part 133.155–133.158) recognizes four categories of mozzarella based on composition: mozzarella, low-moisture mozzarella (also called whole milk mozzarella by the industry), part-skim mozzarella, and low-moisture part-skim mozzarella (LMPS). The CFR also lists scamorza as an alternative name with all types of mozzarella. All types of mozzarella must be made from pasteurized milk and can be made from all cow's milk or buffalo milk but not a mixture of the two. The CFR also accepts alternative manufacturing technologies for mozzarella if it produces a finished cheese having the same physical and chemical properties for a particular category (see Table 15.1) and only uses accepted ingredients as listed in the CFR. This has allowed for the manufacture of low-moisture part-skim mozzarella without using the traditional cooking and stretching of the curd step (often called the pasta filata step) and is direct salted rather than brined. The cooking and stretching step is often referred to as the mixer molder step in large-scale manufacturing as the curd is mixed in hot water and

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Table 15.1 Mozzarella and provolone standards of identity from the CFR Title 21, parts 133.155–133.158 and 133.181 (US FDA, 2022)

	Moisture	FDM[a]
	(- - - - - - - - - - - - - - - - %	- - - - - - - - - - - - - -)
Mozzarella	>52–60 max	≥45
Low-moisture mozzarella	>45–52 max	≥45
Part-skim mozzarella	>52–60 max	30 min – <45
Low-moisture part-skim mozzarella	>45–52 max	30 min – <45
Provolone	45 max	≥45

[a]*FDM* Fat in the dry matter

Fig. 15.1 Example of "fresh" mozzarella (left) and LMPS mozzarella (right)

transferred mechanically into forms while still molten. It is often called block mozzarella by the industry as it is pressed in very large blocks; 18–290 kg (40–640 pounds), but after conversion, it is sold mainly in retail stores in 170–900 g (6–32 ounce) packages. Block mozzarella allows for exact weight packages with less trim loss.

String cheese and whips must be labeled as the category of mozzarella whose composition standards it meets, i.e., most commonly low-moisture part-skim mozzarella and occasionally low-moisture mozzarella.

The proposed Codex standards (WHO/FAO) recognize only two categories of mozzarella, which are based on composition and on how the cheese is used. The first is a mozzarella with high moisture and typically very little salt content (<0.5%) and is ready for consumption immediately after manufacture. It has a shelf life of only a few weeks. This cheese is commonly referred to in the United States as fresh mozzarella (Fig. 15.1). The second category, over which there was considerable discussion internationally, is a compromise to allow for a lower-moisture version of mozzarella. This version was proposed due to the pervasive use in the United States of the name mozzarella for a cheese lower in moisture and often lower in fat than mozzarella. This style of cheese was developed in the United States to prolong the shelf life and is principally used for pizza.

Another difference between the two styles is that the first category of mozzarella is too soft to be shredded while the second category is made for this purpose. The CFR would recognize this second style as either low-moisture mozzarella, part-skim mozzarella, or low-moisture part-skim mozzarella (LMPS).

The FDA (CFR) sets no requirements for pH, salt, sensory, or functional attributes of mozzarella. However, the USDA (2008), pizza manufacturers, and other commercial users of mozzarella set their own criteria for acceptability based generally on machinability and baking performance. These criteria are often initially tested at the cheese plant. Retail stores simply ask that the mozzarellas they sell meet the compositional standards set by FDA. Consumer complaints are directed ultimately to the cheesemaker. Retail mozzarella is evaluated at the cheese factory to ensure that it meets composition requirements, acceptable flavor, and machinability, and again at the convertor for the ability to be sliced, cubed, or shredded. However, cheese purchases at retail will have significant variability in shred and bake performance that is outside the cheesemaker's and converter's control. This is due to the differences in cheese age and storage conditions after the cheese has left the factory.

In cheese contests, mozzarellas are evaluated on appearance, taste, body, and texture but rarely on bake characteristics. Cheese contest judges also evaluate the integrity of the packaging. Mozzarella contest categories include flavored or fresh mozzarellas packaged in flavored oils or cheeses with smoked flavor. These are also judged according to the quality and intensity of the flavor added. Many contests put priority on cheese flavor rather than the added flavors. Excessive added flavor is seen as a fault even though the consumer may prefer it.

15.2 Characteristics and Manufacturing Practices for Mozzarella Cheeses

A general manufacturing outline for mozzarella cheeses is presented in Fig. 15.2. The physical and functional characteristics of all mozzarellas beyond those imparted by cheese composition are based on decalcification of the casein, pH, and ultimately the extent of proteolysis. Acidification solubilizes calcium and initially determines stretch and melt characteristics. Proteolysis will increase melt, decrease stretch length, increase blister size and color, increase off-flavors, increase matting of shreds, and can also result in a cheese that may be hard to shred or slice (Johnson & Lucey, 2006). Proteolysis will cause the cheese to become pasty bodied with a smooth mouthfeel.

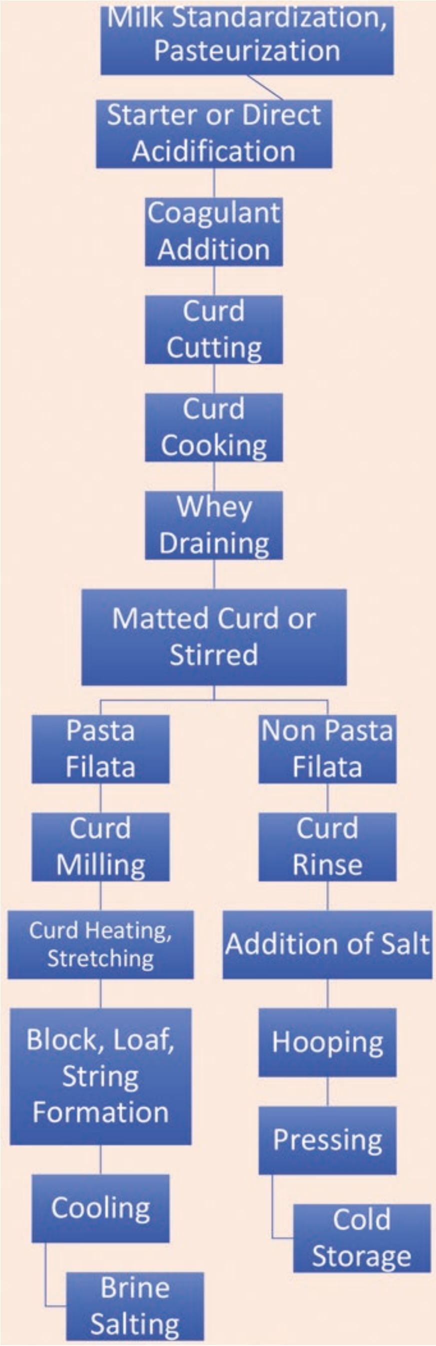

Fig. 15.2 General manufacturing outline for both stirred curd and milled curd mozzarella cheese and pasta filata and non-pasta filata styles

15.2.1 Mozzarella

Desired characteristics of Mozzarella, also called fresh mozzarella, are sweet, milky flavors, easily sliced, and, if baked, has a long stretch and melts but does not flow extensively. The main fault for this category tends to be the lack of the desired flavor attributes (sweet and milky), which is referred to as flat or uncharacteristic of variety. Other potential undesirable attributes are bitter, unclean, acid, oxidized, or stale and excessively soft body. If the cheese is warmed (>4 °C, 40 °F), some watering off may be observed if the cheese is cut open, but this is unavoidable and therefore acceptable. If oven baked, as is the case for Neapolitan style pizza, the cheese should be soft but maintain its slice identity (usually a circle) and not flow into a larger mass. Blister quantity should be very limited in size and number, and the baked cheese should remain white, but there will be considerable amount of water released, which is expected and taken into account by the pizza maker. As the fresh mozzarella ages, it will start to develop some blisters and begin to flow more when baked due to proteolysis by residual rennet (Figs. 15.3 and 15.4).

Fresh mozzarella is manufactured with pasteurized whole milk or partially skimmed milk. Milk with a low casein to fat ratio will produce a cheese with excessively high FDM and, if combined with a high moisture content, will result in a cheese of excessively soft body, tendency to water off excessively, flow excessively when baked, and have a very short shelf life even when held under refrigeration.

Fresh mozzarella is traditionally made by adding vinegar (acetic acid) to cold milk to obtain pH 5.6–5.7. The desired pH is influenced by the casein content of the milk, with more casein requiring more acidification, or lower pH. The temperature is raised to 32–37 °C (90–98 °F), and a coagulant is added. Starter cultures and calcium chloride are not added. The choice and amount of coagulant used is very important since it is the main proteolytic agent in the cheese, and excessive proteolysis is the number one cause for body softening leading to a shorter shelf life and excessive flow when baking. The recommendation is to use as little rennet or coagulant as possible and one that is very specific in enzyme activity in order to avoid

Fig. 15.3 Example of a pizza baked with fresh mozzarella and oregano (left) pizza made with an older mozzarella presenting more blistering (right)

Fig. 15.4 Example of a pizza baked with fresh mozzarella presenting a lot of stretch (left) and a close-up of the mozzarella with some water release (right)

bitterness and to slow proteolysis. After the addition of the coagulant, the milk is clotted, and the coagulum is cut into large cubes, followed by very little if any stirring, without additional heating. The curd is often allowed to settle before the whey is drained and is handled very gently to avoid curd breakage which leads to moisture loss. The drained curd is placed into hot water (71 °C, 160 °F) and kneaded (stretching step). Too high a pH may require excessive kneading, and this will lead to greater fat loss and a tougher bodied cheese. Traditionally stretching was done by hand and is often done this way in delis and with cheesemakers who make mozzarella at home, but commercially it is done mechanically.

Since both coagulant activity and growth of contaminants are influenced by temperature of storage, the best means to control them is to store the cheese at very cold temperatures (0 °C, 32 °F) until used. Unfortunately, fresh mozzarella cheese is often stored in retail at too high a temperature and for too long which leads to excessive proteolysis and off-flavor development. One solution that has been found effective at reducing the coagulant activity is to use very high heat during the mixing molding step (>66 °C, 150 °F curd temperature).

Fresh mozzarella is formed into logs, or semispheres and various sizes and shapes of spheres (ciliegine/cherry, perlini/pearl, ovolini/egg, bocconcini/bite-sized), which are usually placed in a dilute (<0.5% salt), slightly acidified (pH 5.6–5.8) brine. Unless calcium chloride is added to the brine, the outer layer of the cheese may become soft and slough-off. Sloughing-off is when pieces of cheese can be easily peeled from the cheese surface without much pressure. Softening is due to hydration of the outer layer due to loss of calcium from the casein. However, excessive addition of calcium chloride to the brine can lead to bitterness.

Occasionally, yeasts may contaminate the cheese during packaging, and this can result in a yeasty flavor, gassy or puffed packages, and occasionally off-colors. If the cheese is contaminated with yeasts prior to packaging, the cheese can also develop an open or gassy texture (Fig. 15.5). The brine may become cloudy with age because whey entrapped in the cheese escapes into the brine or because of microbial growth in the brine.

Fig. 15.5 Severe gassy defect in fresh mozzarella ball caused by yeast contamination in the mixer/molder

15.2.2 Low-Moisture Part-Skim Mozzarella, Low-Moisture Mozzarella, or Part-Skim Mozzarella

Milk is first standardized to a protein (casein) to fat ratio (generally a casein to fat ratio of 0.94–1.1) to ensure that the desired fat-in-dry matter in the cheese is obtained. Milk standardization is done by either the addition of casein (NDM, membrane, or condensed skim milk) or removal of cream. The latter is used more by traditionalists, while the former is used mainly to increase cheese yield and productivity. The milk is then pasteurized, cooled (33–37 °C, 92–98 °F), and starter is added. If the milk has been standardized by addition of casein (higher % casein in the milk), some manufactures will preacidify by adding an acidulant (CO_2, glucono-delta-lactone, acetic, lactic, or citric acids) prior to rennet addition. Rennet is then added.

The starters used for pasta filata style mozzarella are thermophiles, typically *Streptococcus thermophilus* (coccus), and rods, *Lactobacillus delbrueckii* or *Lactobacillus helveticus*. Traditionally, combinations of both the cocci and rods were used, but *St. thermophilus* is now often used by itself. All thermophilic strains currently used in the manufacture of mozzarella release galactose into the cheese (Hutkins & Morris, 1987). Consequently, there will always be residual galactose in mozzarella (generally 0.3–0.6%) as well as some lactose (0.4–1.0%). Residual sugar, mainly the galactose, will be very reactive in Maillard browning and caramelization during baking which results in the blisters being light brown to dark brown (Matzdorf et al., 1994). In addition, both sugars, especially lactose, can be fermented by contaminating microorganisms. If the contaminants are heterofermentative, the result of fermentation may be gas holes in the cheese or blown (gassy) packaged cheese. Some round holes in cheese may be occluded air from the stretching and molding operation, and these are generally more common than those produced by microorganisms (Fig. 15.6). These are only seen in slices or loaves of mozzarella prior to shredding. Many graders view occluded air holes as a defect in

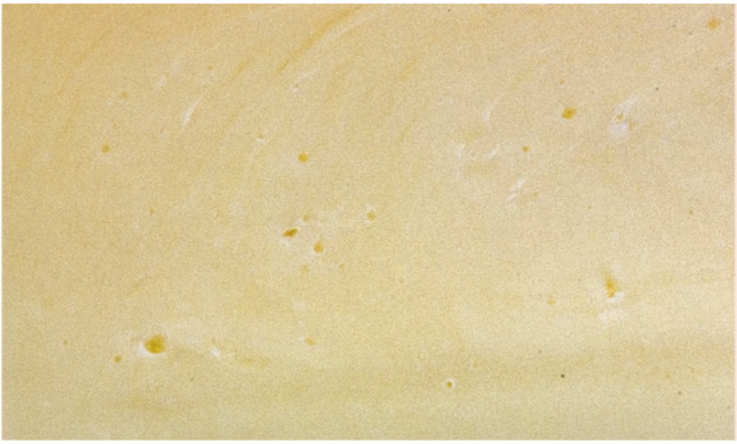

Fig. 15.6 Entrapped air resulting in small holes. These holes are often called steam holes. The cheese also exhibits some color variation called mottling and small pockets of free fat (thin white lines)

workmanship and downgrade the cheese. However, air holes do not impact taste or functional performance, nor do they impact shred appearance, and therefore, any deductions should be minimal and perhaps relegated only to contests where physical perfection is held to high esteem.

The pH of the milk at coagulant addition is a critical control point for developing the desired functional properties, as it is an indicator that the desired decalcification has occurred. After the milk is clotted, the coagulum is cut, the curd and whey mixture are heated (41–42 °C, 106–108 °F) to allow optimum starter activity and acid development and to expel whey. At a prescribed pH, the curd and whey are separated. The curd is either continuously stirred or allowed to mat. Additional fermentation by the starter will continue to decrease the curd pH to the desired pH that will allow the curd to be stretched and molded into shape. The pH of the curd at this step is the second critical control point for the cheese to have the desired functionality. Matted curd is milled and may be lightly salted. Stirred curd may also be lightly salted prior to introduction of the curd into hot water (71–77 °C, 160–170 °F) of the cooker stretcher (pasta filata step) where the curd is kneaded into a molten mass and eventually shaped into blocks or strings. The blocks are cooled briefly and then added to approximately 90% saturated brine.

There are two forms of mozzarella that could be made at the cheese factory: pasta filata and non-pasta filata (pressed block). The latter being made in large 18–290 kg (40–640 pounds) blocks, curd is not heated and stretched after whey drainage, curd is direct salted, and the salted curd is pressed for several hours. The starters used for non-pasta filata style can be thermophiles, but mesophilic strains, *Lactococcus* sp., or blends of thermophiles and mesophiles may be used. Lactococcus strains do not release galactose. Because there is no pasta filata process, the cultures would continue to ferment lactose, and this may result in excessive acidification.

Consequently, after whey drainage, the curd is rinsed or soaked with water to reduce the level of residual sugar. As a result of low sugar content or no galactose, the blisters on a pizza made with non-pasta filata cheeses tend to be yellow rather than shades of brown. Commercial pizza manufacturers generally do not like the yellow blistering and, thus, usually use pasta filata mozzarella. Non-pasta filata style is used for conversion into retail blocks for grocery store sales.

With non-pasta filata style after at least 2 weeks of storage, the blocks are typically cut into smaller retail-sized blocks rather than converted to shreds or slices. The cheese may be curdy, but this is not a fault unless the cheese is crumbly and cannot be shredded. The cheese should not be excessively soft or pasty as the consumer hand shreds or slices the cheese prior to use. Main faults of non-pasta filata are the same as pasta filata mozzarella. They may be more prone to bitterness due to the cultures and coagulants used.

Non-pasta filata and pasta filata cheeses can be readily identified by bending the cheese block and viewing the inside shape of the cheese. A pasta filata made cheese will bend substantially before breaking, but the non-pasta filata cheese will break across curd junctions. Mozzarella that is made by the non-pasta filata and stirred curd process will have a curdy appearance, while mozzarella that has undergone the pasta filata step will have a chicken breast-like texture (Fig. 15.7).

For pasta filata mozzarellas, the cheese is packaged after brining. In low-moisture part-skim mozzarella, the cheese is generally held for a minimum of 7–10 days prior to conversion into shreds, slices, or smaller blocks. During this time, there is some loss of calcium from the casein, and this results in the absorption of most of the entrapped whey into the casein network. In addition, the loss of calcium enhances the flow (melt) and stretch characteristics. Care must be taken to prevent excessive acidity in the cheese as this negatively impacts functional characteristics.

Low-moisture, low-moisture part-skim, and part-skim mozzarella can also be made by direct acidification with vinegar but without the use of cultures, and this is mainly used for string cheese. The make process begins with acidification of cold

Fig. 15.7 Visual comparison of stirred curd (left) vs. pasta filata (right) mozzarella

pasteurized milk to pH 5.5–5.6 prior to rennet addition. Some manufacturers, especially those using higher casein milks, will use a combination of direct acidification and starter addition. String cheese made with direct acidification may exhibit a slight vinegar taste, but this is not considered a fault unless it detracts from enjoyment of the cheese. In the United States, there are regional differences in consumer acceptance with the Northeast favoring string cheese made by direct acidification and the rest of the country favoring cultured string cheese.

15.2.3 Impact of Manufacturing Practices on Characteristics of Low-Moisture Part-Skim Mozzarella or Low-Moisture Mozzarella or Part-Skim Mozzarella

These mozzarellas should be milky, with a slight acidic flavor, as well as a slight to definite salty flavor, and have a distinct buttery note before and after baking. Due to the pasta filata process, the cheese will have a fibrous body and a mealy mouthfeel. Samples should not be downgraded for possessing these qualities. However, the cheese should not be dry, nor should it result in pieces clinging to the roof of the palate. These mozzarellas must be machinable or able to be shredded into long shreds or sliced, with few fines (small cheese particles that break off) being formed during the process. The potential for machinability is in the pliability and firmness of the cheese. Short-bodied or very soft cheese will not be machinable.

A plug or slice of the cheese should be extremely pliable and bend at least to the point of almost touching and be firm. Upon squeezing a plug or square of the cheese, the proper firmness for acceptable shredding is that the cheese gives slightly but bounces back. A cheese is considered to be short bodied if it does not spring back or is hard to squeeze. This type of body will result in excessive fines after shredding

Fig. 15.9 Weak-bodied cheese (left) and extremely weak-bodied cheese to the point it can be molded like playdough (right)

Fig. 15.8 Shreds with excessive clumping and number of fines due to a weak body

(Fig. 15.8). A weak, soft, or pasty body (Fig. 15.9) will result in short shreds or small pieces but excessive clumping. The cheese will also stick to the cutting blades making slicing and shredding almost impossible. Temperature of shredding is important as a cheese at 4 °C (40 °F) may be too soft and slightly inelastic, but the same cheese at 0 °C (32 °F) will slightly firm and may shred without forming fines. However, if this cheese is ultimately used in baking, it will exhibit excessive flow with a weak or short stretch and more numerous and larger blisters.

Low-moisture or low-moisture part-skim mozzarellas are widely used as ingredients in baking, especially on pizza. There is a wide range of desirable attributes, and these will be examined later in the chapter. Additionally, the type of oven and temperatures and times used in baking will influence acceptability. End users, typically pizza manufacturers, will set the desired criteria.

15.3 Evaluation Criteria for Fresh Mozzarella

Fresh mozzarella should be tempered to about 11 °C (52 °F) for evaluation. This is to prevent free moisture release from the cheese. Some free moisture is inevitable in fresh mozzarella made by direct acidification, especially if the cheese is warmed above 5 °C (41 °F), which is sometimes unavoidable in retail.

Appearance is the first thing to grade. Cheese should be white to ivory or cream in color. Fresh mozzarella should be free of mold and colored spots. There may be a small amount of free moisture at the seams of packaged cheeses, but it should not be excessive.

The cheese should be smelled to check for undesirable odors especially yeasty, rancid, unclean, or sulfur notes. The brine can be tasted for the same reason. If cheeses are packaged in brine, one complete piece is taken out and rubbed with some pressure to test for the ease at which the skin can be rubbed off (sloughing). Effortless sloughing is considered an undesirable trait. Sloughing could be due to lack of calcium in the brine, excessive proteolysis, or lack of proper acidification of the brine (pH should not be above 5.8). Excessive calcium added to the brine can impart bitterness to the cheese and may make the outer layer very firm.

Next, the piece of cheese is warmed in the mouth while chewing. There will be some moisture release, but it should not be excessive. Excessive moisture release may be accompanied by a flavor reminiscent of the brine. The cheese should be slightly chewy and not melt in the mouth. The flavor should be sweet and taste like fresh milk. Fresh mozzarella should have only a hint of salt and not be acidic nor have a vinegar flavor. The major taste faults in fresh mozzarella are lacking flavor (aka flat), bitter, oxidized, and unclean (Table 15.2). These flavors may come from the milk used to make the cheese, but they may also develop during storage. If non-fat dry milk powder (NDM) is used, it should also be tasted prior to being added as any unwanted flavor in the powder, especially cooked, stale, and oxidized flavors will be imparted to the fresh mozzarella. Sometimes manufactures will inadvertently add old cream that has oxidized or that has developed off-flavors such as excessive acid, unclean, or rancid. Rancid cream is most likely due to the cream coming from milk that has a high somatic cell count or has been agitated excessively. It is common for manufacturers to add whey cream. This should be tasted by the manufacturer prior to use, as a common defect in whey cream is oxidized flavor that imparts a whey taint in the cheese. In retail samples, oxidation by intense light exposure is common.

Table 15.2 Common flavor defects that can be found in fresh mozzarella cheese and their causes

Name	Cause
Acid/ vinegar	Low pH due to excessive starter fermentation or excessive addition of vinegar
Bitter	Excessive calcium chloride in brine or excessive proteolysis by starter/coagulant, sometimes contamination with bacteria, especially *Bacillus* sp.
Cooked	Excessive heat treatment of milk or addition of bulk starter media
Flat	Lack of milky and buttery notes. The main contributing factor is excessive age
Oxidized	Exposure of milk or cheese to light or sanitizers
Rancid	Two main causes are use of milk from mastitic animals and excessive agitation of raw milk. Pasteurization destroys the lipases naturally found in milk, but it may be less effective with milk from mastitic animals as the level of lipase is increased
Unclean	Metabolism of contaminating microorganisms or absorbed flavors from the environment

15.3.1 Fresh Mozzarella Made from Buffalo Milk

Buffalo mozzarella currently has an infinitesimal share of the mozzarella market in the United States, but it is a major contributor in other countries such as Italy and India. It is almost exclusively made as a fresh mozzarella cheese, acidified by added acids, with no starter added. Much of the buffalo mozzarella cheese found in retail in the United States is imported, and, unfortunately, this has resulted in much of it being of poor quality. This is primarily due to excessive age (over 1 month) and poor handling of the cheese, especially excessive exposure to light and warm temperatures. One of the major flavor defects of this cheese is excessive animal flavor, a somewhat ambiguous term in the United States since most graders or judges are unfamiliar with fresh buffalo milk taste. A nondescript term used is unclean. Bitter and excessively acid tastes are also common defects. Freshly manufactured buffalo mozzarella made from high-quality buffalo milk can have a sweet taste if made using direct acidification but is still a distinctly different taste from mozzarella made from cow's milk and should not be faulted for it. However, buffalo mozzarella that is described as acidic, with a yoghurt odor, or is salty or cohesive indicates that the cheese was made with a starter culture or wild strains of bacteria acidified the cheese after manufacture (Pagliarini et al., 1997). In discrimination testing of cow milk mozzarella and buffalo milk mozzarella by consumers in Italy, consumers who prefer the cow milk mozzarella cheeses were clearly separated from those who prefer the water buffalo milk products (Pagliarini et al., 1997).

15.4 Grading or Judging LMPS and Other Mozzarella-Style Cheeses

15.4.1 String Cheese and Whips

String cheese and cheese whips (Fig. 15.10) are pasta filata style, mostly low-moisture part-skim mozzarella, that are shaped into long tubes of cheese. The curd may be acidified by direct addition of acid or by culturing. If made by direct acidification, the label will list vinegar but will not include the words culture. If the cheese is made with direct acidification and added starter culture, both will be listed (Fig. 15.11). The molten mass of curd is extruded through small openings to facilitate the formation of the tube or sticks of cheese. The tubes are cut into roughly 11.5 cm (4.5 in) long by 1.3 cm (.5 in) in diameter sections for string cheese and 91 cm (36 in) long by .6 cm (.25 in) in diameter for cheese whips. They are brined briefly and packaged singly or in a bundle. The sticks of string cheese can also be cut, breaded, and frozen.

Since string cheese and whips are low-moisture part-skim mozzarella, they are judged under similar criteria. String cheese should taste milky and buttery, with lack of acidity, but it may have more salt than low-moisture part-skim mozzarella. It will

Fig. 15.10 Cheese whips

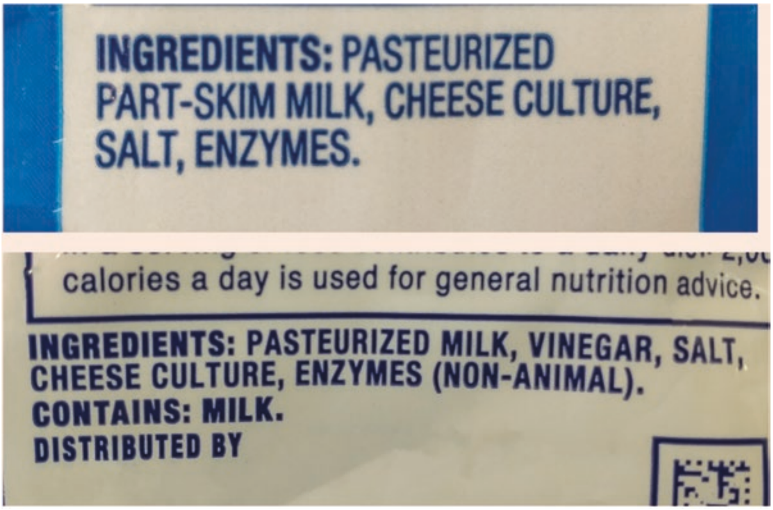

Fig. 15.11 Cultured (top) vs. acidified (bottom) string cheese labels. Enzymes are coagulants

be firm and not give under pressure. However, the most important attribute is the stringy characteristic; it must string, and the fibrous structure must be evident (Fig. 15.12). To assess the string character, the judge will pull on top of the cheese to try to tear it lengthwise. It should rip off in strings, i.e., have a fibrous structure. Excessive proteolysis will cause the cheese to soften and lead to the string breaking before it has torn the total length of the piece of cheese.

Flavored string cheese is graded on the stringy character in addition to the quality and intensity of the added flavor. The most popular flavors are smoke and pepper. As with all flavored cheeses, the consumer will determine acceptability. In contests, flavored cheeses are judged on whether the added flavors either compliment or outcompete the cheese flavor, but consumers may want intense flavor and may not care about the classic mozzarella flavor.

Fig. 15.12 String cheese with no stringing (top) vs. string cheese with plenty of stringing (bottom)

15.4.2 Oaxaca

Oaxaca cheese is a string cheese of Mexican heritage but with a twist. Instead of brining, the cheese is direct salted after the string shape is formed, the string is not cut, but a long length of the salted cheese is wrapped into a ball.

Because Oaxaca may be hand stretched, the long strings may not be of even form or thickness. The ball is unraveled for consumption, but the unraveled pieces may not always string due to the contortions of making the ball (Fig. 15.13). This is not a defect, but a fibrous structure and mouthfeel must be observed. Oaxaca is generally not used in baking.

15.4.3 Burrata

Burrata is in a way a combination of mozzarellas. It is made by forming a hot molten mass of curd into a pocket or pouch and filling the pouch with fresh curd, before it has been stretched, and that has been soaked in cream. It can alternatively be filled with strips of stretched curd (basically string cheese pulled apart) soaked in fresh cream (Fig. 15.14). Once filled, the pouch is sealed to keep the filling inside and

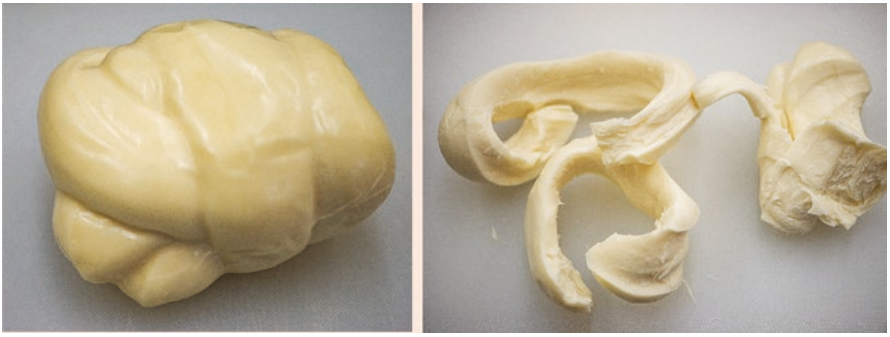

Fig. 15.13 Oaxaca cheese raveled (left) and unraveled (right)

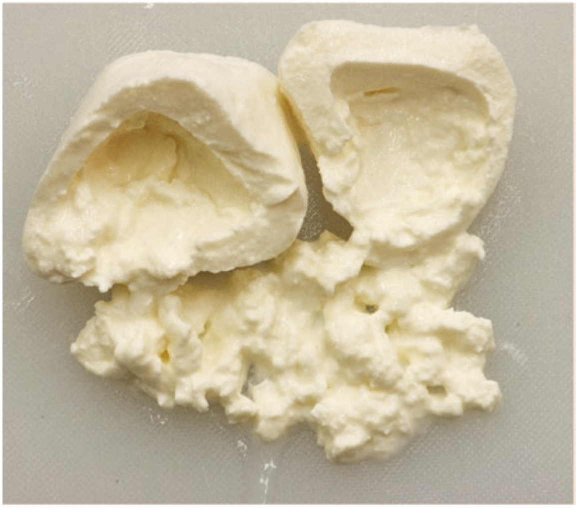

Fig. 15.14 Burrata cheese cut open

then cooled immediately. It may be is sold in a weak brine (<0.5% salt). The curd is stretched at a lower pH (~5.1) than low-moisture part-skim mozzarella to facilitate ease of forming the pouch. Burrata is typically served at room temperature. Since the shell is stretched at a lower pH, it may not be stringy, but this is not considered a fault. Burrata is not meant for baking. The mouthfeel of the shell can be mealy but not dry.

The Burrata shell may be slightly acidic, but since the cream is sweet and not fermented, the overall taste is that of fresh cream. Burrata has a very short shelf life due to its high moisture content, low salt, and fresh cream center. The major defects are too much cream, stale, or oxidized flavor, and flat flavor usually associated with faults of the cream, and slimy surface due to excessive proteolysis and microbial growth. Due to its high interior pH, there is potential for rapid growth of undesirable microorganisms and off-flavors associated with their metabolism. Since the cream is not acidic, it can cause the shell and fresh curd within the shell to increase in pH, and this causes both to become very soft. This is not generally considered a defect and may be a desired attribute.

15.4.4 Provolone

Provolone is a pasta filata cheese made similarly to low-moisture mozzarella cheese, but it has a lower maximum moisture content of 45% (Table 15.1). Manufacturers are allowed to make provolone cheese from raw milk, provided the subsequent cheese is aged for 60 days at or above 1.7 °C (35 °F). Provolone cheese is often molded in a salami shape but comes in a number of other unique shapes including a pear shape (Mandarino) and a truncated cone (Gigante), among others. Like mozzarella, provolone may be sold within a few weeks of manufacture and is evaluated on the same flavor and body characteristics of low-moisture mozzarella cheese before and after baking on a pizza. It may or may not have detectable rancidity. It is not a fault to have or to not have rancidity. It is most often used as a component of the cheese blend on pizzas to add additional flavor (slight rancid notes), and its use may result in an increase in free oil release. It is, therefore, evaluated on pizzas as a blend and not by itself. Unlike mozzarella, provolone is often aged for several months to develop very intense flavor notes. The desired flavor is sweet (but not buttery) with a pleasing, balanced level of rancidity from butyric acid. Generally, the desired level of rancidity in aged provolone is described as definite to pronounced. Aged provolone may be brittle, have a mealy and dry mouthfeel (due to the pasta filata process), and have poor stretch but will melt readily. These are not faults for aged provolone cheese.

Lipase enzymes may be added to the milk to develop rancidity in the cheese. Mild provolone may have no lipase added or relatively small amounts to give just a hint of rancidity to the cheese. It may take several weeks before a rancid note is detected. Traditionally, lipase enzymes from young mammalian animal sources were used, including kid goat, lamb, and calf. Each of these enzymes gives different flavor profiles to the cheese, with kid goat and lamb lipases giving sharper piquant flavors and calf lipase giving milder piquant flavors. Frequently blends of these different species lipases were used to give a more rounded piquant profile to the cheese.

Many provolone cheese manufacturers have switched to using lipases derived from microbial sources due to the need to have Kosher and Halal certification, especially if whey products are made. While microbial lipases are readily available and offer lower cost than lipases derived from mammalian sources, the flavor profile generated by microbial lipase enzymes is typically not as acceptable. This is likely due to their nonspecific hydrolytic activity resulting in cleavage of longer chain fatty acids. Longer chain fatty acids result in a cheese that lacks the sweet and butyric flavor notes seen when animal sources lipases are used. A common sensory defect in provolone cheese made using microbial lipases is the soapy flavor imparted by the higher chain fatty acids.

The standard of identity for provolone cheese specifically allows for smoke flavors to be used. Traditionally, this smoke flavor was imparted to the cheese through a cold smoking process. However, sometimes liquid smokes are used, either by direct application to the curd prior to cooking and stretching or more commonly by immersion of the finished salamis of provolone in a solution of liquid smoke. Regardless of the type of smoking agent used, the flavor should not be harsh, biting, and overly intense to the point that it overwhelms rather than compliments the flavor of the cheese.

15.4.5 Cheese Slices

The most important criterion for sliced mozzarella is the ease of slice separation and the integrity of the slice (complete, no corners missing). After visual inspections are complete, the cheese is evaluated for flavor and body. The scoring system and list of attributes vary depending on the end user. A scoring may be a simple +/− assessment or a more detailed rating which quantifies attributes in terms of intensity (slight, definite, pronounced).

15.4.6 Evaluation of Mozzarella as a Predictor of Performance

End-use application of mozzarella requires that it can easily be machined into shreds and slices. The convertor does not want to purchase cheese that cannot be easily sliced, cut into even weight blocks or shredded. This requires that either the cheese manufacture's grader or the convertor's grader assess the cheese for the potential to be machined prior to the actual conversion. What do they look for? A premium is placed on slice characteristics as this is the characteristic that is often the hardest to achieve. For a cheese to be sliceable, it must be cohesive, not curdy, at least slightly flexible and not pasty. Pasta filata mozzarella is more apt to possess these characteristics than non-pasta filata mozzarella so the latter is rarely, if ever, used for slicing applications. The position in the slicer or shredded is important since a crosscut can easily lead to fines (small pieces of cheese). Pasty cheeses will gum up the blades, and they become ineffective for their purpose. Very short-bodied cheeses do not slice and when converted to shreds may produce excessive fines.

Prior to conversion, mozzarella made by the pasta filata process is evaluated for consistency of firmness. The most commonly occurring fault is soft end, but the defect can be observed anywhere on the outside of the cheese. The ends may absorb salt at a faster rate than the sides and much more so when the cheese is very hot when placed into the brine. Since the cheese is still very hot, serum trapped within the block is readily able to migrate to the outside of the blocks where the cheese is high in salt. This can create a noticeable color difference. The high salt content attracts the serum, and this results in high-moisture cheese that is very soft and not cohesive and may not be machinable. The serum comes from the interior of the block, and this can lead to a drier, potentially brittle cheese prone to excessive fines when shredded (Fig. 15.15). The high salt causes the casein to aggregate so that it scatters light and appears white. In the interior, the casein network is more dispersed (if the pH is around 5.1–5.2) and cannot scatter the light, so the appearance is straw colored. This phenomenon occurs in lower fat mozzarellas, because in higher fat cheeses, the fat will disperse the light. Rinsing or soaking the cheese in a cold-water bath prior to brining can lessen or eliminate this issue. Coincidentally upon heating, the straw-colored cheese will become white due to aggregation of the casein by heat, but when cooled, it will revert to the straw color (Johnson & Lucey, 2006).

15.4.7 Contest Judging of LMPS Mozzarella

Low-moisture or low-fat versions of mozzarella cheeses are usually plugged horizontally for judging. They are first examined for evenness of color, firmness, the absence of excessive holes, and pliability. Next a sample is chewed to evaluate flavor and body.

Most LMPS mozzarellas are used in baking applications; however, in contests, they are not judged on their baking characteristics but rather on criteria that may have no impact on baking performance.

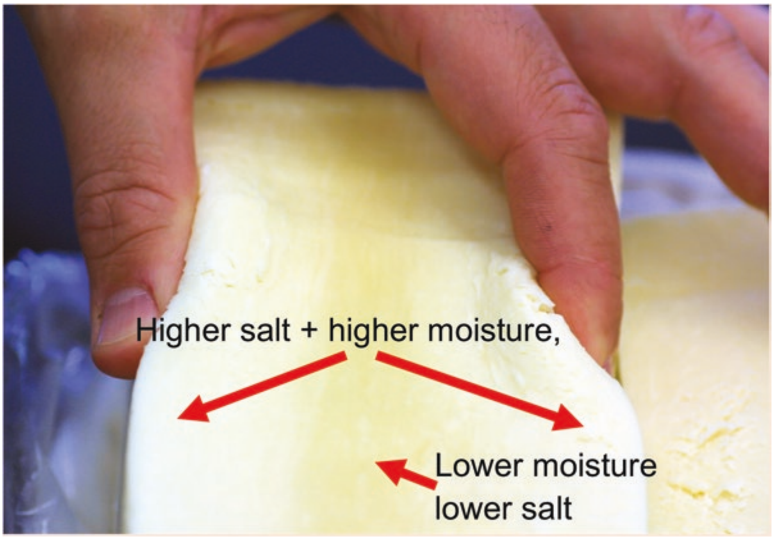

Fig. 15.15 Influence of moisture, pH, and salt on color and body of cheese

15.4.8 Defects in Appearance, Texture, and Body of Uncooked LMPS Mozzarella

15.4.8.1 Open Texture

Open texture refers to openings or round holes in the cheese. The holes most commonly originate from entrapped air due to poor mechanics of transporting molten curd into forms. It is possible that microbial fermentation is the source of the gas that causes the holes but that is rarely the case. In the unlikely event that fermentation does happen to be the source of the gas holes, it is potentially due to fermentation of urea by the starter, *Streptococcus thermophilus*, which can release carbon dioxide that accumulates as gas holes. Openness is cosmetic and will not influence bake performance. Cheese may exhibit openness (holes and slits), and packages may be blown due to metabolism of heterofermentative microorganisms such as *Leuconostoc*, *Lactobacillus*, or yeasts.

15.4.8.2 Mottled Appearance

Mottled appearance refers to white broken by semitranslucent (straw colored) areas. This is a defect because Mozzarella should be white without interruptions.

During the mixing molding step, fat accumulates in large pools. If there is too much churning (long time), some areas of the cheese will be high in fat, and others will be much lower in fat. Since fat reflects light, the low-fat areas will be straw colored. Sometimes the cheesemaker will notice that the cheese coming from the mixer molder will not have the desired smooth body and will put the cheese back into the mixer molder to be "reworked." Excessive amounts of "reworked" cheese will result in a mottled appearance. Excessive mottling can alter the cheese bake performance as there will be low- and high-fat areas, and fat has a major influence on bake performance. Differences in pH can also cause mottled appearance in low-fat cheeses with very high pH or low pH areas being white and cheeses with a pH or 5.1–5.3 being translucent.

15.4.8.3 Cream-Colored Specks or Globules in the Cheese

Cream-colored specks are churned fat. Sometimes specks are related to mottled appearance, especially if rework cheese has been added. These fat pockets will have a higher buttery flavor than the rest of the cheese.

15.4.8.4 Tiny White-Brown Specks in Cheese

Occasionally rehydrated dried milks are used in the manufacturing of reduced-fat or skim milk mozzarella cheese. Undissolved powder will be caught in the casein network during the clotting process and appear as very tiny specks. If the dried milk has been produced under excessive heat and there is substantial denatured protein, the specks may appear brown to black. In this case, the cheese may taste overly cooked and may brown as the cheese gets older due to continued Maillard browning. The melt and stretch characteristics of cheese made from milk that has substantial denatured whey protein may also be impaired. Furthermore, there may be many shreds that burn in place, and the network of cheese on the pizza may take on a pocked-marked appearance. Once melted, the cheese may not stretch. Often upon biting into a slice of pizza, the cheese may come away as one piece.

15.4.8.5 Surface Defects of Packaged Mozzarella

The three most common issues of packaged mozzarella are uneven color (mottled), blown or gassy packages, and slimy (damp) surface. A mottled surface is most often seen in low-fat cheese as the result of either excessive moisture loss in the brine due to the brine being too high in salt or the cheese being excessively acidic. Blown or gassy packages are the result of gas formation due to heterofermentation of residual lactose or galactose by contaminants that have gained access to the cheese during conversion. *Leuconostoc mesenteroides* has been used, albeit rarely, as a potential diacetyl producer in cheese from metabolism of citric acid. It produces carbon dioxide from citric acid and residual lactose. A damp surface (usually only seen in fresh mozzarella not packed in brine) is due to the high pH or very low pH often with exposure to warm temperatures or excessive proteolysis. Free serum can lead to slimy surfaces due to microbial growth.

15.4.8.6 Evaluation of Mozzarella for Non-pizza Baking Applications

A major use of mozzarella is in the use of lasagna, chicken parmesan, and fried cheese curds. The main criteria are that the cheese melts but not excessively, that it stretches, and that it is slightly chewy.

15.5 Assessing the Baking Performance of Mozzarella

15.5.1 Fresh Mozzarella

Fresh mozzarella should soften when baked but not have excessive flow. The cheese stretch will often be extremely long (>90 cm, 3 ft), especially if the pH is around 5.7. Long stretch and lack of flow when heated are two characteristics that go hand in hand. Excessive proteolysis limits shelf life and will cause the cheese to flow excessively and have a short stretch. The edges of the cheese may also burn because the cheese is thinner there. If the cheese has lost too much calcium or is low in pH

(<5.6), the baked cheese may also flow excessively, have a shorter stretch, and form blisters that will dry out and burn, especially at the edges where the cheese is thin.

Other mozzarellas when baked are assessed on blister coverage, blister color, melt and stretch characteristics, free oil release, ability to cut cleanly, taste, and mouthfeel including chewiness, cohesiveness, and fat release. Evaluations are based on criteria set between the cheesemaker, convertor, and the end user, usually a pizza manufacture.

15.5.1.1 Sample Preparation of Low-Moisture Mozzarella for Baking Performance

The most common model for evaluating mozzarella bake performance, or functionality, is a cheese pizza made with a standardized minimal amount sauce and a standard amount of shredded cheese with no additional toppings. Toppings will drastically change the surface characteristics of the baked cheese, especially the blister coverage and color. Care also needs to be taken to ensure to choose a sauce that will not impart a strong flavor. Oven type and temperatures and times used in baking are set by the end-user specifications, as are crust thickness and type of baking pan. A suggested standard formulation for mozzarella pizza evaluation is as follows: 30 cm (12 in) par-baked thin crust (ordered from the food service sector), three tablespoons of tomato sauce, and 300 g (10.5 oz) of shredded cheese. The pizza is then covered with plastic wrap and tempered to 4.2 °C.

Whole pizzas should be evaluated with only one mozzarella sample used per pizza. Partial pizzas may cook differently, and evaluators can more accurately appraise the surface characteristics on a whole pizza. Examples of cooking specifications for different types of ovens are as follows: home oven, 218 °C (425 °F) for 12 min, and forced air oven (i.e., impinger or conveyor oven) 260 °C (500 °F) for 5 min. Impinger ovens are often the industry standard and represent the harshest conditions of baking since they effectively eliminate the protective moisture that would otherwise protect the pizza surface against the heat. Thus, use of an impinger oven can yield significantly different bake performances (Fig. 15.16).

Upon removal from the oven, the interior temperature of the mass of melted cheese should be taken. With many samples tested, an average temperature range can be established and will help in evaluation. Temperatures below or above this average temperature may indicate improper baking or indicate changes in cheese characteristics that might allow or prevent excessive evaporation.

15.5.1.2 Evaluation of Visual Pizza Characteristics

The appearance of the baked pizza provides an immediate quality impression. The most common assessed surface characteristics are as follows:

Fig. 15.16 Pizzas made with the same cheese but cooked in a conventional home oven (left) vs. forced air oven (right)

15.5.1.3 Skinning

Skinning refers to a film of partially dehydrated cheese at the surface of the melted cheese layer. Skinning is not the same as blistering as the skin is not burned cheese, nor is it caused by the raised surface of the cheese due to internal steam being released. It is very common when fat is not released during baking or when blisters are not formed as occurs with fresh mozzarella. Very low-fat mozzarella baked without condiments on the pizza often exhibits excessive skinning. In the latter, it appears as though a plastic film was placed over the cheese as it was baked. Excessive skinning can result in the entire cheese being pulled from the pizza surface upon biting into it. To evaluate skinning, a fork is placed on the cheese surface and pulled across the pizza, while it is still relatively fresh from the oven. The more the cheese moves as a single sheet, the more skinning is present. It is not the same as stretching as no cheese is pulled. Excessive skinning can result in the cheese sticking to the teeth when it is eaten.

15.5.1.4 Blister Coverage and Blister Size

Blisters are defined as raised areas on the surface of the baked cheese. They are common on pizzas baked in impinger ovens. Shreds that are not melted are not considered blisters even though they are burned and browned.

Blisters occur due to steam from beneath the cheese surface, pushing upward on the cheese. If the surface of the "pre-blister" dries before it can release the steam, a blister is formed. The more continuous the casein network, the greater the potential for blisters. Consequently, the higher the fat content of the cheese, the less blister coverage (Fig. 15.17). A zero-fat mozzarella, as it ages, typically forms very large blisters and in some cases one blister that covers the whole pizza surface when baked on a pizza using a forced air oven. Young, zero-fat mozzarella may not blister, and the shreds will not melt (Fig. 15.18).

The addition of condiments will greatly reduce blister coverage and color. They not only break up the casein network which prevents blisters, but they can release either fat or moisture that may cool the surface preventing burning. Blends of skim milk and whole-milk mozzarella to obtain a 10.5% fat content (required by USDA for school lunch program) produce better surface characteristics than a cheese manufactured with 10.5% fat content. Fresh mozzarella should not blister although the edges of the mozzarella slices may dry and thus burn. This is more likely to occur as the cheese ages (more proteolysis), and there is more flow when heated (Figs. 15.19 and 15.20). Excessive flow can also occur if the pH is too low (<5.6) or if the cheese is too high in fat.

Proteolysis may enhance blister size if there is enough intact casein network with sufficient pliability to allow the blister to form. In older cheeses, the height of the blister may be shorter, but the area covered by the blister will be larger. Proteolysis will also result in a thin skin on a blister, which will dry and burn more rapidly. In addition, free moisture release from the cheese may be enhanced as the hydrolyzed casein may not be able to hold entrapped moisture and the moisture evaporates quickly. Free oil release also increases since a hydrolyzed casein network can no longer entrap it. Fat release does not prevent larger blisters from forming, but it may reduce blister color if there is a lot of free oil release.

15.5.1.5 Blister Color

Blister color is defined as the intensity of browning at the surface of blisters. The color is caused by the burning (dehydration) of the casein layer on the blister and caramelization of residual sugars. Even though cheese under the blister may contain

Fig. 15.17 A pizza with the left half made with low-moisture part-skim mozzarella and the right half with low-moisture whole-milk mozzarella

Fig. 15.18 Very young fat-free mozzarella cooked in an impinger oven, shreds do not melt

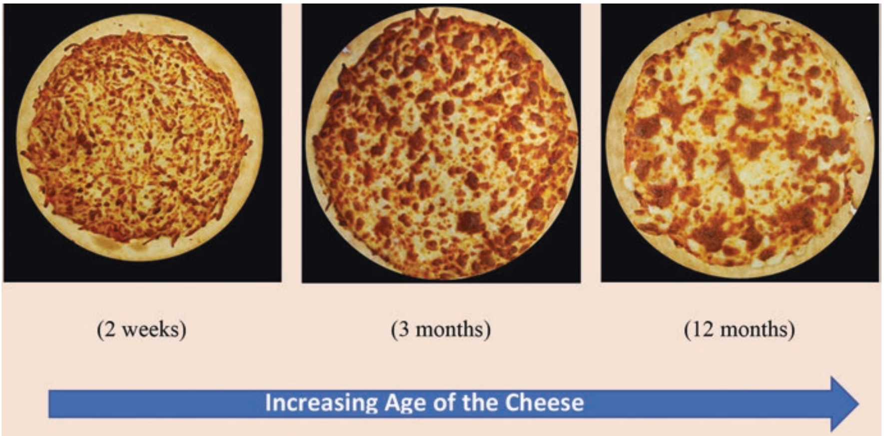

Fig. 15.19 Pizzas made with the same cheese but at different ages will present different melt behaviors, from low melting at 2 weeks to larger blister development at 12 months

high amounts of residual sugar (>0.6%), it does not brown because it does not become dehydrated. Lack of residual sugar in cheese will often result in yellow blisters. Blister color is also increased by use of flow agents, forced air ovens, higher bake temperature, longer bake time, and reduction in cheese fat.

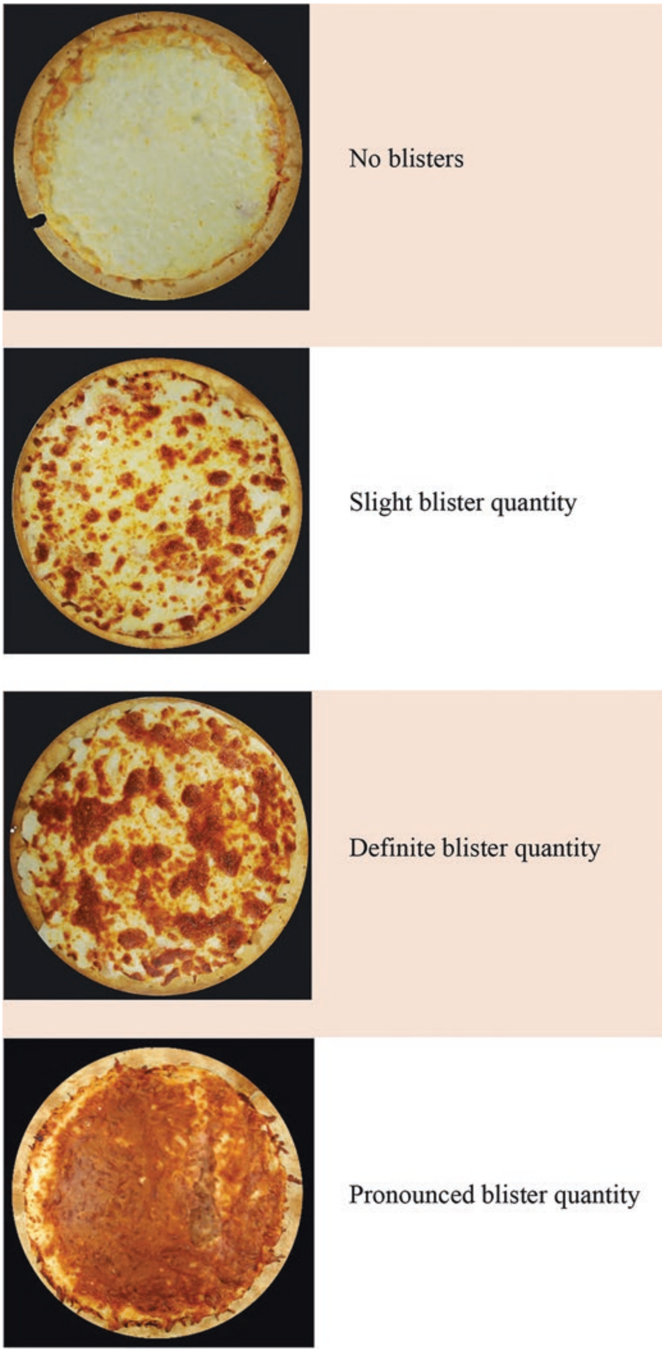

Fig. 15.20 Different degrees of blister quantity, from none to pronounced

15.5.1.6 Oil Release

Oil release, more commonly referred to as free oil, is defined as the amount of fat that pools at the cheese surface after baking. Often the pooling occurs around blisters as fat drains downhill from the sides of the blister. It has been suggested that the loss of fat from the blister surface allows for more moisture evaporation, which in turn hastens the burning of the blister (Rudan & Barbano, 1998). Free oil should be measured shortly after the pizza is removed from the oven at a predetermined temperature.

Typically in cheese, fat is entrapped by the casein network during the clotting process and remains in small discrete pools in the casein network. However, in pasta filata mozzarellas, the cheese mass is churned in the mixing molding step, and the casein network tightens due to the heat and aggregates into threads. Moisture is squeezed out from the casein network and the molten fat and is now free to coalesce into large pools between the casein threads. Even when the cheese cools, the pools of fat remain since the casein network cannot reabsorb the fat; however, the moisture will be reabsorbed if the pH is within the limits of approximately 5.1–5.7. When the cheese is subsequently heated again, the casein tightens and the large pools of fat are released. This is why care should be taken to consistently evaluate this attribute at the same temperature, as the amount of oil release will increase greatly as the pizza cools. Release of moisture is partially related to the pH of the cheese. Shredded cheese offers a greater surface area and greater opportunity to release fat. Proteolysis will cause the casein network to flow more readily, and this will expose more of the pools of fat and consequently more free oil.

Fresh mozzarella, even though it has gone through the pasta filata process, only shows minor free oil release, unless the cheese has undergone extensive proteolysis. Much more moisture is released from fresh mozzarella compared to LMPS during baking. Fresh mozzarella is higher in pH (pH 5.7) than cultured mozzarella (pH 5.2). Retention of moisture by casein is highest at pH 5.2 and falls off tremendously at pH below 5.0 or above 5.7.

The amount of oil released is influenced by the same factors that affect cheese flow: pH, fat content and proteolysis (age). Another major factor, at least initially, is the manufacturing style: pasta filata vs. non-pasta filata. Pasta filata may exhibit twice the amount of free oil than non-pasta filata style in a young cheese, but with age, proteolysis will enhance oil release to similar amounts. Furthermore, cheese baked in ovens in which cheese temperatures rise sharply (i.e., forced air ovens) or where the heating process is disruptive (microwave or combination microwave/forced air ovens) tend to exhibit more free oil.

15.5.1.7 Shred Identity or Shred Melt

Shred fusion is defined as the degree to which baked shreds melt (fuse) together into a homogeneous mass. Evaluation is done by observing the number of individual shreds that have burned in place without losing their shape. They are not blisters.

The presence of burned shreds is caused by lack of cheese flow during baking and perhaps lack of fat release, which allows the cheese to rapidly lose moisture and burn. The shred is burned in place and is most likely very dark (Fig. 15.21). Excessive shred identity is indicative of a tough dry cheese.

Some additional factors that contribute to the lack of flow and subsequent incomplete fusion are: cheese is very young, use of anticaking agents, and the pH of the pizza sauce is too low. A young cheese (<2 weeks) can present an insufficient loss of casein-bound calcium, resulting in a stiff protein network that will not flow. Regarding the pizza sauce, if a pizza is made with excessive amounts of a low pH sauce and allowed to sit for a few hours, the sauce will reduce the cheese pH. If the pH drops below 5.0, the cheese may not flow when heated.

15.5.1.8 Flow-Off Crust

Flow-off crust refers to the degree to which the melted cheese flows off the crust. It is related to cheese composition (high-fat melts more readily), use of flow agents (restricts melt and flow off crust), and degree of proteolysis (more proteolysis more flow-off crust).

Fig. 15.21 Pizza with incomplete shred fusion

15.5.1.9 When to Evaluate Surface and Stretch Characteristics of Baked Pizza

Surface characteristics are the first attributes to be examined and should be evaluated before any disruption to the surface is done. A standard evaluation temperature should be designated for free oil and free moisture to ensure consistency across measurements. The whole pizza is examined, and a judgment is based on median intensity. An individual location should not be taken as the point of evaluation, but rather the whole pizza surface should be looked at holistically.

The baked cheese is also evaluated for stretch characteristics at a designated temperature, as stretch is strongly influenced by temperature. A typical evaluation temperature is 91 °C (195 °F). If cheese is examined right out of the oven, the stretch may be short and thin. The length of stretch is performed by placing a fork tine 1 cm into the melted cheese and pulling up. The stretch test is done at three different areas on the pizza. There may be considerable variation in length, so more sites may have to be evaluated. Blisters are to be avoided, and if they cannot, the cheese underneath the skin or blister is evaluated. The fork is slowly and steadily pulled upward until the strand of cheese breaks. To evaluate tenting and thickness of the stretch, the cheese is only pulled to a height of 15 cm (6 in).

15.5.1.10 Stretch Characteristics

Stretch characteristics that are routinely evaluated are length, tenting, splintering, and the force to stretch. The evaluator will not only determine the maximum length of the cheese strand before it breaks but will also evaluate how much force it took to pull the cheese and how the cheese pulled from the pizza surface.

Young cheese will require more force to pull the cheese, and the cheese will want to stay on the pizza surface. Consequently, a cone forms at the base of the strands being pulled. This is called tenting (Fig. 15.22). A low pH or proteolysis will decrease tenting as well as decrease stretch length. Tenting is evaluated as it may be indicative of the tendency of the cheese to separate from the crust as one piece, when the pizza is initially bit into. Tenting will be indicative of a young or tough cheese.

Splintering or cheese roughness is the amount of cheese strands that break away from the main strand as the cheese is being pulled. Splintering indicates a cheese with too much calcium bound to the casein. This is also indicative of a young, firmer cheese.

The strand length and splintering are both affected by pH. A slightly higher cheese pH (>5.25) and a higher FDM will increase stretch length and decrease splintering. Long stretch may be a desired attribute for some pizzerias, especially in China, but may not be so in others.

Fig. 15.22 Example of tenting during stretching of cheese

15.5.2 Thickness

Strand thickness is defined as the width of the strands at a height of 8 cm (3 in) above the pizza surface when the strand is pulled 15 cm (6 in) (Fig. 15.23). If the cheese breaks before it reaches, 15 cm the thickness is scored as none.

15.6 Evaluation of Body and Mouthfeel Characteristics of Pizza

15.6.1 First Chew Hardness

First chew harness is the force required to bite through a melted cheese sample using the molars. This is evaluated by stripping a small square (approximately a 4 cm × 4 cm (1.5 in) of cheese from the pizza surface and folding it into quarters (can be done in the mouth) by folding the outer surfaces inward to avoid the influence of skinning and blistering and then completely bite through it with the molars. Evaluate the force required to bite through the cheese. Examination will require that the cheese be at a prescribed temperature that will not burn one's mouth and

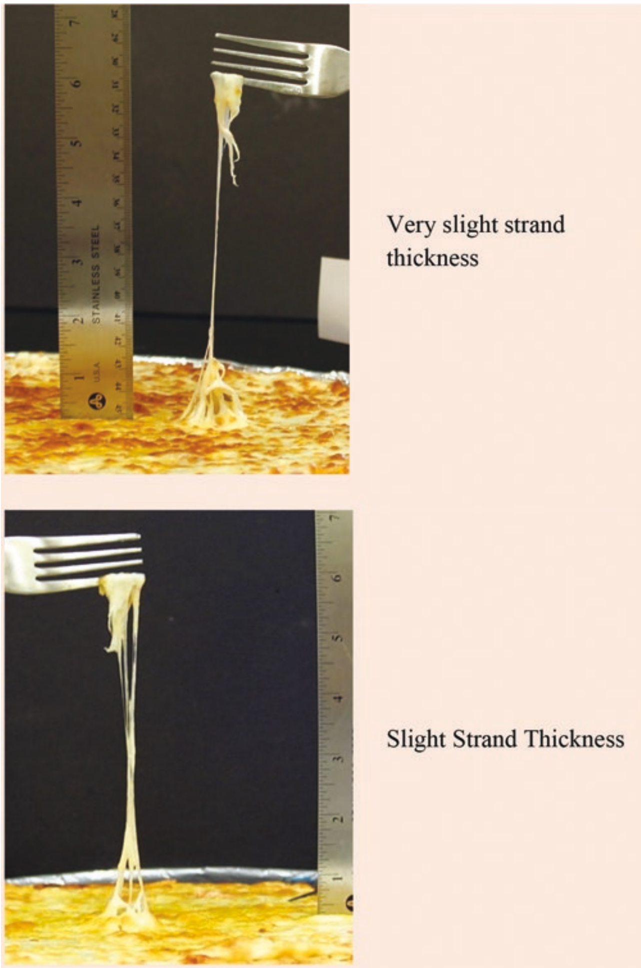

Fig. 15.23 Different degrees of strand thickness from very slight to pronounced

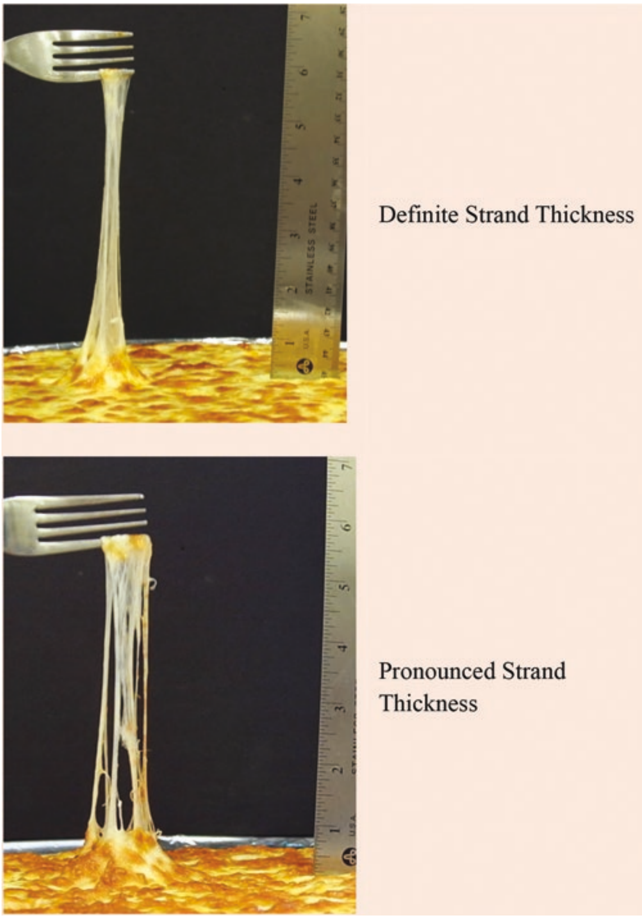

Fig. 15.24 (**continued**)

is comparable to the temperature a consumer would usually consume a slice (62 °C (145 °F)). Table 15.3 describes the effects of different factors on first chew hardness.

15.6.2 Chewdown/Chewiness

Chewdown/chewiness is described as the total effort to break down the cheese before the evaluator is ready to swallow the sample. This is a product of cohesiveness, hardness, and springiness. As these three factors increase, so does the

Table 15.3 Effect of different factors/conditions on the intensity of first chew hardness

Factor	Effect on first chew hardness intensity
Increased fat content	Decreased
Higher protein	Increased
Higher pH	Increased
More calcium bound to casein	Increased
Less proteolysis	Increased

chewiness of the sample, albeit, these factors may increase or decrease independently of each other. For example, as a cheese ages, it becomes softer (decreasing chewiness) and more cohesive (increasing chewiness).

15.6.3 Cohesiveness

Cohesiveness is defined as the degree to which a sample holds together while chewing. It is evaluated by chewing the cheese sample a specific number of times, then gathering the sample to the palate, and evaluating how much of the mass is compacted or in loose particles. High level of cohesiveness means that the chewed sample forms a continuous compact mass. However, this may or may not be indicative of a chewy cheese. If a cheese rapidly breaks up into pieces, the smaller pieces may still be firm enough to require substantial chewing.

15.6.4 Liquid Release

At times during the initial chew, the cheese will release copious amounts of fat and moisture. This will occur more intensely in young cheeses and decreases with aging due to proteolysis. It is assessed by chewing the sample a specific number of times (typically 10–15), then pressing the chewed mass against the palate. The assessor then evaluates the volume of the expelled liquid. The remaining cheese can be chewy as it is made of mostly casein. The higher the fat and moisture content, the greater the liquid release. It is particularly important to specify the number of chews to be applied before assessing as the amount of liquid released changes with the progression of chewing; the initial chews release the highest volume of liquid, while the rate of liquid released decreases with chewing. To avoid mixing excessive saliva into the released liquid, the cheese should be chewed on only one side of the mouth.

15.7 Evaluation of Shreds

15.7.1 Evaluation of Shred Quality

It is of utmost importance that convertors can predict shred characteristics or slice-ability of the mozzarella blocks. However, the temperature of evaluation can impact the results. A cheese at 5 °C (42 °F) may not shred, but the same cheese at O °C (32 °F) may do so beautifully. However, at O °C, the cheese is so cold that it can be hard to evaluate clumping.

Once the cheese is shredded, the following attributes should be regularly evaluated:

15.7.2 Matting and Fusion

The matting or clumping of shreds occurs when the shreds have been compressed (Fig. 15.24a). Clumping is more likely to happen with high-moisture and high-fat cheeses. Shreds should preferably present little to no clumping, especially if they are to be sold to the consumer. However, some clumping can be forgiven if the clumps break apart easily and are not sticky. If left to clump for too long, shreds can eventually fuse back together, losing their individual shred identity (Fig. 15.24b).

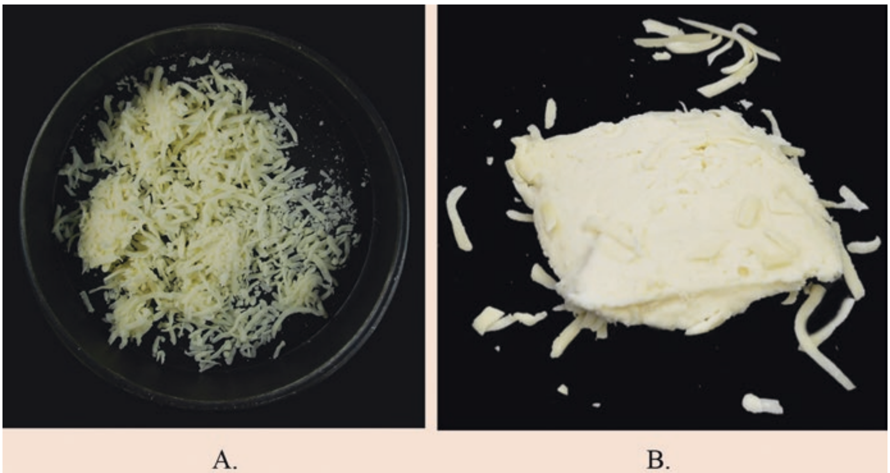

Fig. 15.24 (**a**) Excessively clumped shreds. (**b**) Shreds which have started to fuse back together

15.7.3 Flow Agents

Flow agents are compounds (usually either cellulose or potato starch based) that are tumbled with the shredded cheese to allow it to move through processing and packaging. They help to prevent the shreds from matting. However, excessive use of these agents can give the cheese a powdery texture in the hands as well as in the mouth (Fig. 15.25). The use of anticaking agents will also affect the bake of the pizza, as they will tend to burn more readily and cause more blistering.

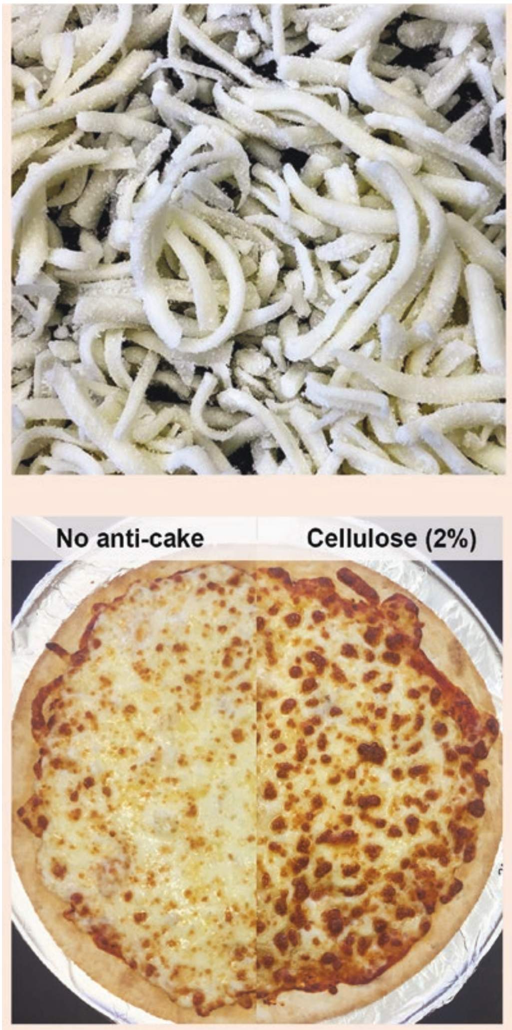

Fig. 15.25 Example of shreds with excessive anti caking agent (top); impact of anticake on blistering and color (bottom)

Fig. 15.26 Shreds that have an excessive number of fines

15.7.4 Fines

Fines are pieces of shreds that have broken off during processing (Fig. 15.26). Fines can be caused by an insufficient loss of calcium and are commonly formed when a short-bodied, tough cheese is shredded. They can be examined by placing a predetermined amount in a pan and lifting or moving the shreds to see what fines fall underneath. Fines are particularly a problem when making pizzas as they will burn and dry in place during baking.

15.8 Manufacturing Parameters that Determine Mozzarella Quality and Desirable Functional Characteristics

After the evaluation of mozzarella either for direct consumption (fresh mozzarella, string) or for baking on a pizza, the question is: what can the cheese maker do to accommodate the complaints?

The physical and bake characteristics of mozzarella cheeses are governed by three basic concepts that the cheesemaker controls: cheese composition, loss of calcium from the casein, and cheese pH (Guinee et al., 2002, Pastorino et al., 2003, Lucey et al., 2003, Johnson & Lucey, 2006, Ah & Tagalpallewar, 2017). Most issues with poor performance of mozzarella can be alleviated by adjusting these concepts to fit the needs and desires of the end user.

However, even if the cheesemaker produces a cheese that exactly fits the criteria that the end user desires, at some point, the cheese quality will deteriorate due to proteolysis. Excessive proteolysis limits shelf life. This can be perceived by an excessively soft body, lack of machinability, lack of string in string cheese, and undesirable bake performance noted by excessive free oil release, excessive melt, loss of stretch, and excessive blister coverage and darkness of blister color (Johnson & Lucey, 2006). In addition, there is always the potential for microbiological contamination during manufacture of conversion.

Most undesirable cheese characteristics are due to one of seven causes, six of which are under direct control of the cheesemaker. *First*, because of the mild, subtle flavor characteristics of mozzarella, any flavor defects in any ingredient including the milk used to make the cheese have the potential to carry over to the cheese. The same holds true for any ingredient used in standardizing the milk, i.e., nonfat dry milk (NDM) and whey or sweet cream. Stale and oxidized flavors from these ingredients are readily imparted to the cheese. In addition, excessive heat application during manufacture of NDM may produce scorched particles that if incorporated into the cheese will be visible as very small brown to black spots. Browning of the cheese may occur during storage as it appears that excessive heating during manufacture of the NDM can lead to intermediates of the Maillard reaction that continue to form darker color in the cheese. Use of high-heat NDM can also lead to crumbly cheese and restricted melt and stretch of the cheese when baked on a pizza. Incorporation of denatured whey protein is used to boost cheese yield though an increase in moisture can also lead to restricted melt, loss of stretch, and mealy mouthfeel, if too much is added.

The *second* cause for undesirable characteristics is due to inconsistencies in cheese composition, generally too much moisture and fat, due, in part, to inconsistencies in milk composition. Milk composition in terms of casein to fat ratio (or protein to fat ratio) determines the FDM of the cheese. The manufacturing schedule determines the moisture content of the cheese. While this issue has generally been solved by standardization of milk composition, it is sometimes not done correctly, or manufacturing protocols are not adjusted for the method of standardization. Adjustments in manufacturing schedules may have to be made to adjust moisture content of the cheese in relation to the FDM.

A high FDM coupled with high moisture content can lead to excessively soft cheese and shorter shelf life, which is manifested by issues with poor machinability (gummy, pasty body) and bake performance including excessive free oil, excessive melt, and low stretch length. Some of these issues can be alleviated by manufacturing cheese with slightly higher pH and using as little as possible of a less nonspecific coagulant. Blister size increases as the fat decreases, and with an increase in proteolysis.

Most manufacturers standardize milk to a consistent protein to fat ratio (or fat to protein ratio), but they should also be standardizing milk to a consistent percentage of protein and fat. In conjunction with standardizing the milk composition, it follows that the rate and extent of acidification should also be standardized. However, this works best if the milk is of consistent composition.

Third, many undesirable characteristics have their roots in improper acidification of the milk prior to coagulant addition and improper cheese pH. The rate and extent of acidification required will change due to the amount of casein in the milk and not the casein to fat ratio. Higher casein in the milk will require more acidification prior to coagulant addition. As with any cheese, the bake characteristics are strongly influenced by loss of calcium from the casein, pH, and proteolysis. Too high a pH (less solubilization of calcium) will lead to a tough cheese, poor melt, and stretch. Because calcium equilibrium (additional loss of calcium) may take several days to 2 weeks to occur, the baking characteristics will also change during that time. The cheese will be firmer, and the shreds may not melt or flow when baked. This will leave shreds that will burn. Consequently, evaluation prior to 2 weeks may lead to an error in determining whether or not the mozzarella cheese will meet expectations. Fresh mozzarella however, which is acidified by addition of acid rather by starter fermentation, can be evaluated the day of manufacture as very little if any further loss of calcium occurs after the milk has been acidified.

Fourth, there is considerable residual rennet activity in mozzarella cheese, unless the curd has been heated for several minutes above 74 °C (165 °F). Rennets, however, do vary in the sensitivity to heat. Extensive proteolysis by residual rennet will soften mozzarella to the point of being pasty or weak bodied, and it will result in excessive flow when baked accompanied by more fat release, loss of stretch, and larger blister size which may also be darker compared to a cheese with less proteolysis. Cheesemakers can also decrease the amount of proteolysis by using less rennet and using a rennet with a more specific activity. Cold storage of the cheese will slow proteolysis and the colder the better, even as low as −2 °C (28 °F). Freezing and thawing may result in an increase in the rate of proteolysis and result in more blistering. Freezing may result in moisture accumulation in large ice crystals. When thawed, the moisture may not reabsorb into the cheese and evaporates rapidly, and this dries the cheese surface making it more prone to blister formation, burned shreds, and skinning. Frozen, then thawed, but then refrozen cheese tends to dry much faster than cheese only frozen once and may result in higher skinning, and numerous, unmelted, and burned shreds. The cheese may also have reduced stretch.

Fifth, microbiological contamination either at the cheese plant (commonly yeasts in the brine) or convertor (yeasts or molds) can cause off-flavors as well as visual defects to the cheese. Nonstarter lactic acid bacteria such as *Lactobacilli* and *Leuconostoc* can cause gas formation and unclean flavors.

Sixth, cheese picks up taints from the environment (air) or from the brine. Excessive amounts of bromine in the salt or the use of antimicrobials such as chlorine or hydrogen peroxide, especially with the presence of free fat at the surface of the brine, can lead to the formation of halophenols (Lindsay, 1997; Mottram, 1998; Schlegel & Babel, 1963). These flavors are often described as chemical or oxidized.

Seventh, retail abuse, i.e., warm exhibition temperatures and exposure of the cheese to bright lights, can deteriorate mozzarella cheese quality. Warm temperatures increase proteolysis and microbiological growth. Bright lights may be the cause of the warm temperature, but they also can cause the development of light oxidation of fat (cardboard or crayon-like flavors).

15.9 Conclusions

What good is an evaluation if it is not used? Cheesemakers can make changes in cheese manufacturing protocol if they know what the end-user needs are and if their cheese is not meeting those expectations. Evaluations are done to ensure that specifications are met, and if not, constructive comments can be given to the appropriate entity to help rectify the situation.

Evaluations can be a moving target; a cheese that initially meets all expectations may shortly after be considered unacceptable due to excessive proteolysis. Alternatively, cheesemakers may alter manufacturing protocol to produce the desired cheese for one buyer but the change can result in the rejection of the cheese by another buyer.

Although mozzarella evaluations are often based on performance upon baking, most baking applications are not done in such a minimalistic manner. Blister formation and skinning are often negated by the inclusion of condiments on a pizza and are obviously not important when mozzarella is used in lasagna, baked or fried as cheese sticks. In these applications, stretch quality is often the only criteria used for evaluation. Fresh mozzarella is often used in non-baking application, so ease of slicing, mouthfeel, and flavor evaluations are all that is required.

Because the evaluation of many attributes of mozzarella is subjective and done as a pass-fail test, it is highly recommended that photos be taken during the evaluation of the baked cheese. Such pictures could include stretch, flow, blister, or even string characteristics. Furthermore, these pictures can be valuable in training panelists as they can be used to create reference scales or anchors.

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Chapter 16
Latin American-Style Cheeses

Luis A. Jiménez-Maroto and Rodrigo A. Ibáñez

16.1 Introduction

Latin American-style cheeses are often referred to as *Hispanic cheeses* in the United States due to the way in which production of this type of cheeses is tracked. The term *Hispanic* was coined as an ethnic category in 1976 with the passing of a federal law that mandated the collection of data for "the ethnic group comprised of Americans of Spanish origin or descent" by the US Census Bureau, which began using it during the 1980 census. For the next two decades, *Hispanic* slowly morphed from "pertaining to Spain, its people, and the Spanish language" to the official way to refer to the people, things, and concepts associated with most countries of the Americas that are not Canada or the United States. The term *Latino*, popular in California and other southern states in the 1980s and 1990s to refer to people of Latin American descent living in the United States, was not officially used in government forms until the 2000 census (Tienda & Mitchell, 2006). Thus, only the term Hispanic was officially available in 1993, when the State of Wisconsin began tracking specialty cheese production, including that of "Queso Blanco and other Hispanic cheeses" (Groves, 2016). Same thing in 1996, when the US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) began tracking the production of "Hispanic cheese," which until then had been included in the "all other types" category. However, when referring to Hispanic cheese, most

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people in the United States are more likely to be referring to cheeses that are commonly made not in Spain, but in countries of Latin America, that is, countries of the Americas in which Spanish or Portuguese is the dominant language. So, it would be more correct to call the cheese category *Latin American style*.

Interest in Hispanic, or more accurately, Latin American foods in the United States began in earnest in the 1990s and truly expounded around the time when the 2000 US Census showed that the Hispanic or Latino population was the largest and fastest growing ethnic population. As the Hispanic or Latino population increases in the United States, so does the market potential for Latin American cheeses. The combination of Hispanic population growth and increased interest in Latin American food has allowed production of Latin American-style cheeses in the United States to grow from 30.6 thousand metric tons (67.4 million lb) in 1996 to 159.4 thousand metric tons (351.5 million lb) in 2021 (Fig. 16.1).

One last but very important fact to remember is: Latin America is *not* a single, uniform political, economic, and cultural entity. Latin America refers to an area that covers Mexico, Central America, South America, and most of the islands in the Caribbean. As of 2021, that includes 20 countries and 6 non-sovereign territories containing >658 million people (The World Bank, 2022) spread over ~19.2 million km^2 (7.4 million mi^2) (The World Bank, 2020), each with its own culture, ideology, cuisine, political leanings, economy, demographics, and history.

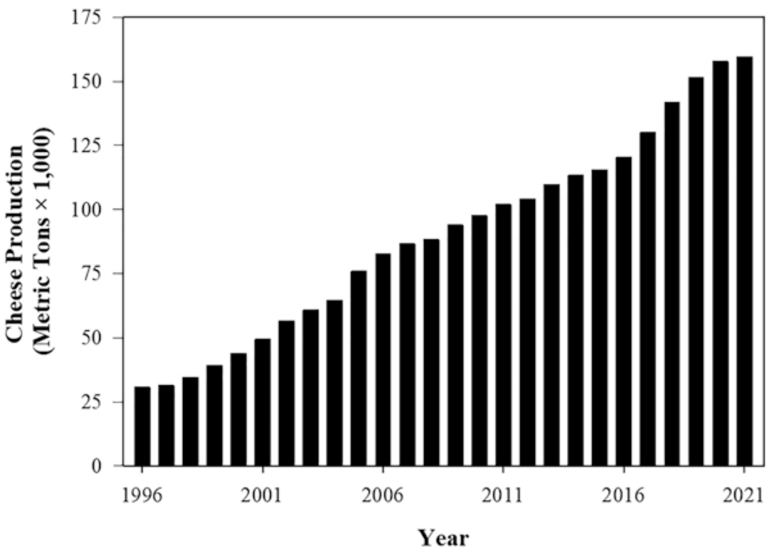


Fig. 16.1 Annual production trend for Hispanic cheeses in the United States. (NASS, 2022)

16.2 A Brief History of Cheese in Latin America

Before the arrival of Europeans to the Western Hemisphere, there was no domesticated livestock from which to obtain sufficient milk to sustain cheese production. And although the Incas in South America domesticated the llama, they were primarily used as beasts of burden and for the production of fiber and meat. Llamas produce ~1.9–2.3 l (64 – 78 oz) of milk per day (Tibary et al., 2014), but hand milking llamas is difficult due to their short teats, limited udder storage capacity, and frequent milking time requirements of every 2–3 h to reach that level of daily production (Riek et al., 2007), not to mention their poor disposition toward milking (Morin et al., 1995). There are few historical documents mentioning the consumption of llama milk. The earliest appear to be a letter from the Bishop of Cuzco, Vicente de Valverde, to the Holy Roman Emperor Charles V in 1553, where he lists the tithe collected that includes "[…] wool from the sheep from here, cheese and milk […]" (Torres Saldamando et al., 1888), and the book *Desengaño y reparo de la guerra del Reino de Chile* by Alonso González de Nájera, who completed it in 1814, where he mentions that the natives in Chile round up "some sort of rams […] that our people call sheep of the land […] the natives use their wools to dress and their bones for arrowheads […]" and that they "obtain as much milk from a female animal as they do blood from the head of a male animal, which in times of hunger they bleed from time to time" (González de Nájera, 1889), which can be interpreted as implying that both the milk and the blood obtained are a very small amount. Valverde calls the animals tithed in the region of what is now Peru "the sheep from here," so there are questions among historians if he was actually referring to llamas. Nájera uses the term "ground sheep" to refer to herd animals with long wool in the region of what is now Chile, which is thought to be llamas or alpacas. Both accounts are several decades after the Spanish had conquered the regions, so it is also possible they refer to some animal brought by the Europeans that had established in the area.

Latin American cheeses were developed using milk from Eurasian animals brought to the region during the Colonial Era, and European cheesemaking techniques that were then adapted to the local tropical and subtropical climates, and the emerging cultures of the different regions of the Americas. They are the outcome of several centuries of culinary cultural exchange and adaptation, resulting in unique cheeses that are both culinary and cultural icons of their countries of origin.

16.3 Latin American Cheeses: Overview

The production of Latin American cheeses in the United States primarily focuses on cheese varieties of Mexican origin, in part because Mexicans form the largest group of Hispanics or Latinos in the United States (Table 16.1) and in part due to the popularity of Mexican and Tex-Mex food.

Table 16.1 Estimated Hispanic or Latino population in the United States by origin for year 2021

Hispanic or Latino by origin	Estimated population year 2021	Percentage (%)
Hispanic or Latino	62,529,064	100.0%
Mexican	37,235,886	59.5%
Puerto Rican	5,798,287	9.3%
Cuban	2,400,152	3.8%
Dominican (Dominican Republic)	2,393,718	3.8%
Central American	6,306,931	10.1%
Costa Rican	188,054	0.3%
Guatemalan	1,771,850	2.8%
Honduran	1,148,209	1.8%
Nicaraguan	457,005	0.7%
Panamanian	237,706	0.4%
Salvadoran	2,473,947	4.0%
Other central American	30,160	<0.1%
South American	4,348,015	7.0%
Argentinean	297,155	0.5%
Bolivian	131,424	0.2%
Chilean	187,572	0.3%
Colombian	1,401,720	2.2%
Ecuadorian	812,838	1.3%
Paraguayan	29,389	<0.1%
Peruvian	720,626	1.2%
Uruguayan	65,571	0.1%
Venezuelan	659,631	1.1%
Other south American	42,089	0.1%
Other Hispanic or Latino	4,046,075	6.5%
Spaniard	995,583	1.6%
Spanish	905,797	1.4%
Spanish American	92,282	0.1%
All other Hispanic or Latino	2,052,413	3.3%

Made with data from US Census Bureau (2021)

However, a great diversity of other cheese varieties can be found throughout Latin America and the Caribbean that are only produced locally in their countries of origin (Table 16.2). These regions (excluding Mexico) exhibited an increase of ~14% between years 2010 and 2019, reaching levels of production of nearly two million metric tons per annum, which represents nearly 22% and 8% of the Americas and worldwide production, respectively (FAO, 2022). In this book chapter, we will discuss about the diversity of major cheeses found in Latin American and the Caribbean, with emphasis on several cheeses that trace their origin to Mexico due to their significance in the US market, and we will describe some of the most representative cheese varieties from countries that exhibit either the largest records of cheese production or the largest increase in cheese production rate in the region (e.g.,

Table 16.2 Statistics of total cheese production with emphasis on Latin American countries and the names of their more recognized cheese varieties

Region/country	Cheese production in year 2019 (metric ton × 1000)	Variation since year 2010 (%)	Main cheese varieties
North America	*6927*	*+21.1*	
United States	6159	+20.9	
Canada	592	+25.1	
Mexico	175	+20.0	Añejo, Asadero (Oaxaca), Cotija, Panela, Queso de bola, Chihuahua, Manchego, Ranchero (Fresco), Sierra
South America	*1841*	*+10.3*	
Brazil	798	+35.6	Catupiri, Coalhada, Quartirolo, de Coalho, de Manteiga, Minas, Prato, Reino, Requijao
Argentina	429	−17.5	Crema, Gaucho, Goya, Quartirolo, Reggianito, Sardo, Tafi, Patagras
Chile	101	+41.5	Chanco, Mantecoso, Quesillo, Queso Fresco
Uruguay	67	−11.4	Colonia, Yamandu, Goya
Ecuador	121	+12.0	Quesillo, Andino
Colombia	62	+5.6	Bernian, Pera
Peru	27	+37.0	Mantecoso, Andino, Requesón
Bolivia	10	+0.7	Altiplano, Quesillo, Benianco, Chaqueño
Venezuela	225	+4.1	Cuajada, Guayanes, Llanero, Queso de Cavallo, Queso de Cincho, Queso de Mano
Paraguay	N/A	N/A	Campesino, Paraguay (Quesillo)
Central America	*118*	*+31.1*	
Costa Rica	26	+105.0	Maduro, Turrialba, Palmito, Suero
Panama	14	+7.0	Queso Blanco
Honduras	15	−3.1	Quesillo de Honduras
Nicaragua	48	+43.3	Queso Blanco (Quesillo)
Guatemala	14	3.0	Queso Fresco
El Salvador	2	−20.6	Coyotlio, Duro Blando, Majado, Petacones, Prunera
The Caribbean	*21*	*−0.8*	
Cuba	12	−26.6	Patagras
Dominican Republic	8	+105.0	Queso de Freir
Puerto Rico	N/A		Queso de crema, Queso de Hoja, Queso del Pais, Queso de Prensa, Queso de Puna

(continued)

Table 16.2 (continued)

Region/country	Cheese production in year 2019 (metric ton × 1000)	Variation since year 2010 (%)	Main cheese varieties
Latin America (excluding Mexico) and the Caribbean (total)	*1980*	*+13.8*	
World (total)	*23,321*	*+13.0*	

Made with data from Path (2008), FAO (2022), (ODEPA-Chile, 2022), and USDA (2020, 2022)
N/A Not available

Brazil, Argentina, and Chile) between the years of 2010 and 2019 (before the COVID-19 outbreak, Table 16.2).

16.3.1 Diversity of Latin American Cheeses and General Factors Affecting Their Sensory Properties

The most common type of cheeses produced and consumed in Latin America are fresh cheeses, and they most often have the name Queso Fresco (fresh cheese) or Queso Blanco (white cheese). These cheeses are produced from rennet or acid-heat coagulation, most commonly using cow's milk and less commonly goat's or sheep's milk. They are generally high in moisture, range in pH between 5.5 and 6.4, undergo no ripening, and consequently have a very short shelf life and are highly susceptible to microbial contamination.

Each region and country have specifically adapted cheese manufacture protocols to obtain products with desirable shape, appearance, flavor, texture, functionality, and shelf life according to their culture and climate conditions. Hence, a variety of fresh cheeses with varying names and characteristics can be identified (Table 16.3).

For example, fresh cheeses produced in Chile may have two names: Queso Fresco or Queso Chacra. But they only differ in their shape: the former is round, and the latter is square. However, these names are commonly used interchangeably by cheese manufacturers and retailers due to the lack of standards of identity for fresh cheeses. Similarly, Mexican and Venezuelan fresh cheeses are often named after the region where they are produced and do not necessarily differ in their cheesemaking or physicochemical properties. Additionally, there are fresh cheeses with major differences in their composition that will impact their sensory properties. Increasing levels of salt not only affect the flavor (saltiness) and texture of the cheese (brittle body and crumbly texture) but also the shelf life. For example, Queso Criollo from Central America has a very high salt content (6–7% salt) and longer shelf life than Quesillo from South America (1–4% salt). Fresh cheese made from skim milk in Costa Rica (*Queso Huloso*, which means rubbery) has the translucent appearance and hard, rubbery texture commonly found in low-fat cheeses. Acid set Queso

Blanco exhibits a grainy texture and sour aroma, contrasting with fresh cheeses made with no acid added. Except for acid set cheeses, fresh cheeses generally have low acid development (i.e., high pH values) that limits melting when heated, making them suitable for baking, grilling, or frying applications (Fig. 16.2); examples include Queso Panela (Mexico), Queso para Freir (frying cheese from Dominican Republic), and Coalho (Brazil). When consumed, fresh cheeses are characterized by their fresh milk flavor and tend to release water when pressed, and if the cheese is truly recently made, a squeaky noise can be perceived during mastication. However, these cheeses are prone to develop defects that are mainly affected by the quality of raw materials as well as processing and storage conditions.

Some common defects that may occur in fresh cheeses include the following:

- Excessive watering-off (syneresis) due to temperature abuse during storage and transportation
- Uncontrolled acid development (lactic and/or acetic acid) due to fermentation of lactose and citrate from undesired bacteria
- Undesirable gas formation commonly observed as puffed or bloated packaging and/or the formation of slits or round eyes of varying size in the cheese structure

Table 16.3 Different styles of Latin American fresh cheeses and their different regional names

Style of fresh cheese	Common names and countries of manufacture
Fresh cheese made with various types of coagulants (mainly rennet) from whole, partially skimmed or skimmed milk and varying salt content.	Queso fresco (generic name in various countries of Latin America). Panela or canasta (Mexico), Paraguay (Paraguay), Blanco (Nicaragua) or Quesillo (Bolivia, Chile, Ecuador). Del Pais or De la Tierra (Puerto Rico). Llanero, Maracay or Perija (Venezuela). Estera (Colombia) Descremado or Huloso (Costa Rica) Altiplano (Bolivia). Coahlo (Brazil). Crema or Criollo (various countries from central and South America). Campesino (Paraguay) Chacra (Chile). De Puna (Puerto Rico). Ranchero (Mexico)
Fresh cheese generally made with acid and heat coagulation	Blanco (Puerto Rico). De Prensa (Mexico, Venezuela). De Freir (Dominican Republic). Sierra (Mexico) Turrialba (Costa Rica)

Made with internal information from the Center for Dairy Research (University of Wisconsin-Madison) and Path (2008)

due to fermentation of sugars and/or organic acids caused by contaminant bacteria
- Development of bitterness due to:
  - Increased proteolysis caused by excessive use of coagulant (rennet) during manufacture
  - Occurrence of contaminant microorganisms with high proteolytic activity
  - Temperature abuse during storage/transport
  - Low salt content
- Surface mold growth due to low acid development, low salt, and high moisture content (i.e., high water activity)
- Blue discoloration due to contamination with *Pseudomonas fluorescens* during storage at low temperature
- Development of cardboard-like off-flavors due to light-induced lipid oxidation of milk prior to cheese manufacture or during transport/storage of the finished product

Several of the defects associated with microbial activity can be found exacerbated in raw milk cheeses made with poor hygienic practices.

Melting cheeses are very popular in Latin America and are highly valued for their functional properties. Their characteristics are reminiscent of Pasta Filata cheeses or Gouda-style cheeses, with pH values between 5.1 and 5.4, and moisture contents of 45–60%. Examples of Pasta Filata cheeses include Oaxaca and Chihuahua (Mexico), Quesillo (Honduras), Queso de Mano (Venezuela), and Palmito (Costa Rica), whereas examples of Gouda-style cheeses include Prato (Brazil), Gauda (Chile), Patagras (Cuba, Argentina), and Yamandu (Uruguay).

Fig. 16.2 Appearance of fried Queso Fresco with limited melting. (Photo from the authors' private collection)

Semihard cheeses are also popular in various regions of Latin America. These groups of cheese present a great diversity of specific and unique sensory characteristics depending on manufacture and ripening/storage conditions. For instance, Queso Colonia (Uruguay) resembles a Swiss cheese with typical eyes and nutty notes; Queso Tafi (Argentina) has a rind that is fully covered by mold; and Queso Chanco (Chile), Mantecoso (Peru), Minas Padrao (Brazil), Maduro (Costa Rica), and Benianco (Bolivia) usually have mechanical openings and a rind of varying thickness.

Aged cheeses are less common but still culturally important types of Latin American cheeses. Dry, salty, hard, and often grated, they have strong flavors and aromas that can be reminiscent of aged Parmesan or Romano cheese but can also include flavors that are often considered defects, such as excessive rancidity, yeasty, floral, barny, and fruity notes (Jimenez-Maroto et al., 2016). Examples of these cheeses include Cotija and Cincho (Mexico), Duro (Costa Rica), Criollo (Central America), Goya (Argentina, Uruguay), Majado and Petacones (El Salvador), Pera (Colombia), de Prensa (Puerto Rico), Reggianito (Argentina), and Reino (Brazil).

Lastly, it is important we mention analogous or imitation cheeses in Latin America. Generally, these are cheeses that have nondairy components, such as the partial or total substitution of the milkfat for vegetable fat, or the use of starches in their manufacture. These nondairy ingredients can change the flavor, texture, and functional properties of the products in subtle or noticeable ways. And, although they have their place in their domestic marketplaces, this chapter will not cover their sensory properties, focusing instead only on natural cheeses.

16.3.2 Safety Concerns with Latin American-Style Cheeses

Raw milk may contain pathogenic bacteria such as *Salmonella*, *E. coli*, and *Listeria*, which have been linked to many foodborne illness outbreaks (FDA, 2018). Therefore, the Code of Federal Regulations dictates that cheese made from raw milk must be held at no less than 1.7 °C (35 °F) for at least 60 days (CFR, 2022). This is impractical in the case of Queso Fresco and Queso Blanco due to their high moisture content and subsequently short shelf life. Thus, these cheeses must be made from pasteurized milk. Latin American cheeses such as Queso Fresco, Panela, and Queso Blanco may be sold in the United States only if they are made from pasteurized milk (FDA, 2018).

Yet the traditional use of raw milk in the production of Latin American cheeses gives them distinctive flavors, textures, and cooking properties. Unfortunately, and paradoxically, US-produced Latin American cheeses made from pasteurized milk may not exhibit the full range of properties of cheeses made from raw milk. This creates the dilemma of simultaneously trying to achieve both safety and consumer acceptance quality in Latin American cheeses. One approach to this challenging issue has been the incorporation of exogenous starter cultures. Since naturally occurring lactic acid bacteria from raw milk are inactivated by pasteurization, starter cultures are now more frequently added as adjunct microflora in the manufacture of soft Latin American cheeses that are traditionally made with raw milk (Van Hekken & Farkye, 2003). However, even if made from pasteurized milk, the commonly high moisture content and pH level of Latin American cheese may prove problematic in terms of food safety if any post-pasteurization contamination occurs (Path, 1991).

While yields increase with higher moisture cheeses, this comes with a loss in shelf life and greater chance of survival of pathogenic post-pasteurization contaminants, especially with the high pH levels (~6.2) common to Latin American cheeses (Path, 1991; Clark et al., 2004). Because soft Latin American-style cheeses (fresh) are not aged, they rarely develop acidic conditions whereby unwanted bacterial growth may be inhibited. Furthermore, if the cheeses are brined, an additional advantage is afforded to *Listeria* spp., halo-tolerant microorganisms, over other bacteria if they happen to be present (Linnan et al., 1988). This emphasizes the importance of high-sanitation protocols and standards in the manufacture of Latin American cheeses (Path, 1991). In 2002, the FDA and FSIS advised at-risk individuals, particularly pregnant women, not to consume soft cheeses (including Latin American-style cheeses and soft cheeses made from pasteurized milk) due to increased incidences and risk of contamination with *L. monocytogenes* (FDA, 2002). This warning was modified in 2003 to state that soft cheeses, including Queso Blanco, Queso Fresco, and Panela, made from pasteurized milk and properly stored were safe for consumption by at-risk consumers (FDA, 2003).

16.4 Latin American Cheeses: Mexico

16.4.1 Queso Panela

Queso Panela is a Mexican fresh cheese named after the name given to the basket mold used in its manufacture (panela). It is related to Queso Blanco, but is self-pressed, has an open body, and is not acid-set. It is typically made with whole or part skim cow's milk using mesophilic starters. The curd is cut and worked for a short time, around 10 min, before draining the whey. There is no milling or grinding of the curd, which can be direct salted or brined, and undergoes a self-press step where the basket molds are stacked a few molds high and rotated every 4–6 h (Villegas de Gante, 2004). Its typical composition range is: 53.2–58.3% moisture, 18.8–12.1% fat, 18.4–20.5% protein, 1.3–1.8% salt, and pH values of 5.6–6.4 (Ramírez-López & Vélez-Ruiz, 2012). The appearance of this cheese requires the presence of the grooves left by the basket mold to be considered authentic (Jimenez-Maroto et al., 2016), although the pattern can vary (Fig. 16.3). The body is open due to being self-pressed, knit enough to be easy to cut and curdy but not crumbly: can be separated into large curd particles if kneaded between the fingers unlike Queso Fresco, where the curd is ground, the mouthfeel of Queso Panela should not be mealy or grainy. Because it is a fresh cheese, its taste should be slightly salty and mildly acid, but never bitter, as that would imply the whey is fermenting due to temperature abuse and/or high microbial load due to lack of good manufacturing practices. The flavor should be that of fresh milk: milkfat with perhaps a minor note of diacetyl depending on the cultures used, grassy notes are acceptable too since the milk is often from grazing animals. A small amount of free whey is permissible, but large amounts can indicate temperature abuse during storage or transportation, especially if the whey is opaque. Its very mild flavors make defects readily evident, and most of the time they are caused by the fermentation of the whey: bitter taste, whey taint, unclean, fruity/fermented, barny, and even yeasty.

16.4.2 Queso Fresco

Queso Fresco, which translates to "fresh cheese", is more commonly named Queso Ranchero, Queso de Aro, or Queso Molido in Mexico. Debatably even more popular than Queso Panela due to the simplicity of its manufacturing process. It is a fresh, soft, unpressed cheese typically found in the shape of a short cylinder in pieces of 0.2–1 kg (0.4–2.2 lb) (Fig. 16.4). Its typical compositional range is: 47–60% moisture, 20–29% fat, 15–21% protein, 0.7–3% salt, and pH of 4.8–6.2 (Tunick & Van Hekken, 2010). This huge range of compositional values includes artisanal cheeses made using raw milk and cheeses made with pasteurized milk and industrialized equipment and hints at the large variation in texture, flavor, and functionality that encompasses what can be considered a Queso Fresco.

Queso Fresco is traditionally made of whole or part-skim cow's or goat's milk, raw if artisanal make, or pasteurized and with mesophilic starters if made at industrial scale. The curd is cut soft, cooked at 30–35 °C (85 °F–95 °F), drained, salted, and ground up. This grinding step used to be done by hand with a *metate* (a ground stone tool used for processing foods, traditional in Mesoamerican cultures), but in modern times, it is more often ground using a mill (Villegas de Gante, 2004). The ground cheese is then packed into short cylindrical hoops, unmolded, and is ready to be sold. The body is fairly closed, with the small curd particles packing closely together but most often not fully knitting, making it very crumbly. This functional property is critical to its authenticity, as it is often used as an ingredient crumbled over soups, salads, beans, etc. Although high in moisture, they rarely present much free whey. Because the curd was ground, it has a mealy or grainy mouthfeel. The taste should be salty, with a slight acid note. Like other fresh cheeses, its flavors are primarily those of fresh milk: milkfat, grassy, or feed, and sometimes a hint of diacetyl depending on the cultures used. Its mild flavors make defects easy to detect, which are often caused by temperature abuse allowing bacteria to ferment the whey left in the cheese. Common defects include any amount of bitter, whey taint, unclean, fruity/fermented, and barny.

Fig. 16.3 Queso Panela must have the imprint of the basked used in its manufacture to be considered authentic, although the pattern can vary. (Photos from the authors' private collection)

16.4.3 *Queso Oaxaca*

Queso Oaxaca gets its name from the state of Oaxaca in southern Mexico, where it originates. However, in the state of Oaxaca, it is called *Quesillo*, and in other places *Queso de Hebra* (string cheese). The origin story of this cheese, as told by the inhabitants of the "cradle of Quesillo," the Reyes Etla municipality in the state of Oaxaca, is that in 1885, Leobarda Castellanos García, a 14-year-old girl in charge of preparing her family's cheese, got distracted and allowed the milk to set for too long after adding the rennet. She tried to cover her mistake by adding hot water to the firm curd in an attempt to soften it a bit, which resulted in a molten curd that stretched without breaking when it was pulled. The resulting cheese was found to be very pleasant and unique by the family and neighbors. This cheese was named *Quesillo*, and it became popular enough for neighboring cheesemakers in the Central Valleys region of Oaxaca to begin producing it too. Eventually, the cheese was marketed in the neighboring state of Puebla, where it was called "Queso de Oaxaca" (cheese from Oaxaca) and eventually renamed to *Queso Oaxaca* (Osegueda, 2022).

Nowadays, its manufacture is based on Mozzarella cheese, with some adaptations to perform better in subtropical and tropical climates (González-Córdova et al., 2016). As such, there is no single manufacturing method: it can be made using raw cow's, sheep's, goat's, or water buffalo's milk allowing the pH to drop from the milk's native flora, or using pasteurized cow's milk either acid-set using organic acids or with mesophilic or thermophilic starter cultures and rennet. The final curd pH is a critical step and must be between 5.1 and 5.4, or it will not melt and stretch properly (Villegas de Gante, 2004). The resulting cheese can be a Queso Oaxaca compositionally similar to whole milk Mozzarella, part-skim Mozzarella, low-moisture Mozzarella, or low-moisture part-skim Mozzarella, depending on the composition of the milk and the manufacturing protocols. Typical composition ranges are 49.3–52.4% moisture, 20.6–24.2% fat, 20.4–22.4% protein, 1.4–2.3% salt, and pH values of 5.0–5.3 (Ramírez-López & Vélez-Ruiz, 2012). Like in

Fig. 16.4 Queso Ranchero, de Aro, Molido, or Fresco showing the typical short cylinder shape and crumbly, grainy texture. (Photo from the authors' private collection)

Mozzarella manufacture, this cheese goes through a cook-stretch step in which the curds are placed in water at >70 °C (>160 °F), after which the molten curds are stretched into a strand that is then rubbed with salt and rolled into a yarn-ball shape (Fig. 16.5) that should maintain its definition throughout its shelf life and is critical for its authenticity. The body and texture should be very similar to string cheese Mozzarella, reminiscent of chicken breast when the strand is pulled apart (Fig. 16.6). The taste should be slightly salty and mildly acidic, and the flavor should present buttery and milky notes. Queso Oaxaca is highly sought after for its melting properties and extensively used in melting applications throughout Mexican cuisine.

16.4.4 Queso Asadero

Queso Asadero is pasta filata cheese developed in the Villa Ahumada municipality of the state of Chihuahua, in northern Mexico. It is not a Queso Oaxaca in a loaf form. Traditional manufacture of Queso Asadero mixes fresh raw cow's milk with day-old, acidified raw milk that is then warmed to 30–33 °C (86–91 °F) and set with animal, microbial, or vegetable rennet extracted from the fruit of *Solanum elaeagnifolium*, a local, wild-growing plant commonly known as "trompillo" (Martínez-Ruiz & López-Díaz, 2008). The curd is then cut wide, cooked, and drained but retaining some of the whey. The curd is allowed to drop in pH to 5.1–5.3 in a process similar to cheddarization, while the retained whey is heated to 70 °C (160 °F) and added back to melt and knead the curd. Salt is added in the whey washing step. The molten mass is then molded, often in loaves, but sometimes in the shape of flat patties, balls, or stretched and rolled into a yarn ball like Queso Oaxaca. The industrialized version uses pasteurized milk, starter cultures, and animal or microbial rennet, keeping the rest of the process the same (Villegas de Gante, 2004). Its sensory characteristics are very similar to Queso Oaxaca: good melting properties, slightly less acid taste, and flavors similar to Mozzarella cheese.

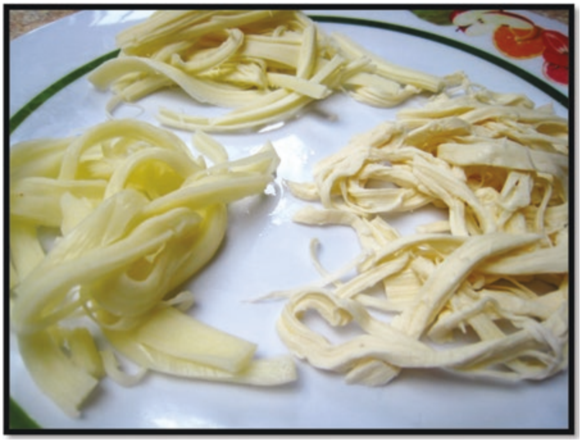
16.4.5 Mexican Manchego

Mexican Manchego shares the name with Queso Manchego from Spain. But that is where the similarities end: Mexican Manchego is made with cow's milk instead of sheep's milk and is aged only a few weeks instead of months, resulting in very different texture and flavor profiles.

The story of Mexican Manchego's development and commercialization begins sometime in the second half of the twentieth century: a Mexican cheese manufacturer wanted to develop a new cheese for the Mexican market and called their culture house for help. The technician sent followed a make procedure that was a variation on Monterey Jack cheese, but using different cultures. The resulting cheese impressed the manufacturer so much that they decided to name it after their

Fig. 16.5 Two examples of Queso Oaxaca or Quesillo, showing variations of the yarn-ball shape that gives them their authenticity. (Left: Photo from the authors' private collection. Right: Photo courtesy of Dr. Stephanie Clark)

Fig. 16.6 Chicken breast-like texture of Queso Oaxaca or Quesillo after strands are pulled apart. (Photo from the authors' private collection)



personal favorite cheese: Queso Manchego. Its mild but pleasant flavor and melt characteristics made it a success in the Mexican marketplace, quickly becoming ubiquitous with consumers, who did not know the traditional Spanish version of Queso Manchego.

Mexican Manchego is made with part-skim cow's milk, mesophilic cultures, undergoes a curd wash step, the curd is then ground, salted, molded, and pressed into cylinders that then are ripened for 10–15 days at 10 °C (50 °F). The cylinders are from 3 to 5 kg (6.6–11 lb), and their composition is typically 41–45% moisture, 27–30% fat, 22–25% protein, and 2–2.5% salt (Villegas de Gante, 2004). Mexican Manchego has a light yellow color, a closed semisoft body, slightly salty and very mildly acidic taste, and milky and buttery flavor notes. Although sometimes eaten as a snack, it is most often used as an ingredient in melting applications.

16.4.6 Queso Chihuahua

Queso Chihuahua is a traditional cheese native to the state of Chihuahua in Mexico, where it is known as Queso Menonita after the Mennonite community that lives in the state and first developed and commercialized the cheese. These Mennonites, however, call it Queso Chester, after the English Chester cheese they were initially trying to produce while using Cheddar manufacturing techniques (González-Córdova et al., 2016).

In the United States, the name "Queso Chihuahua" has been trademarked by one cheese manufacturer, so it is often found in the marketplace under the moniker of *Queso Quesadilla*. It is made of part skim cow's milk inoculated with mesophilic cultures. After cutting, the curd is cooked 30 min at ~32–38 °C (90–100 °F), drained and must undergo a cheddaring step. The cheddared curds are then milled, salted, molded, pressed, and ripened for 15–30 days (Villegas de Gante, 2004). The cheese is sold in wheels of varying sizes (Fig. 16.7) depending on the end user and is highly valued for its flavor and versatility, being used for snacking, pizzas, fondue, and especially quesadillas. Its typical composition varies and can contain 32.5–44.9% moisture, 26.2–36.1% fat, 17.6–27.6% protein, 0.73–1.55% salt, and a pH between 5.5 and 6.5 (Villegas de Gante, 2004; López-Díaz & Martínez-Ruiz, 2018). Its flavor is similar to a mild Cheddar cheese and can develop excessive acid and bitterness as it ages. Slight butter, brothy, and very slight sulfur notes are also sometimes present in this type of cheese.

16.4.7 Queso Cotija

The name comes from the town of Cotija, in the state of Michoacan in Mexico, although production of this cheese, with slight variations, occurs in the region located along the mountain range known as Sierra Jalmich, between the states of Michoacan and Jalisco. In 2005, a collective mark was registered for the manufacture of this cheese in the Jalmich region, and over the last 20 years, the artisanal manufacture of this cheese has been regulated and standardized to differentiate the original Queso Cotija from imitations made in other states. Queso Cotija is the only cheese in Mexico that has its artisanal production regulated by an official Mexican Norm (González-Córdova et al., 2016).

Queso Cotija is produced exclusively from mixed native-Zebu livestock (Holstein-Zebu, Brown Swiss-Zebu). The raw milk is standardized, allowed to naturally acidify, rennet set, cut, drained, kneaded, and salted. The curds are placed in cylindrical molds that are tightened with belts for 18–24 h, then pressed to further remove water. The cylinders are aged for at least 3 months under conditions that vary depending on the cheesemaker from refrigerated and moisture-controlled caves to ripening chambers barely below room temperature (Villegas de Gante, 2004; González-Córdova et al., 2016). The exterior surface of Queso Cotija is sometimes rubbed with chili pepper paste to add some flavor and make it stand out in the marketplace (Fig. 16.8). The resulting cheese comes in cylinders that weight from 1 to 30 kg (2.2–66 lb) and have a hard and dry texture, closed, crumbly body (Fig. 16.9), with a unique blend of flavors developed by the native flora in the raw milk that varies based on the environmental conditions during its ripening and that can be harsh and unexpected to those unfamiliar with the cheese. The flavors in Cotija cheese can include cowy/barny, cooked milk, fruity, floral, yeast, musty, sulfur, butyric, waxy, soapy, oxidized, bite, and burn (Jimenez-Maroto et al., 2016).

Queso Cotija-style cheese made outside of the Sierra Jalmich region can be found under the names of Queso Sierra and Queso Cincho.

16.5 Latin American Cheeses: Brazil

16.5.1 Minas Cheeses

Minas (mines) cheeses are named after the state of Minas Gerais in Brazil, which were originally made by Portuguese immigrants on the seventeenth century who settled in that region to extract gold. Minas cheeses can be classified based on the final moisture content: Frescal (>55%) and Padrao (<46%; Oliveira & Brito, 2006).

Minas Frescal is a soft cheese that is produced at various manufacture scales (from small dairy farmers to high-scale industry), and its physicochemical properties are detailed in Table 16.4.

Fig. 16.7 Small format cylinders of Queso Chihuahua. (Photo from the authors' private collection)

Due to its high moisture content, Minas Frescal cheeses are typically consumed within 10 days after they are made. The manufacture protocol is similar to those used for other fresh cheeses, including the use of mesophilic starter cultures or direct milk acidification with lactic acid. These cheeses can also use different salting methods that can also contribute to rather variable composition. Direct salting of milk leads to an even distribution of salt in the final product, although a large proportion of the salt is lost in the whey. The application of a salt brine to the surface of the cheeses during the molding/turning stage produces cheeses with an uneven distribution of salt, which may lead to unbalanced flavors in the final product (lack of saltiness and bitterness). The immersion of cheeses into brine is currently the most common salting method used to unsure an even salt distribution in the final product.

Minas Frescal cheeses are produced in cylindrical shapes with varying sizes (0.5–3.0 kg or 1.0–6.0 lb) and have a white-pale color with mechanical openings in their structure. It is slightly salted and may have varying levels of acidity, which mainly depends on the use of direct acidification at low levels (pH 6.1–6.3; low acid, sweet cheeses) or the use of starter cultures. The latter tends to over-acidify cheeses, which may contribute with watering off and a grainy, undesirable texture. However, cheesemakers can address these issues during manufacture and thus avoid several of the defects in the final product. It is important to highlight Minas Frescal is closely related to a fresh cheese variety; hence, they can present various attributes/defects previously discussed.

In contrast, Minas Padrao cheese originated from modifications of the cheesemaking protocol from Minas Frescal that leads to a product with extended shelf life

Fig. 16.8 Two varieties of Queso Cotija: enchilado (surface rubbed with chili pepper paste) on the left, and plain on the right. (Photo courtesy of Dr. Arnoldo López-Hernández)

Fig. 16.9 Typical appearance of Queso Cotija, with a dry, hard body. The red specks come from close contact with the surface of an adjacent Queso Cotija that had red chile powder. (Photo from the authors' private collection)

and increased flavor development, due to a lower moisture content (<46%) and extended ripening time, respectively. These changes include pre-pressing the curd during whey drainage, pressing unsalted cheeses after molding and storing cheeses in a dry room (10–12 °C and 70% relative humidity for 24–48 h), followed by a ripening period (10–12 °C, or 50–54 °F, and 85% relative humidity for 10 days) to induce rind formation, as well as 10 days of extra storage (10–12 °C) in sealed packaging for flavor development and to avoid further moisture loss. The physico-chemical properties of Minas Padrao cheeses are detailed in Table 16.4. These cheeses are produced in cylinders of 0.8–1.0 kg (1.6–2.0 lb). On the exterior, they have a yellow protective rind with varying thickness, while the interior has a pale-yellow color with mechanical openings of irregular shape, caused by the way the cheeses are pre-pressed and pressed during/after manufacture (Fig. 16.10). They have a smooth body, slight acid development and tend to have a milky note due to their reduced ripening time, with some slight development of buttery notes, which is also dependent of the fat content.

16.5.2 Prato Cheese

In late 1880s, a Brazilian dairy manufacturer imported from Europe the technology and knowledge to adapt the production of rennet-coagulated cheeses with scalded (or cooked) curd step, similarly as traditional Dutch-style cheeses. Characteristic manufacture steps for Prato cheese include the addition of annatto to increase yellowness, the use of mesophilic starter culture blends for acid and flavor

Table 16.4 Physicochemical parameters of selected South American cheeses produced in Brazil, Argentina, and Chile

Cheese	Moisture (%)	FDM (%)	pH
Brazil[a]			
Minas Frescal	55.0–59.9	38.0–50.0	5.0–5.2 (microbial) 6.1–6.3 (acid-set)
Minas Pedrao	36.0–45.9	42.0–57.0	5.0–5.2
Prato	36.0–45.9	45.0–59.9	5.7–6.0
Argentina[b]			
Cremoso	46.0–54.9 (high moisture) >55.0 (very high moisture)	>50.0	5.1–5.4
Reggianito	<35.9	>32.0	5.3–5.5
Chile[c]			
Gauda	46.0–48 0.0	45.0–59.9	5.1–5.3
Chanco (farmhouse – Young)	46.0–50.0	>52.0	5.2–5.4
Chanco (farmhouse – Matured)	44.0–48.0	>50.0	5.2–5.4
Chanco (industry made)	44.0–48.0	>45.0	5.2–5.4

[a]Brazil, Ministério da Agricultura (1997, 2004, 2020) and Oliveira and Brito (2006)
[b]ANMAT (2018) and Wolf et al. (2021)
[c]Chile-INN (1999a, b) and Oliveira and Brito (2006)

development, a whey dilution step (i.e., partial whey drainage, around 25%, followed addition of warm water to the original whey level) to reduce excessive acid development, a curd-cooking step to 39–41 °C (102–106 °F) to reduce the final moisture content, pre-pressing of the curd in the whey, the addition of sodium nitrate (<50 mg/kg) to reduce the incidence of gas defects, brine salting, a 24 h drying period in a cold room, followed by vacuum sealing, and ripening at 12–14 °C (54–57 °F) for at least 25 days, but traditionally for 60 days. The physicochemical properties of Prato cheese are detailed in Table 16.4. Due to the curd cooking step, the moisture content is reduced (<46%) and exhibits relatively high pH values (5.7–6.0), due to the application of whey dilution. This makes the use of sodium nitrate critical, which is allowed by Brazilian legislation, to reduce the incidence of undesirable gas formation. However, the manufacture of cheeses with lower pH values (<5.6) and storage conditions that prevent the occurrence of gas defects are being preferred in recent years to avoid the use of this compound. Prato cheese is usually made in varying sizes, typically from <1 to 3 kg (<2 to 6 lb), and shapes: cylindrical (Prato Coboco), a loaf shape (Prato Lanche) for slicing applications, as well as a round shape (Prato Bola or Ball). Prato cheese has a characteristic yellowish appearance due to the addition of annatto, with a soft-firm texture (suitable for slicing) with milky and buttery notes, but milder overall flavor when compared with traditional Dutch-style cheeses, due to the relatively reduced ripening time. This variety does not form eyes and is considered as a defect when formed. Development of excessive acidity can occur when cheesemakers target low pH values to avoid the use of nitrates, which can lead to a brittle texture that makes them unsuitable for slicing.

Fig. 16.10 Body of Minas Padrao cheese exhibiting a thin rind and mechanical openings. (Photo from the authors' private collection)

16.6 Latin American Cheeses: Argentina

16.6.1 Cremoso

Cremoso is one of the main varieties produced in Argentina, leading up to 40% of total cheese volume produced. This cheese was originally developed by Italian immigrants, who made a product with similar characteristics to the traditional Italian varieties of Crecenza, Taleggio, and Bel Paese. Its manufacture process uses mesophilic starter cultures for acidification and rennet for coagulation of pasteurized milk, followed by cutting the curd, whey drainage, curd washing, molding, brine salting, and a ripening time of 20–45 days at 12–14 °C (54–57 °F) and 85–90% relative humidity. The physicochemical properties of Cremoso cheese are detailed in Table 16.4. According to Argentinian legislation, Cremoso cheese can be made with high (<55%) or very high moisture content (>55%). It is usually made in 2.5–5.0 kg (5–10 lb) square-like shapes, with a yellow-pale appearance, a soft, long body, with no eyes or mechanical openings, pasty texture, very low acidity, and definite milky notes. Cremoso cheese is generally served with sweet deserts, such as dulce de membrillo (a typical South American jelly made of quince) or dulce de batata (sweet potato jelly), and is also used as a substitute of Mozzarella cheese for pizza applications due to its melting properties.

16.6.2 Reggianito

Similar to Cremoso, this variety was originally made by Italian immigrants who were trying to produce their own version of the traditional Parmigiano Reggiano cheese. It is the only hard grana-style cheese produced in Latin America that is made by cheesemakers from small and large manufacturing scales. The physicochemical properties of Reggianito cheese are detailed in Table 16.4. When compared with European varieties, Reggianito has a reduced ripening time (6–12 months instead of ≥2 years), as well as higher moisture and fat contents. This variety is made in wheels of 5 or 10 kg (10–20 lb) and contains a pale-yellow rind of varying thickness (Fig. 16.11). The rind can also be painted, mostly black. It is common to place labels above the rind, which can be glued or not. On the inside, Reggianito cheese has an ivory-yellow appearance with a compact, grainy, and hard-brittle texture. Depending the manufacture conditions (composition and pressing), mechanical openings can be observed. The flavor intensity could be milder than traditional varieties due to its reduced ripening time but is perceived as definite salted, with slight piquant notes and characteristic notes found in these varieties, due to metabolism of main components of milk during cheese manufacture and ripening. A common defect for this variety is undesirable gas formation caused by metabolism of lactic acid by clostridia spores that can also produce butyric acid, which is associated with development of undesirable aromas, known as "baby vomit."

16.7 Latin American Cheeses: Chile

16.7.1 Gauda

This variety is a local version of the traditional Dutch-style cheese Gouda and is considered one of the most common cheese varieties produced in Chile, with nearly 45% of the total volume produced. It was introduced by European manufacturers to the Chilean dairy industry in the 1950s and nowadays is mostly made in large-scale cheese plants. The manufacture protocols are similar than those used in Prato cheese, although the target moisture content is higher in Gauda (Table 16.4) and can be made in full-fat or reduced-fat versions. The use application of sodium nitrate is allowed (≤50 mg/kg). It is ripened for 15–30 days at 10–15 °C (50–60 °F). The physicochemical properties of Gauda cheese are detailed in Table 16.4. Cheese blocks of rectangular shape vary in size from 2 to 15 kg (2–30 lb). It has no rind, a yellow color, a semi-firm and elastic texture that makes it suitable for slicing and may present small eyes in the body due to citrate fermentation. Similar to Prato, it is a milder version of Dutch-style cheeses with milky and buttery notes.

16.7.2 Chanco

Chanco is a cheese variety named after the town of Chanco, located approximately 300 km (186 mi) south of Santiago, the capital of Chile. Originally made by Spanish immigrants in the eighteenth century, Chanco is the second most common cheese produced in Chile, making up ~25% of the total volume. It is made by small and

Fig. 16.11 Typical appearance of Reggianito cheese. (Photo courtesy of Dr. Elisa Ale and Dr. Guillermo Peralta (Instituto de Lactologia Industrial, Santa Fe, Argentina))

artisan cheese manufacturers that typically use raw milk as well as by large cheese companies that use pasteurized milk. This cheese is made with the use of mesophilic starter cultures and rennet. As with Gauda and other Latin American varieties, a whey dilution step is applied to reduce the level of acid development in the final product, which can differ based on the scale of production. After partial (25–35%) whey drainage, small/artisan cheesemakers add hot water (~70 °C; 158 °F) back into the curd/whey mixture in the same proportion to that of the whey that was drained to reach typical cooking temperatures (38–40 °C; 100–104 °F), whereas large manufacturers add water at the same temperature to the curd/whey mixture, following a gradual increase of temperature to reach cooking conditions. Chanco cheese can be salted by various approaches:

1. Prior to molding, the curd is partially salted with 1 L (1 quart) of 30% (w/v) brine solution per 100 L (25 gallons) of cheese milk, followed by brine salting of the cheese blocks/wheels after pressing.
2. Salting the curd with a 2 L (2 quarts) of 18% (w/v) brine solution per 100 L (25 gallons) of cheese milk.
3. Dry salting prior to molding.

One of the advantages of the last approach is that reduced levels of salted whey are produced. The ripening time can range between 7 days and 6 weeks at 10–14 °C (50–57 °F) and 85% of relative humidity (Fig. 16.12). During this time, cheeses are turned daily to allow the formation of a homogeneous thin rind. In addition, the rind is washed with a brine solution to avoid the formation of fungi. Alternatively, cheeses can be coated with wax or other commercially available products (Fig. 16.13).

The physicochemical properties of Chanco cheese are detailed in Table 16.4. These parameters can differ based on the scale of production as well as the final use of the cheese. For instance, Chanco cheese with increased moisture content is referred as Mantecoso cheese and is desirable by some consumers that associate its pastiness with increased fat content (creamier). Similarly with Gauda, the application of sodium nitrate is allowed (≤ 50 mg/kg), although it is not generally used by cheesemakers. Chanco cheese is also known as Campo Bueno, El Rincon, Huentelauquen, Llifen, Los Alerces, Los Alpes, Los Fundos, Quilpue, and Ranco. Nevertheless, there is no standard of identity for any of these names. Chanco cheeses can be found in several sizes and shapes: rectangular cheese blocks of 5 or 10 kg (10–20 lb.; Fig. 16.12), as well as wheels of 0.5 to 2 kg (1–4 lb.; Fig. 16.13). The color is pale yellow, and the rind should be free of molds. On the inside, Chanco cheese should only present mechanical openings of irregular shape (Fig. 16.14), due to a relatively gentle pressing. Chanco cheese has a semi-hard consistency and a creamy body and has typical milky and buttery notes. Some defects found in this variety are development of excessive bitterness which can be caused by high residual chymosin activity that contributes with increased proteolysis, due to low salt content, high levels of coagulant added during cheese manufacture, as well as temperature abuse during ripening, storage, and transport; accumulation of calcium lactate crystals on the surface of retail blocks (Fig. 16.14) and slices, due to development of excessive acidity (inadequate control of acid by whey dilution) and temperature abuse. However, this defect can also occur in various Latin American varieties if those two conditions take place. Undesirable gas formation leads to the formation of rounded eyes and is caused by the metabolism of sugars and/or organic acids by

Fig. 16.12 Ripening of Chanco cheeses. (Source: Guzman & Ilabaca, 2007)

Fig. 16.13 Typical appearance of an artisan Chanco cheese with waxed rind. (Photo courtesy of Hardy Aviles (Osorno, Chile))

Fig. 16.14 Accumulation of calcium lactate crystals in the surface of a retail Chanco cheese block. This defect is common in various cheese varieties that exhibit excessive acid development and accumulation of serum in the surface. (Photo from the authors' private collection)

nonstarter lactic acid bacteria and contaminants, such as coliforms or spores. Interestingly, Chanco cheese has been made with different proportions of cow's and goat's milk, in which increasing levels of goat's milk lead to cheeses with a whiter appearance, brittle texture, and goaty notes (Vyhmeister et al., 2019).

16.8 Final Remarks

Increased popularity of Latin American-style cheeses in the US market is caused by a large proportion of consumers with Hispanic heritage, along with the high popularity of Latin American cuisine among US consumers, which has increased >5 times the production of Latin American cheeses in US cheese plants over the last 25 years. However, most of the cheese varieties found in the United States are from Mexican origin. Despite the great diversity of cheeses found throughout Latin America (i.e., fresh-style cheeses, melting cheeses, semi-hard cheeses, and age-hard cheeses), there are various examples of cheeses made with similar manufacturing approaches and composition, although the final sensorial experience perceived by consumers of Latin American cheeses can greatly differ, due to the cheeses' historical, cultural, and regional background.

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Chapter 17
Mold-Ripened Cheeses

Marc Bates and Stephanie Clark

17.1 Introduction

Historically, mold-ripened cheeses likely came about by accident. But the mold-ripened cheeses of today are far from accidents—they are carefully crafted masterpieces of science and art. Broadly speaking, mold-ripened cheeses can be subdivided into two categories: those characterized by bloomy rinds (or surface mold-ripened cheeses) or blue-veined. Within each of those categories, great variability exists throughout the world, which will be further discussed in subsequent sections, along with general make procedures, expected characteristics and defects, and explanations for the sources of such characteristics.

The German scientist Weigmann (1906) reported that "It has long been known that the characteristic rancid, sharp taste of French Roquefort, English Stilton, and Italian Gorgonzola cheeses is caused by the green Penicillium." Much of the early published science on mold-ripened cheeses was conducted as a result of American consumers' desire for imported Roquefort, which was restricted after the First World War. Some of the premier American blue cheese research pioneers included Charles Thom, James Currie, and Kenneth Matheson (1900s–1920s) at the United States Department of Agriculture (USDA), Bernard Hammer and Clarence Lane at Iowa State College (1930s–1940s), and Samuel Coulter and Willes Combs at the University of Minnesota (1930s–1940s). Thom was the first to describe the importance of *Penicillium camberti* and *P. roqueforti* in mold-ripened cheeses. Thom and colleagues at the USDA were instrumental in defining the taxonomy of Aspergillus and Penicillium genera (Thom, 1906) and for determining microorganisms

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responsible for proteolysis and lipolysis (Thom, 1906). Currie (1914) stated that "Every cheese connoisseur is familiar with the peculiar pepper or burning effect of well-ripened Roquefort cheese on the organs of taste." Currie went further to elucidate that *P. roqueforti* produces a water-soluble lipase, which is the chief factor in causing fat hydrolysis and subsequent formation of the primary volatile fatty acids responsible for typical blue cheese flavor: caproic, caprylic, capric acids.

Microbiologists Lane and Hammer are credited with establishing and patenting the method later used to produce Maytag Blue Cheese in Newton, Iowa. Their method involved separation of cow milk, homogenization of the cream (14–24 MPa of pressure), and blending back in raw skim milk to promote milk fat hydrolysis by the native lipase during ripening. Their research revealed that pasteurization of homogenized raw milk more rapidly developed volatile acidity, yielded more typical flavor than cheese made from non-homogenized raw milk, but was inferior to cheese made from raw homogenized milk (Lane & Hammer, 1938). Subsequently, Coulter and Combs (1939) reported that the addition of a lipase enzyme (called steapsin) enhanced flavor development in blue cheese, but cheeses had a bitter taste. Later still, Parmelee and Nelson (1949) showed that addition of select microorganisms that produce lipase (*Candida lipolytica*) to pasteurized, homogenized milk improved blue cheese flavor, with no bitter taste.

Later, Morris, Jezeski, and Combs, from the University of Minnesota, created the white-veined mold-ripened cheese called Nuworld cheese. The scientists induced mutants of *P. roqueforti* from a parent Minnesota strain by irradiation with ultraviolet light, then Morris et al. (1954) made "Minnesota Blue cheese" with the standard and mutant strains. Their experiments revealed that "Excellent cheese can be made with a white mutant… color, body, texture, and comparatively milder flavor are different enough from Blue cheese to constitute a new cheese, which may be classed within the semi-soft, mold-ripened group of cheese."

The classics among the surface ripened or bloomy cheeses are Camembert and Brie in the United States. Valencay and Poligny should also be considered if we look to include other styles originating from France. One legend credits Marie Harel, a farmer's wife from Normandie, France, with the origin of Camembert de Normandie (AOC) in 1791. Brie de Meaux and Brie de Melun, both French AOC cheeses, are made from raw milk. Here in the United States, we will likely only see a modern Brie made from pasteurized milk due to the short aging time and the 60-day aging requirement for raw milk cheeses. In France, the raw milk versions would be marketed prior to 60 days of age.

Dupont/Danisco Technical Manual (2014) tells us about the flavor compounds found in bloomy rind cheeses in Table 17.1.

These early works were instrumental in setting the groundwork for understanding and producing high-quality mold-ripened cheeses worldwide.

Table 17.1 Flavor compounds associated with bloomy rind cheeses

Families	Compounds	Associated flavors
S-compounds	Dimethyl sulfide (DMS) dimethyl disulfide (DMDS)	Sulphur, cabbage-like
Esters	Ethyl acetate, ethyl butanoate, ethyl propanoate, ethyl lactate, ethyl valerate, isoamyl acetate, isobutyl isobutanoate, ethyl hexanoate	Fruity, apple, pineapple, sweet, banana
Ketones	Acetone, 2-butanone, 2,3-pentanedione, 2-heptanone, acetoin, diacetyl	Solvent-like, etheric, buttery, blue cheese
Aldehydes	Acetaldehyde, 2-methyl butanal, isovaleraldehyde	Green, malty
Alcohols	Ethanol, 1-propanol, isobutanol, 2-methyl, 1-butanol	Ethanol-like, pungent, solvent-like, malty

Source: 2014, TM 2106-2e Dupont-Danisco

17.2 Bloomy Rind Cheeses

17.2.1 Definitions and Standards of Identity

The U.S. Code of Federal Regulations (CFR) includes a standard of identity for soft-ripened cheese at 21CFR133.182. While nowhere in the standard is the term "bloomy rind" used, this is the standard which provides for the production and marketing of such cheeses in the United States. Key elements of the standard include a minimum of 50% butterfat on a dry basis and the provision to be made from raw milk only if such product is cured at a temperature of not less than 2 °C (36 °F) for not less than 60 days. While the standard allows for the production of these cheeses from raw milk, the requirement to age for at least 60 days uses up much of the potential market suitability for the cheeses noted in the introduction.

The surface ripening cultures necessary for production of bloomy rind cheeses are provided for in the standard as follows:

A. Harmless flavor-producing microorganisms may be added.
B. The cheese is cured under conditions suitable for development of biological curing agents on the surface of the cheese, and the curing is conducted so that the cheese cures from the surface toward the center.
C. The word "milk" (in this particular standard) means cow's milk, goat's milk, sheep's milk, or mixtures of two or all of these.

Internationally, the Codex Alimentarius for Milk and Milk Products (FAO & WHO, 2011) has been established for Coulommiers, Brie, and Camembert. Some main differences between these three international standards and our U.S. soft-ripened standard are:

A. The harmless flavor-producing cultures include named cultures.
B. Each of the three cheeses must be made from cow or buffalo milk or mixtures thereof.

Additional international standards are prevalent in the European Union. Union-wide is the Protected Designation of Origin (PDO), while national systems like the French Appellation d'Origine Côntrolée (AOC) and the Italian Denominazione di Origine Protetta (DOP). The intent of these standards is to tie the production of a particular named cheese to both methods and a geographic area or region, thus protecting the production of local foods.

The fat content of bloomy rinds may lead to different naming conventions, such as double or triple-cream designations. Fat content is expressed as percent fat in the dry matter, also called fat on a dry basis. The soft-ripened cheese standard 21CFR 133.182 requires a 50% minimum fat in dry matter (FDM) with no maximum, which allows for the higher fat cheeses to be made under this standard. Codex standards for Brie and Camembert (FAO & WHO, 2011) show a minimum of 40% FDM and 30% FDM, respectively, and further indicate a reference range of 45–55% as being normal. While there is no legal definition in the United States, the French require double crème to have 60–75% FDM and triple crème to be greater than 75% FDM.

17.2.2 *Production of Bloomy Rind cheeses*

The surface mold-ripened cheeses, also called bloomy rinds, are characterized by the surface growth of white or off-white *Penicillium camemberti* and some yeast-like cultures of Geotrichum and Debaromyces. The bloomy category, with its common white rind or crust, can have a variety of curd production methods (Table 17.2). Lactic cheeses, more common in Europe and in the goat cheese industry, are distinguished by being acidified before coagulation. This technology may be referred to as 'traditional." At the other extreme are what are referred to as "stabilized soft

Table 17.2 Comparison of bloomy rind technologies

Technology / Parameter	Traditional technology	Mixed technology	Stabilized technology
Acidifying cultures	Mesophilic	Blends of mesophilic and thermophilic	Thermophilic
Coagulation	Late-primarily caused by acidification	Intermediate-aided by both acidification and rennet	Early- caused by rennet
Mechanical steps of cutting and stirring	Neither	Large cut and little stirring	Smaller cut with modest stirring
pH at unmolding	≤4.45	4.65–4.85	4.95–5.20
Ripening cultures	Geotrichum + *P. camemberti* or *P. album*		
Culture ratio	2:1	1:1	1:2
Optional adjuncts	Corynebacteria	Corynebacteria, *P. roqueforti*	Corynebacteria, *P. roqueforti*
Marketing window	2–9 weeks	6–10 weeks	7–15 weeks

Source: 2014, TM 2106-2e Dupont-Danisco

cheeses" or "enzymatic," whose coagulation is caused by rennet action early in the process with most acidification occurring after coagulation. Additionally, the cheese makers get creative and use methodologies of production in between, referred to as "mixed technology."

It is no wonder that with all the possible technology variations for white surface-ripened cheese there are so many different cheeses available. Considering milks from different species, and mixtures of milks (e.g., goat and sheep), there are even more cheeses in the mold-ripened cheese category. As we think of cow's milk, we have the classics, including Camembert, Brie, Coulommiers, and triple creams. For goat milk, it would be the small crottins, bloomy logs, and pyramid shapes. Ewe's milk provides such classics as Perail de Brebis and Le Brebio. The American Cheese Society Judging & Competition provides category B – Soft Ripened Cheese, where makers can enter cheeses in the bloomy or white molded style. Subcategories include opportunities for milk from each major species plus mixed milk subcategories.

We will summarize the production steps of a classic bloomy rind such as Camembert from cow's milk. Bloomy rind cheeses are uncooked, meaning there is no step beyond pasteurization that requires any further heat.

Milk Supply We need to have fresh, high-quality milk. Milk can be from a farm's own herd or be purchased from other approved dairy farms or companies.

Receiving/Storage The milk must be evaluated for quality, composition, and free from contamination such as antibiotics during this step of the process. Its temperature must be kept below 4 °C (40 °F) to preserve quality and prevent outgrowth of any pathogens.

Standardization Standardization is the process of adjusting the composition of the milk's fat:protein ratio. If done, it is usually done by separation/addition of cream to achieve the desired composition. Not all makers have the ability to do this step, so it may be a point of differentiation.

Pasteurization The milk is pasteurized as a critical food safety process. While the standard allows for making from raw milk if aged for 60 days, it is typically not done in the United States for reasons discussed in the introduction.

Pre-fermentation Post pasteurization, the milk is tempered to approx. 32 °C (90 °F) and starter cultures or bulk starter are added so that they can become acclimated to the warm milk from the dry or frozen state the cultures may have come from. This is also called ripening the milk, as the starter work through their lag phase to growth phase and prepare to rapidly reproduce and ferment the lactose to lactic acid. Depending on the source and amount of starter culture, the duration of this step can be from 30 to 90 min.

Renneting/Coagulation The amount of rennet to use will be determined by whether the cheesemaker is following a traditional technology or stabilized technology (previously discussed). Coagulation in the traditional technology is primarily acid driven, so very little rennet is required and it is more an aid to draining than functioning as a coagulant. Stabilized technology depends on a rapid and complete coagulation early in the process, with fermentation occurring mostly post-coagulation. The stabilized technology uses enough rennet to coagulate the milk in approximately 30 min. Rennet comes in single and double strengths so it is important to know this when determining how much to use. The maker may also choose several sources of rennet, including animal, plant, and fermentation-produced sources. Calcium chloride may be added to aid/improve the rennet action, especially in milk that has been pasteurized significantly above minimum requirements.

Cutting Traditional technology may not employ cutting as such but just ladling the curd into the forms or molds ("dipping"). Stabilized technology would likely cut the curds into ½–1 inch cubes according to the needs of their particular process. Ladling and cutting increase the surface area available for moisture to escape or syneresis from the curd to reach a desired firmness and moisture content.

Stirring Stirring is not used for the traditional technology because the cheese is dipped into the form and drained. Stabilized technology uses some combination of cut size (above) and stirring to aid in getting enough whey out to reach desired moisture content and firmness. Stirring might be done with a few strokes every 3–5 min over about 25–30 min in a manual method. Mechanical stirring would only be used for very large-scale production where it could be managed with programmable automation.

Draining This step begins with the curd and whey separation. About 1/3 of the whey is pre-drawn or removed from the vat before transferring the remaining curds and whey to the molds for further draining while also being shaped.

Molding Molding has the purpose of creating uniformly shaped and sized wheels or discs of cheese. It also allows for continuation of drainage for as long as overnight.

Salting Salt may be applied to Camembert by either dry salting the curd or by placing the discs into a brine solution. Salting is usually done the next day, with parameters designed to achieve about 1% salt in the finished cheese. Dry-salted cheeses may rest with occasional turning for about 24 h or longer before proceeding. Brine salting for these small-format cheeses may take only an hour or two depending on the salt concentration of the brine.

Ashing This optional step is done for two reasons. First, it helps neutralize the surface acidity, making it a better environment for the ripening cultures to grow. Second, it provides a striking visual appearance of the finished product (Fig. 17.1).

Ripening We are now at day 3 since the start, and moving the cheese to a controlled temperature and humidity space where the *Penicillium camemberti* will literally 'bloom' on the surface over the next 10–12 days. Hence the name bloomy rind. The Geotrichum or other yeast cultures will grow first, de-acidifying the surface and making it more hospitable to the Penicillium. Penicillium blooms best at a humidity level above 90% and temperatures in the 10–12 °C (50–54 °F) range. The ripening cultures could have been added directly to the milk in the cheese vat. They could have been delivered to the surface by mixing with salt and applying the dry salting method. Otherwise, they would need to be applied to the surface by spraying or wiping methods. Uniform development of the bloom is aided by turning the cheeses every 3–5 days during this ripening step.

Packaging After a full bloom has developed over the surface of the cheese pieces, they may be wrapped in appropriate materials such as sulfurized paper, cellophane, or other patented wraps made especially for these cheeses. Depending on the technology used, desired product characteristics, and the market preferences, the product could be ready in as little as in 2–3 more weeks.

17.2.3 Sensory Evaluation

17.2.3.1 Preparing Samples for Evaluation

Tempering bloomy rind cheeses takes a bit less time than large-format cheeses (e.g., Gouda) due to the small size of the cheese and the consequently greater surface area to volume ratio, especially of the flat disc formats. Piece sizes of a pound or less would likely temper from refrigeration to the mid 10 °C (50 °F) range in as little as

Fig. 17.1 Goat cheese with bloomy rind, exhibiting surface mold and layers of ash (S. Clark image)

30 min. Tempering helps the evaluator to sense and appreciate the volatile components of the cheese, and having a set standard is best for comparing one cheese to another and one occasion to another. A full-size Brie or Coulommiers, on the other hand, will need 1–2 h to temper, as they may weigh as much as 6–8 pounds (Fig. 17.2).

Knives or wire harps (Fig. 17.3) are both acceptable to cut or open the cheese for visual inspection and portion it for tasting. When deciding how to portion the cheese, it is important to consider that there may be variations in the cheese from the exterior to the inner core of the cheese. Thus, we want to cut or slice so as to best expose a representative cross-sectional view to allow one to see from the rind all the way to the center of the cheese mass (Fig. 17.4).

17.2.4 Bloomy Rind Cheese Sensory Characteristics

Ideal Characteristics

Roustel (2020) described modern Camembert as having a rind with a fine white bloom that may develop brownish striations when fully mature. Its flavor should be mushroomy and earthy, with slight ammonia towards the end of its life. The paste should be homogenous, supple, and slightly elastic, with occasional fermentative openings. Mushroomy and earthy are terms that seem to be associated with most cheeses in this category. As the milk source changes from cow to other species, we expect to sense more animal notes associated with the shorter-chain fatty acids characteristic of the milk from sheep and goats.

When evaluating samples, we use all our senses in some sequence. We first see the external appearance and get some aroma. When cutting or slicing, we may get more volatile aromas and a visual of the interior of the cheese. Decorative shapes, leaves, spices, and/or condiments may be occasionally used on top of or inside some bloomy rind cheeses (Fig. 17.5). We note textural characteristics as we slice and handle the cheese, bringing it to our mouth. In the mouth, it gets really busy as we continue to evaluate the mouthfeel, tastebud responses, and even more volatile aromas via retro-nasal olfaction. A good product leaves us wanting more. If we are evaluating more than just a couple of samples, it is important to expectorate each sample to avoid satiation, which will dull our senses and fatigue us.

17.2.4.1 Defects in Bloomy Rind Cheeses

Bloomy rind cheese defects can be segmented into three categories: Appearance, color, and mold development, Body and texture, Aroma and flavor. Defect descriptions are included in subsequent pages. Many of the terms are also found in the American Cheese Society’s T.A.S.T.E Test® scoresheets found on their website, https://www.cheesesociety.org/ccse-scoresheets/.

Fig. 17.2 A full-size Brie or Coulommiers may need 1–2 h to temper, as they may weigh as much as 6–8 pounds (S. Clark image)

Fig. 17.3 Cheese knife and small wire harp tools for working with bloomy rind cheese (Image by Bates Consulting)

17.2.4.1.1 Appearance, Color, and Mold Development

Cracked or Disturbed Rind A jagged, cracked, or split rind may be due to excessive drying or physical damage.

Discolored/Dull Color/Uneven Color Multiple terms are used when the color is not a fine white bloom with only some fine tan striations.

Excessive Mold Coat/Rind The term is used when the mold coat or rind is quite thick and upon further examination may even be tough or leathery when cutting or in the mouth.

Greasy/Free Butterfat Sometimes when a bloomy cheese is temperature abused such as in shipping or distribution the butterfat will come to the surface to yield this defect.

Fig. 17.4 A disc and a pyramid shape cut to display a good cross section of each cheese (S. Clark images)

Fig. 17.5 Examples show the presentation of the cheese may be enhanced by the addition of a colored spice or condiment (left), wrapping with bark and adorning with leaves (center), or using a unique shape (right) (S. Clark images)

Malformed/Crooked /Lopsided The terms are used to describe a lack of symmetry.

Slipped Coat/Rind/Skin The terms are used when the rind is found to be separating from the cheese itself (Fig. 17.6).

Undeveloped/Immature Mold Coat If the bloom is very thin and/or does not fully cover the cheese, or patchy coverage appears, these terms are used (Fig. 17.7).

Wet/Free Whey The terms should be used when the cheese has a wet appearance or actual free whey or moisture on the surface.

Undesirable Mold Type The term is used with the appearance of obvious growth of unintended or undesirable mold types not associated with the category (Fig. 17.7).

17.2.4.1.2 Body and Texture

Crumbly The term is used when the center cheese falls apart or crumbles when sliced or pressure is applied, as with the thumb and forefingers or in the mouth.

Curdy In curdy cheese, the original, individual curd particles may be seen or felt as the cheese is manipulated.

Excessive Gassy Some openings due to gassiness from flavor-producing bacteria are expected, so this term is used when the structure of the cheese is threatened by excessive gas holes.

Mealy/Grainy/Sandy A mealy texture is one that appears like and has the mouthfeel of corn meal. Grainy might have randomly dispersed granules visible or that can be felt in the mouth. Sandiness is usually a mouthfeel that persists after the sample has been expectorated/swallowed. It can happen when excessive lactose crystallizes.

Gummy/Pasty/Sticky These terms are applicable when the cheese doesn't let go. It sticks to the roof of your mouth, your fingers, and/or the knife.

Open The term open refers to the angular openings in the mass of the cheese left when the individual curds have not compacted and knit into a smooth mass.

Short Short refers to the brittleness of the curd when manipulated with the fingers and it readily breaks apart. The curd is inflexible.

Weak The term is applied when the cheese lacks resistance to pressure by the fingers or tongue against the roof of the mouth. This lack of resistance may be associated with excessive moisture content of the cheese.

17.2.4.1.3 Aroma and Flavor

Ammoniated As bloomy cheeses ripen and the protein breaks down, some ammonia is produced. Usually, it occurs in fully ripe cheese, and it may be present in a slight amount but more than that it is a sign of overripe product.

Atypical The product does not contain the basic characteristics of the category (see Ideal above) or includes attributes characteristic of a different cheese.

Barnyard The aroma or flavor is reminiscent of the barnyard, animals, and/or manure.

Fig. 17.6 Examples of slipped coat defect (S. Clark images)

Fig. 17.7 Examples of ideal (left) vs. undeveloped/immature mold coat (center) and undesirable "Wild" mucor mold type (right) (S. Clark images)

Bitter Bitter is a basic taste, detected only in the mouth and mostly at the back of the tongue or pallet. It has no odor or aroma. One cause is bitter peptides forming during the proteolysis that occurs during ripening or aging. For persons not blind to bitterness, this is an undesirable attribute, as the flavor may linger or persist after the sample is gone.

Chemical Chemical flavors are also described as medicinal, phenolic, or band-aid like. They could be reminiscent of sanitizers like chlorine bleach or iodophors.

Feed Flavors from highly aromatic feeds like alfalfa or silage fed within 2 h of milking or during milking can impact the milk's flavor.

Flat/Lacks The descriptor is applied to products lacking the primary character of the category. It could be applied to a mild cheese in an aged category.

Fruity/Fermented Fruity esters often remind us of apple or pineapple or other sweetish flavors. Krautlike is a fermentation flavor associated with some particular cultures.

High Acid This term is applied when the acid is the only flavor characteristic noted or it is out of balance with other components of the product's flavor. Bloomy rinds are quite acidic in the first days, but as they bloom and begin to ripen the pH goes up and so they become less acidic when ready.

High Salt The term is used when salt is out of balance and noticeable as a primary characteristic.

Lacks Freshness/Old Milk If the product has a stale or old component that is slightly unpleasing, the terms may be used.

Metallic Metallic is both a flavor and a mouthfeel that is puckery or astringent. It is caused by the animals' diet, especially on poor feeds in winter or by the metal in the water system they drink from.

Moldy or Musty The flavor or aroma is very earthy or reminiscent of a damp basement. It is not particularly pleasant, and not like the characteristic mushroomy flavor of bloomy rinds.

Rancid The flavor is caused by the lipolysis of the butterfat splitting off butyric acid from the fat molecule. Highly aromatic and is a positive component of blue cheese or provolone flavors. Not expected in bloomy rinds. It is sometimes described as baby's breath.

Unclean This flavor is an unpleasant experience that may come as an aftertaste or linger long after the sample is gone. It can come from the animals breathing air from a dirty and poorly ventilated barn, or it may be caused by spoilage organisms impacting on the milk or poor sanitation practices in the cheese room.

Unpleasantly Earthy See also moldy/musty above. The term describes flavor or aroma that is very earthy or reminiscent of a damp basement. It may be associated with a cave-aged cheese. It is not particularly pleasant and not like the characteristic mushroomy flavor of bloomy rinds.

Whey Taint The flavor is often caused by excessive whey or moisture being left in the curd. It can be unpleasantly sour or unclean in nature.

Yeasty The flavor is reminiscent of rising or fresh baked bread. It can be caused by too much Geotrichum or other yeast in the culture system of bloomy rinds.

17.3 Blue-Veined Cheeses

17.3.1 Definitions and Standards of Identity

Blue-veined cheeses are made throughout the world from raw, heat-treated, or pasteurized milk of cows, goats, sheep, or mixed milk. Some of the most famous blue-veined cheeses include Roquefort (France, discussed in Chap. 18), Stilton (England), Gorgonzola (Italy), Cabrales (Spain), and Danablu (Denmark). Some blue-veined cheeses have Protected designation of origin (PDO), Appellation d'origine protégée (AOP, in French-speaking countries, Denominacion de origen (DOP, in Spanish-speaking countries), or Denominazione d'origine controllata (DOC, in Italian-speaking countries) status.

According to the U.S. FDA Code of Federal Regulations, Blue cheese "is characterized by the presence of bluish-green mold, *Penicillium roqueforti*, throughout the cheese. The minimum milkfat content is 50% by weight of the solids and the maximum moisture content is 46% by weight… is at least 60 days old" (USFDA, 2022a). Nuworld cheese has the same requirements, except that it "is characterized by the presence of creamy-white mold, a white mutant of *Penicillium roqueforti,* throughout the cheese…" (USFDA, 2022b).

17.3.2 Production of Blue-Veined Cheeses

As with any dairy food operation, strict sanitation practices and use of fresh raw ingredients are also essential for high-quality blue-veined cheese. Cream and/or milk used to make blue cheese in the United States may be raw or pasteurized, homogenized, or bleached. If benzoyl peroxide or a mixture of benzoyl peroxide with potassium alum, calcium sulfate, and magnesium carbonate is used to bleach the milk, the weight of the benzoyl peroxide must not exceed 0.002% of the weight of the milk, and the weight of the potassium alum, calcium sulfate, and magnesium carbonate, singly or combined, must not exceed six times the weight of the benzoyl peroxide used. Additionally, if bleaching is conducted, vitamin A must be added to the curd in a quantity sufficient to compensate for the vitamin A or its precursors destroyed in the bleaching process (USFDA, 2022b).

Fresh milk (approximately 3.5% fat) is warmed (to approximately 32 °C (90 °F)), then cultured with mesophilic (typically exclusively) lactic acid-producing bacteria (i.e., *Lactococcus lactis*) and chymosin. Some processors have encouraged aeration of blue cheese by adding gas-producing cultures (e.g., *Leuconostoc* species). *Leuconostoc* can expand the mechanical openings in blue-veined cheeses, allowing *P. roqueforti* to colonize the eyes formed (Pujato et al., 2014). In ideal conditions, CO_2 leaves via punch holes; in less ideal conditions, eyes are entrapped in the cheese body.

Upon cutting, curds are gently scooped into perforated forms (approximately 19 cm in diameter, 15 cm in height), for whey drainage. Care should be taken to maintain a somewhat open structure. Spores of *Penicillium roqueforti* may be added to the milk or to the curds while filling forms. The forms are turned several times during draining, then removed from forms when considered sufficiently dry. The wheels of cheese are salted with dry salt or placed into a brine solution. Subsequently, perforations (approximately 50 per cheese) are made with copper or stainless steel "needles," sufficiently long to penetrate through the entire wheel, to enable air circulation, essential for mold growth throughout the open internal structure of the formed cheese.

Punctured wheels are held at a temperature of approximately 10–12 °C (50–54 °F), 90–95% relative humidity, until the characteristic mold growth has developed (approximately 30 days). Mold-inhibitory compounds (antimycotics) may be applied to the surface of wheels to prevent surface mold growth (Fig. 17.8). Alternatively or additionally, cheese surfaces may be scraped to remove surface mold or yeast outgrowth prior to packaging and distribution. Additional affinage may occur in caves at 4–7 °C (40–45 °F), for approximately 60–90 days prior to distribution.

Under European Union law, Gorgonzola is a protected designation of origin (DOP) cheese, made only in specific Italian provinces of Lombardy and Piedmont. It is made with unskimmed pasteurized milk, spores of *P. roqueforti*, and calf rennet, though some producers add lactic cultures (e.g., *L. bulgaricus* and *S. thermophilus)* and even selected yeasts of the Saccharomyces species. Curds are separately made out of the morning and evening milk and then alternately layered in forms to facilitate the open structure needed for aeration (Fox et al., 2000). Gorgonzola is typically aged 3–4 months. Gorgonzola Piccante is aged longer (~3–12 months) than "Gorgonzola Dolce" (at least 60 days) and has at least 48% fat on a dry basis. Gorgonzola has a softer, more smooth, and less crumbly texture than Roquefort unless aged (Gorgonzola Piccante). The body is cream to yellow in color; the pink-to-grey rind is considered in-edible (DOP Italian Food Agency, 2022).

Under European Union law, Stilton (PDO) cheese can only be made in Leicestershire, Derbyshire, and Nottingham, England, from pasteurized local cow milk. *P. roqueforti* mold spores are added to the milk and renneted. Curds are allowed to settle to the bottom of the vat, and cut to facilitate whey drainage, which occurs slowly over a 12–18-h period (Fox et al., 2000). Curds are milled, dry salted, and drained, with turning, for about 7 days in cylinder forms, at 26–30 °C (79–86 °F), 90% relative humidity (Fox et al., 2000). A rind develops during incubation in a cooler room (13–15 °C (55–59 °F), 85–90% relative humidity) for 6–7 weeks. Subsequently, cheeses are pierced, allowed 2–3 weeks to grow mold, then moved to a cold room (5 °C/41 °F) (Fox et al., 2000). Stilton has a minimum of 48% milkfat in the dry matter and resembles a high acid, flaky Cheddar cheese with blue-green veining. Stilton cheeses typically harbor secondary microflora, including but not limited to the adventitious (not intentionally added) yeasts *Yarrowia lipolytica* and *Kluyveromyces lactis*, which contribute to the distinct aroma and flavor profiles in the paste, veins, and brownish outer crust (Gkatzionis et al., 2009; Price et al., 2014).

Cabrales PDO cheese is made from raw cow milk or blended with goat and/or sheep milk. Cabrales is made in a traditional artisan fashion by rural dairy farmers in a small production zone in northern Spain. It has a fat content of 45% on a dry basis. Cabrales is aged at least 75 days in natural caves with *P. roqueforti* spores present (none are added during cheesemaking). Regulation requires that the cheeses be sold in dark-green-colored aluminum foil with the stamp of the PDO Queso de Cabrales (Worldnews, Inc. 2022).

Danablu is made with pasteurized cow milk, *P. roqueforti* spores, and chymosin. Curds are cut and ladled into molds, drained, and then brined. Wheels are pierced, then aged at least 60 days. Danablu has 50–60% fat on a dry basis.

17.3.3 Sensory Evaluation

17.3.3.1 Preparing Samples for Evaluation

Blue cheese stored under refrigeration should be tempered at room temperature for approximately 30 min per pound prior to evaluation to facilitate release of volatile components. Observe the quality of the packaging and the surface condition of the cheese. A sharp knife or wire should be used to cut the blue cheese wheel in half (wire), then into wedges (wire or knife), or crumbles (Fig. 17.9). Begin by observing the aroma upon slicing. Pay attention to the overall impact and impression as it may reveal what is to come when tasting the product. Make note of the appearance of the mold after cutting and again after tasting, as color may change. Pay attention to the slicing properties of the cheese. Tasting should include quarter-sized samples representing the center, middle, and exterior of the wheel to obtain a complete picture of the cheese quality.

17.3.3.2 Blue Cheese Sensory Characteristics

Besides Swiss cheese, blue cheese is likely the most visually recognizable cheese to consumers. Surfaces of wheels of blue cheese may appear white- to cream-colored or may display surface ripening of varying colors; wheels may be bandage-wrapped or even foiled. Color loss may occur if blue cheeses are placed in retail packaging before they are fully ripened ("in-pack maturing"). The atmosphere in which *P. roqueforti* mature post-packaging affects not only conidial color but also the way in which conidiophores are produced and develop morphologically; lanose or "cotton-woolly" appearance forms in higher CO_2 environments (Fairclough et al., 2011). Upon cutting, abundant internal veins and pockets of vibrant blue-green mold should be distributed evenly throughout an open-bodied white- to cream-colored paste.

Blue cheese should slice cleanly, without excessive force or crumbling. The cheese should break down into a smooth paste relatively quickly during mastication.

Similar to other cheeses, blue cheese's body and texture is largely dictated by pH because of its effect on mineral solubilization and casein dissociation from casein micelles. The ratio of intact casein to moisture, manufacturing practices, and storage conditions are also key factors. Further, blue-veined cheese body is affected by proteolysis from fungal protease action as well as residual chymosin, plasmin, and non-starter microorganism enzymatic activity (Diezhandino et al., 2016).

Blue-veined cheeses should have recognizable lactic acid and acetic acid aroma upon opening. Blue-veined cheeses are expected to exhibit extensive, blue-green veining throughout the body (from interior to just below the surface) of the white-to-cream-colored open-textured paste (Fig. 17.10). Consumers associate more blue-green veining with more intensely flavored cheeses, and associate yellow-brown veins with over-ripening (Fairclough et al., 2011).

Blue-veined cheese aroma and flavor result from proteolysis and lipolysis during ripening, yielding pleasing as well as potentially unpleasant flavors (Lawlor et al., 2003; Diezhandino et al., 2015). The question of whether homogenization is necessary for blue cheese flavor development was investigated by Cao and others (2014). The findings indicated the facilitative effect of homogenization of milk fat to enable *P. roqueforti* lipase to release free fatty acids and formation of methyl ketones in aged blue-veined cheese. High et al. (2021) identified 172 volatile compounds that discriminated 17 international varieties of blue cheese, including alcohols (22), aldehydes (3), esters (38), free fatty acids (11), hydrocarbons (10), ketones (19), lactones (3), nitrogenous compounds (7), sulfurous compounds (4), phenyl compounds (5), terpenes (4), and other compounds (2). The study revealed that the esters, hydrocarbons, ketones, and alcohols did the most to distinguish different cheeses. Blue-veined cheeses are often characterized by words associated with the chemical compounds, including but not limited to "moldy flavor" (methyl ketones (i.e., 2-pentanone, 2-heptanone, and 2-nonanone), "musty"

Fig. 17.8 Antimycotic agents modify the surface appearance of blue-veined cheeses (left = with; right = without) (S. Clark image)

(2,4,6-trimethoxy-benzaldehyde), “mushroom” (3-octan-3-ol), “rancid” or “lipase flavor” (fatty acids (i.e., butyric, caproic, caprylic acids)), “waxy” (capric acid), “soapy” (lauric acid), and fruity (ethyl hexanoate) (Drake, 2007).

17.3.3.3 Defects in Blue-Veined Cheeses

Blue cheese defects can be segmented into three categories: Appearance, color, and mold development, Aroma and flavor, Body and texture. Defect descriptions are included in subsequent pages.

17.3.3.3.1 Appearance, Color, and Mold Development

Terminology related to deviations from ideal or appearance and color defects in blue-veined cheese are summarized in the next section.

Closed Properly manufactured blue cheese should possess an open body, enabling oxygen-dependent molds to germinate and spread throughout the body of the cheese. A closed body exhibits a lack of openings and lack of blue veining (Fig. 17.11).

Crystals Blue cheese with extended aging may display crystals (e.g., tyrosine crystals), resulting from extensive proteolysis.

Discolored Upon cutting, blue cheeses are expected to display vivid blue-green-colored “veins” of mold that contrast a homogenous white paste. White, yellow, brown, or gray mold is indicative of contamination by other mold species or inadequate ripening conditions (e.g., low pH, low salt concentration, low oxygen) (Fig. 17.12). A yellow paste may be indicative of grass-feeding and, in such cases, may not be considered objectionable.

Excessive Mold The term “excessive mold” may be used when the amount of blue-green mold predominates the interior and surface of the cheese, with very little white paste evident (Fig. 17.13).

Free Whey/Wet Free moisture inside the packaging or entrapped within the body of the cheese, released upon slicing, should be faulted as free whey or wet (Fig. 17.14).

Inadequate Piercing Approximately 30–50 needle channels are sufficient for a wheel of blue cheese. Fewer than 25 may result in a cheese with a lack of veining (Fig. 17.15).

Fig. 17.9 Two appropriate styles of blue cheese preparation for tasting (wedges (left) and crumbles (right)) (S. Clark images)

Lack of Veining or Undeveloped Mold Undeveloped mold and lack of veining are similar. In a fully ripened cheese, extensive, even vein distribution throughout the body of the cheese is expected. Lack of veining most commonly results from a closed cheese body, caused by packing molds with soft curds, inadequate piercing, excessive retained moisture in curds, and/or excessive proteolysis. Inadequate packaging, ripening conditions, or forgetting to add mold spores during manufacture are other causes (Fig. 17.16).

Malformed A cheese that does not display a uniform shape should be faulted as malformed.

Surface Growth Unexpected surface mold or yeast growth should be faulted (Fig. 17.17).

Uneven Mold Distribution Blue-green veining should be distributed evenly from the cheese center to within a centimeter of the cheese surface (Fig. 17.18). Cheese exhibiting uneven distribution or more than two centimeters of white paste at the cheese surface should be faulted for uneven mold distribution.

17.3.3.3.2 Aroma and Flavor

Terminology related to deviations from ideal or defects in blue-veined cheese are summarized in the next section.

Ammoniated Blue cheese that has undergone extensive proteolysis can exhibit pH above 6.5 and have an ammonia aroma which is associated with the formation of aroma from free amino acids. Ammoniated will also typically be associated with bitterness and soft body.

Atypical The defect atypical is used when the blue cheese lacks typical "blue cheese flavor." In contrast to flat, which is an overall lack of flavor, atypical is the presence of an unexpected flavor or a flavor not expected in blue cheese.

Bitter Bitter is one of the most common defects associated with aged cheese. Bitterness results from excessive proteolysis and is recognized, by some, at the back of the throat or tongue. It may be slow to progress, but it lingers for a long time.

Fermented Although some acetic acid aroma and flavor notes are expected in blue cheeses, the defect "fermented" is indicated when the cheese has an excessive level or predominant vinegar or fermented fruit aroma or flavor.

Flat or Lacks Flavor Flat may be used to describe young blue cheese or that which lacks typical, piquant blue cheese flavor (it may lack blue-green veining). The predominant flavor may be lactic acid rather than complex blue cheese flavors.

Fruity Although some fruity notes (e.g., apple, pineapple, or apricot) are expected and desired in blue-veined cheese, if fruity flavors predominate or are exclusive (no other flavors are noted), fruity may be considered a defect.

High Acid While lactic acid is formed in the production of blue cheese, with aging, other aromatic and flavorful by-products should also characterize blue-veined cheeses. When lactic acid predominates or is in excess of expected levels, the defect "high acid" should be pointed out.

Fig. 17.10 Classic, open body and bright, blue-green mold extending close to within 1 cm of the cheese surface (S. Clark image)

High Salt Blue-veined cheeses contain approximately 3.5–4.5% salt, which is higher than many other cheeses. However "salty" should not predominate the flavor profile of blue-veined cheeses. Salt should help to bring out the complex flavor of blue cheese. If it is out of balance, high salt should be noted.

Rancid Although some rancid (free fatty acid) aroma and flavor notes are expected in blue cheeses, the defect rancid is indicated when the cheese has an excessive level or predominant rancid (butyric, caproic, caprylic, or capric acid) aroma or flavor.

Unclean Unclean blue cheese may have a fecal aroma upon opening the package. Alternatively or additionally, it may have an objectionable flavor or aftertaste.

17.3.3.3.3 Body and Texture

Terminology related to deviations from ideal or body and texture defects in blue-veined cheese are summarized here.

Mealy/Grainy Blue cheese that is too dry and/or crumbly will likely also be mealy and grainy. During and after mastication, the cheese does not fully break down, and after swallowing, the mouth does not clean up.

Too Crumbly Blue cheese that falls apart during slicing is considered too crumbly. Although blue cheese crumbles have many applications (e.g., salads, dressings), the most valuable blue cheese is available in wheel and wedge forms.

Too Dry Young or over-salted blue cheese is sometimes characterized by a dry body. It may slice cleanly or crumble upon slicing.

Too Firm Blue cheese that is difficult to slice is considered too firm. It may also be too dry and mealy/grainy.

Fig. 17.11 Pronounced closed body, lack of veining (right cheese also displays discolored mold and surface growth (left cheese displays an ash coat)) (S. Clark images)

Fig. 17.12 Discolored mold (grey (left) and brown (right) mold formation) and crystals (left) (S. Clark images)

Fig. 17.13 Excessive mold, surface growth, and uneven mold distribution exhibited in a freshly cut wheel (S. Clark images)

Too Soft/Weak Blue cheese that is too soft will be difficult to slice and may crush or smear. Blue cheese that contains too much moisture or that has undergone extensive proteolysis will be soft, weak, and/or pasty.

Pasty Pasty blue cheese is commonly soft and sticky while slicing. The defect is characterized by a sticky mouthfeel and a film may remain in the mouth after swallowing.

Fig. 17.14 Moisture spots (left) and free whey exhibited on the surface (right) and exuding from openings (right) of blue cheese (S. Clark images)

Fig. 17.15 Inadequate (left) or improper (right) piercings. The cheeses also exhibit discoloration due to wild microbial growth and possibly mite infestation (S. Clark images)

Fig. 17.16 Blue cheese exhibiting piercings but a lack of mold development, likely due to the apparent closed body (S. Clark image)

Fig. 17.17 Blue cheese exhibiting unsightly surface growth (the right cheese also lacks veining) (S. Clark images)

a. b.

Fig. 17.18 Fully developed blue-green mold within cheese interior. (**a** even mold distribution; **b** uneven mold distribution (S. Clark images)

17.4 Conclusion

Readily recognized by their appearance, mold-ripened cheeses occupy a unique niche in the cheese case and food supply. These beneficial molds are not a sign of spoilage but of the delicate craftsmanship and maintenance of conditions allowing them to properly develop. Meticulous care in sanitation practices, cultivation of starter cultures and mold spores, production practices, and aging regimen yield a multitude of delightful bloomy rind and blue-veined cheeses worldwide, representing milk of cows, goats, sheep, buffalo, or mixtures of milk from multiple species.

A breakdown anywhere in the system may yield sensory defects as elaborated upon in this chapter. Both accidental and intentional changes to process or conditions have occasionally led to novel cheeses for this category. Training of personnel to recognize and combat sensory defects in mold-ripened cheeses will only improve our ability to ensure consumers have the best-quality mold-ripened cheese experiences.

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Chapter 18
Goat and Sheep Cheeses

Ris Kleve and Stephanie Clark

18.1 Introduction

Legend has it that cheese was discovered by nomads who carried milk in pouches made of goat or sheep stomachs. It is likely that goats and sheep were domesticated before cows and water buffaloes because of their manageable size and that the very first cheeses were made from goat and sheep milk. Although the first livestock species domesticated (Pereira et al., 2009), goat (and sheep) milk products have not been studied or utilized quite as extensively as cow milk products (Salles et al., 2002). Goat milk is reportedly the most consumed milk in the world (Gillingham, 2008) and is often a popular replacement for cow's milk for people (especially children) with allergies. The higher proportion of small fat globules and natural fat globule homogenization makes goat milk easier to digest and a popular alternative for infants and children (Golinelli et al., 2014; Clark & Mora Garcia, 2017).

In the United States, goat and sheep milk represent less than 1% of annual milk production, and 75% of the goat milk and 95% of the sheep milk produced are made into cheeses (Milani & Wendorff, 2011). Although the United States is better known for making cheeses from cow milk, goat and sheep milk cheeses predominate in other countries. As of January 1, 2020, U.S. sheep and lamb inventory was 5.2 million head, and goat and kid inventory was 2.3 million head (NASS, USDA, 2020). Dairy goats and kids made up 440,000 of that number, with highest counts in WI, CA, IA, and TX. It has been reported that approximately 21% of all goats and sheep in the world are dairy animals and produce 3.5% of the world's milk; about 8% of the total agricultural output in Greece and 0.9–1.8% of the total agricultural output in France, Italy, and Spain (Pulina et al., 2018). The island of Sardinia is the source

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of about 65% of the total Italian production of sheep milk, most of which is processed into the primary dairy product of Sardinia: Pecorino Romano (Idda et al., 2018). More than 50 varieties of goat cheese are made in France alone, at least nine of which have Protected Designation of Origin (PDO) status.

18.2 Composition of Goat and Sheep Milk

Before elaborating on goat and sheep milk cheeses, some general information about goat and sheep milk will help lay the groundwork for what makes these cheeses unique. From a proximate analysis standpoint, milk from goats and sheep (in particular), on average, contain more fat and protein than cow milk (Table 18.1). As a result, during cheesemaking, there is potential for higher cheese yield since fat and protein predominate cheese. However, the higher proportion of solids does not always translate to a higher yield. For example, goat milk contains less alpha_{s1}-casein than cow or sheep milk, which partially explains the softer body and lower yield of goat cheese compared to cow and sheep cheeses (Clark & Sherbon, 2000). Sheep cheese yield, on the other hand, is typically higher than that of either goat or cow milk.

The milk and products made from the milk of goats, sheep, and even water buffalo are naturally more white in appearance (Fig. 18.1) than products made from cow milk (Kosikowski & Mistry, 1997a). This is because when goats and sheep consume feeds rich in beta-carotene (a pigment yellow to orange in color), they convert the nutrient to vitamin A, which is colorless (Fedele, 2008). Cows do not convert beta-carotene to vitamin A, so the color of products made from cow milk tends to be more yellow, particularly if they eat feeds rich in beta-carotene (e.g., organic or grass-fed).

Naturally, goat and sheep milk contain more short-chain-length volatile fatty acids (VFA) and branched-chain fatty acids (BCFA) than cow milk (Ha & Lindsay, 1991). Sheep milk naturally contains more butyric acid (C:4) than goat or cow milk, while goat milk naturally contains more caproic (C:6), caprylic (C:8), and capric (C:10) acids than sheep or cow milk (Clark & Mora Garcia, 2017). Volatile

Table 18.1 Mean percent of components and Cheddar cheese yield from milk of cows, goats, and sheep

	Cow	Goat	Sheep
Water	87.4	86.9	83.6
Protein	3.3	3.7	5.2
Fat	3.8	4.2	6.1
Lactose	4.8	4.4	4.2
Ash*	0.7	0.8	0.9
Cheddar cheese yield	10.0	9.8	14.8

Adapted from Clark and Mora Garcia (2017)
*Calculated by subtraction

Fig. 18.1 The interior of goat (left two) and sheep (right) cheeses naturally appear more white than cow milk cheeses (S. Clark images)

compounds are aromatic, so they can be smelled. The 4-methyloctanoic acid of sheep milk fat gives sheep milk products a mutton-like aroma and flavor, and the 4-ethyloctanoic acid in goat milk gives goat milk products a "goaty" flavor (Ha & Lindsay, 1991).

18.3 Goat and Sheep Milk Cheeses

Just about any cheese that can be made from cow milk can also be made from goat (and sheep) milk. An exception is *pasta filata* (stretched curd) cheeses like mozzarella; the different protein composition makes goat cheeses more difficult to stretch (Niro et al., 2014; Faccia et al., 2015). Cheeses resulting from goat and sheep milk have some different appearance, flavor, and body and texture characteristics than cow milk cheeses, which are discussed elsewhere in this book.

Some cheeses require very specific making conditions in order to be labeled as the cheese type. In the United States, cheese definitions are found in the Code of Federal Regulations, Title 21, Chapter 133 (USFDA, 2019). The Appellation d'origine controlée (AOC, primarily for wines), Protected designation of origin (PDO), Appellation d'origine protégée (AOP) notation in French-speaking countries, Denominacion de origen (DOP) in Spanish-speaking countries, and Denominazione d'origine controllata (DOC) in Italian speaking countries (or Italy), systems protect the names of products throughout the European Union (Harbutt, 2009). The AOC, AOP, PDO, DOP, or DOC designation means a product has undergone all production stages according to recognized expertise in the same geographical area, which provides its characteristics. The designations embrace the concept of terroir, wherein interactions between a physical and biological environment influence food produced in the region (NAOQ, no date). Many goat and sheep cheeses have PDO, AOP, or DOP status.

In the United States, on the other hand, most goat and sheep cheeses are not defined in federal standards of identity. However, 21 CFR 133.184 defines

"Roquefort cheese, sheep's milk blue-mold, and blue-mold cheese from sheep's milk" as being made from pasteurized or unpasteurized sheep milk, aged at least 60 days, "characterized by the presence of bluish-green mold, *Penicillium roqueforti*, throughout the cheese" and containing a minimum milk fat content of 50% on a dry weight basis and maximum moisture of 45% by weight (USFDA, 2019). This description does not comply with French regulations, which require that, to have the name "Roquefort," the cheese must be made exclusively from whole raw milk of Lacaune ewes, pastured in southern France, and made and aged in caves only in the Roquefort Causses region of Auvergne, France (Kosikowski & Mistry, 1997a). The first AOC cheese, Roquefort cheese has held that status since 1925 (Harbutt, 2009). The reader is referred to Chapter 17 for additional discussion of mold-ripened cheeses.

Cheeses made from sheep milk include but are not limited to: Manchego (DOP), Idiazábal (DOP), Pecorino Romano (PDO), Fiore Sardo (DOP), and Serra da Estrela. Up to 30% goat milk is allowed to be added to sheep cheeses in traditional Greek cheeses (Litopoulou-Tzanetaki, 2012). Manchego has been a PDO/DOP cheese since 1985. Made only in the La Mancha region of Spain from the milk of Manchega ewes, it is enzymatically coagulated, cooked at about 40 °C, pressed, dried or brine salted, and cured for 1–10 weeks (Kosikowski & Mistry, 1997b). The hard cheese is the most popular cheese variety in Spain (Poveda et al., 2014). Manchego can be made either from raw or pasteurized milk, but if the latter, a commercial mixed-strain starter culture, typically composed of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris* is used. Manchego has a traditional dry grass mold or basket-weave rind. The dry blonde to straw-colored interior of Manchego cheese may have mechanical openings. It is buttery and nutty in flavor with lanolin notes and gains caramel and/or piquant flavors with age. Idiazábal (DOP) originated in the Basque Mountains of Spain. It is an aged, hard, and chewy cheese with tiny mechanical openings and a smoky flavor, obtained from beech wood smoke (Harbutt, 2009).

Pecorino Romano (PDO since 2009) is a semi-cooked (68 °C for at least 15 s) hard cheese made from whole ewe's milk in specific regions of Italy: Sardinia, Lazio, and the Province of Grosseto (Idda et al., 2018). Aged 5–12 months, and cylindrical in shape, it has a somewhat sweet, nutty flavor with a salty tang and hints of lanolin (Harbutt, 2009). Several similar varieties exist in Italy, including Pecorino Sardo (PDO; drum-shaped; aged 1–2 months for dolce, 8 months for maturo), Pecorino Siciliano (PDO; wheel-shaped; aged 4–12 months), and Pecorino Toscano (PDO; drum-shaped; oil-rubbed rind; aged 1–6 months) (Harbutt, 2009).

Fiore Sardo (PDO) is an uncooked and long-ripened hard cheese that is made from the raw whole milk of Sardo sheep, produced in Sardinia, Italy (Zazzu et al., 2019). Serra da Estrela (PDO status since 1985) is a traditional soft (or hard if aged over 6 months) Portuguese cheese made from raw milk of Churra Mondegueira and Bordaleira Portuguese autochthonous breeds, coagulated with wild thistle flower (Lima et al., 2019).

Cheeses typically made exclusively of goat milk include but are not limited to, Chevre, Crottin de Chavignol (PDO), Sainte-Maure de Touraine (PDO), Valençay

(AOP), and Banon (AOP). Chevre is a soft, fresh "lactic" cheese made from pasteurized milk, typically with the aid of chymosin. It is a fairly simple cheese to make. As in the making of most cheeses in the United States, the goat milk is first pasteurized and then cooled to a favorable temperature for mesophilic cultures to grow in, often around room temperature or a bit higher. Culture and/or rennet is added and the cultured milk is left to sit for between 6 and 24 h as the curd forms in response to the lactic acid production by the bacteria. The product is then drained for 6–24 h (depending on method and desired outcome), shaped, and salted. Herbs, spices, flowers, fruits, and other condiments are often added internally and/or to surfaces. Chevre may be served fresh or ripened. Oftentimes, the surface is dusted with food-grade ash to reduce surface acidity, and a rind is allowed to form. The cheese is often dried and aged (Hooper, 2009). For more on soft-ripened cheeses, see Chapter 17. Chevre is generally acidic with a pH around 4.2–4.5, with at least 55% moisture (Santos et al., 2016).

Crottin de Chavignol (PDO since 1986) is a soft-ripened cheese made from raw Alpine goat milk in the Loire and Chavignol regions of France. It is slightly renneted, and the lactic coagulation lasts about 2 days (Rubino et al., 2004). After draining, the cheese is salted (1–2% of the weight of the cheese) and then aged for 10 days and allowed to form a white surface mold (Litopoulou-Tzanetaki, 2012) (Fig. 18.2). It has a nutty flavor, which gets more robust with age, along with a texture that becomes more dry and crumbly with age.

Sainte-Maure de Touraine (PDO) is made by a slow curdling, molding in a long log shape (16–17 cm), and transferral onto pyroengraved rye straw (Rubino et al., 2004; Litopoulou-Tzanetaki, 2012). The cheese is then salted and aged for at least 10 days, but generally 3–4 weeks (Harbutt, 2009; Le Jaouen, 1987). The cheese has a white, soft paste under a grayish-blue, moldy rind from *Penicillium candidum* (Harbutt, 2009; Rubino et al., 2004).

Fig. 18.2 Crottin de Chavignol style cheese made in the United States (S. Clark image)

Valençay (AOP) is a soft, blue-veined cheese made from raw goat milk in the shape of a pyramid with a flattened top (Fig. 18.3). Originating in the Berry and Loire Valley regions of France, the rustic blue-gray cheese (because it is typically dusted with ash) develops during the 4-week ripening in caves (Le Jaouen, 1987).

The origin of Banon (AOP) is north of the Haute-Provence Alps. Pure goat milk or a mixture of goat, sheep, and even cow milk may be used to make the small round (6- to 7-cm diameter, 2-cm height) cheeses. Several varieties of Banon are available in France (fresh, flowered rind), but the most famous is wrapped in chestnut leaves (Fig. 18.4). After drying and ripening for 4–6 weeks, the ball is wrapped in dried chestnut leaves and tied with raffia (Le Jaouen, 1987).

Several popular cheeses may be made from both goat and sheep milk, and sometimes cow milk is added. Feta, Kaseri, and Halloumi are examples. Feta, likely the most famous white brined cheese (WBC), is in the most important class of cheeses (brined cheeses) of the east-Mediterranean and neighboring countries (Alichanidis & Polychronidaou, 2008). The WBC, characterized by their white color that results from the use of goat and/or sheep milk, include but are not limited to Feta and Teleme (Greece), Beyaz peynir (Turkey), Iranian white (Iran), Brinza (Israel), Akawi (Lebanon), and Domiati (Egypt).

WBC production generally follows the same steps (Alichanidis and Polychroniadou 2008), including:

1. Filtration and (maybe) standardization of cheese milk (C:F 0.72–0.75 for sheep and/or goat milk or 0.75–0.8 for cow milk)
2. Pasteurization or thermization
3. Addition of $CaCl_2$ and starter cultures (30–35 °C)
4. Renneting (commercial or artisanal chymosin)
5. Ripening (50–60 min)
6. Cutting (1–3-cm cubes)

Fig. 18.3 Valencay-style cheese made in the United States (S. Clark image)

Fig. 18.4 Banon-style cheese made in the United States (S. Clark image)

7. Healing (10–15 min)
8. Molding (rectangular/square or cylindrical molds)
9. Draining (usually under pressure, some without pressure)
10. Cutting (to final cheese dimensions)
11. Salting (mostly in brine, some with dry salt)
12. Packaging (with or without brine)
13. Ripening (16–18 °C for 5–15 days; until pH ≤4.6)
14. Sealing of the containers and storage (≥4 °C)

Feta has been a European Union protected (PDO) name since 2002, and can only be made in the mountainous regions of Macedonia, Thrace, Epirus, Thessaly, Sterea Ellada, Peloponnesus, and Mytilini from goats and sheep that graze freely in those areas (Harbutt, 2009). However, many U.S. producers make products they call Feta. Feta is traditionally made in Greece from raw ewe milk with no starter and rennet from lamb abomasa, or in large factories from pasteurized ewe milk with culture and rennet (Bozoudi et al., 2018). In addition to being characterized as pure white, feta has no rind, no eyes (gas holes), some mechanical openings, and a smooth, soft, and crumbly body. The flavor is salty, acidic, and piquant, often reflecting the fatty acid flavors representing the source of the milk. The flavors of WBC range from very mild to very piquant, which is, in part, influenced by native or added lipase.

Kaseri (DOC), produced in Greece using a mix of goat and sheep (at least 80% sheep) milk, is reportedly one of the oldest cheeses in the world (Harbutt, 2009). A pasta filata cheese, Kaseri is stretched in hot brine; it is stringy when melted, slightly sweet, and pungent in flavor.

Halloumi, a traditional cheese of Cyprus, is made from non-cultured raw milk from goats and sheep and sometimes combined with cow milk (Harbutt, 2009; Papademas & Robinson, 1998). The renneted coagulum is cut into grain-sized curds (as with other low-moisture granular cheeses), allowed to rest (heal), then cooked in whey with continuous stirring for about an hour prior to draining and pressing into blocks. The pressed curd is cut into 10 × 15 × 3 cm blocks, then scalded in hot whey (94–96 °C) for about 30 min (Alichanidis & Polychroniadou, 2008). Blocks are allowed to drain, then surface-salted and sometimes sprinkled with crushed mint leaves (Alichanidis & Polychroniadou, 2008; Papademas & Robinson, 1998). Blocks are folded in half, kneaded, and chilled overnight, or salted whey is poured into containers of halloumi for sale (Harbutt, 2009; Papademas & Robinson, 1998). Halloumi has a mild flavor and is good for grating or frying (Papademas & Robinson, 1998).

The by-product of cheesemaking, whey, can be made into several popular whey cheeses: Gjetost (goat), Manouri (PDO, predominantly goat), and Mizithra or Myzithra (predominantly sheep). Gjetost is a caramelized whey-and-cream cheese of Norweigan origin. Dark brown in color and sweet in flavor, Gjetost is unlike any other cheese except Mysost, the cow-whey-based version.

Manouri (PDO) and Mizithra are Greek heat- and/or acid-coagulated cheeses produced predominantly from caprine (manouri) or ovine (mizithra) whey, but they are not caramelized, so they appear white to cream-colored. Mizithra may have up to 70% moisture, while Manouri may only have up to 60% moisture and a minimum fat in dry matter of 70% (Kaminarides et al., 2013). Manouri and Mizithra have no rind, a closed texture, a firm, granular body, and a mild flavor. Manouri is only produced from sheep or goat whey and whole sheep and goat milk and/or cream (Kaminarides et al., 2013). The whey-based cheeses are made by first filtering whey to remove curd particles, then heating to 88–92 °C for 40–45 min, under continuous stirring (Alichanidis & Polychroniadou, 2008). If whole milk or cream is added (to improve yield and quality), it is added early in the process (when the whey reaches 65–70 °C); salt is added to the whey at 73–75 °C. After curd particles start floating, part-way through the heating process (at about 80–82 °C), heating is sped up and stirring is slowed. A citric acid solution (100 g/L) is added at the rate of 6 mL/L at approximately 90 °C, just before stirring is stopped. The curds are allowed to float on the whey surface for about 15–20 min, then scooped into molds for drainage over a period of 3–5 h (Alichanidis & Polychroniadou, 2008).

A summary of goat and sheep cheese composition is shown in Table 18.2.

18.4 Sources of Sensory Attributes of Goat and Sheep Cheeses

Variability in goat and sheep milk and cheese quality arises, at least in part, from variability in lactation stage, feeding system, and diet (Inglingstad et al., 2014). Feeding systems have an impact on milk and cheese profiles due to the molecular compounds in the feedstuffs. Feed nutrient composition is influenced by soil nutrients, water quality, season, climate, maturity, and variety of species, among other

Table 18.2 Typical composition of goat and sheep cheeses

Cheese	Milk source	Fat (%)	Total solids (%)	Salt (%)	pH
Camembert	Goat, sheep, cow, mixed	23	47	2.5	6.9
Cheddar	Goat, sheep, cow, mixed	28	62	1.5	5.5
Chevre (fresh)	Goat	6–16	15–35	1	4.4
Chevre (ripened)	Goat	18–32	51–58	1.5	4.5
Crottin de Chavignol (AOP)	Goat	20–23	40 – 41	1.5	4.6
Feta	Goat, sheep, cow, mixed	22 - 31	37 - 50	4.5	4.4
Gjetost	Goat	30	77	0.5	6.5
Gouda	Goat, sheep, cow, mixed	28	59	2	5.8
Halloumi	Goat, sheep, cow, mixed	30	>54	<3	4.6
Manchego (DOP, semi-mature)	Sheep	30–40	65–70	2.2	5.8
Manouri (PDO)	Goat, sheep, mixed	25	>40	1.5	5.0
Myzithra/Mizithra	Goat, sheep, mixed	25	56	1.6	5.0
Ricotta	Goat, sheep, cow, mixed	18	30	<0.5	5.9
Pecorino Romano (PDO)	Sheep	24–30	65–77	5.5	5.4
Roquefort (AOC)	Sheep	31–33	57–60	3.5	6.4
Valencay (AOP)	Goat	20–23	40–41	1.5	4.6

Fox et al. (2000), Bozoudi et al. (2018), Kosikowski and Mistry (1997a), Le Jaouen (1987), Papademas and Robinson (2000), Raynal-Ljutovac et al. (2008), Papademas and Robinson (1998), and Park (1999)

factors (Hooper, 2009). This implies that different feeds or pasture species can be used to diversify product flavor (Fedele, 2008). Compounds that give flavor to cheese include fatty acids, volatile organic compounds, amines, ketones, free amino acids, phenols, alcohols, aldehydes, lactones, and sulfuric compounds, all of which affect the cheese-making and ripening process and all of which can be attributed to feed type (Tilocca et al., 2020). Branched-chain fatty acids give goaty flavor to chevre, in particular 4-ethyl-octanoic acid, which is fairly specific to goat milk. It is found in very low concentrations or not at all in cow milk but is curiously found in some plants, such as tobacco. Scientists speculate that it is released during the aging process of cheese as lipolysis occurs (Salles et al., 2002).

Concentrates and forages each contribute different qualities to milk and can be used to manipulate characteristics of the end product. A dry lot system with a very consistent ration of dry hay and grain yields milk and cheese with different sensory characteristics compared to a variable pasture-based system or a silage-based ration (Fedele, 2008). Indoor feeding systems generally involve a higher feed intake of good-quality feeds but may also lead to overfeeding concentrates, which leads to milk high in protein but comparatively low in fat (Morand-Fehr et al., 2007). As concentrates become a larger portion of the ratio (>60%), milk fat drops due to a lack of dietary fiber (Morand-Fehr et al., 2007).

Natural pasture leads to milk high in fat, fatty acids, vitamins, and volatile compounds such as terpenes, which give milk grassy flavors (Morand-Fehr et al., 2007). Terpenes are unsaturated hydrocarbons built of isoprene units that are volatile liquids with strong odors found in plant flowers, leaves, and fruit (Fedele, 2008). When grass is at an early growth stage, goat milk production and fat content may both be higher, as well as having higher levels of polyunsaturated fatty acids (PUFAs) and conjugated linoleic acid (CLA) due to the higher feed quality (Morand-Fehr et al., 2007). Early grazing season has more favorable rennet coagulation properties that result from α_{s2}-casein and calcium concentrations, prompting a shorter firming time and higher curd firmness (Inglingstad et al., 2014). Pastured goats have more protein (α_{s1}-casein and κ-casein) and milk yield, and thus a better cheese yield, than hay-fed goats (Inglingstad et al., 2014).

Valdivielso et al. (2016) evaluated changes in the volatile composition and sensory profile of raw milk cheeses made on farm from the milk of six commercial flocks of Latxa sheep in the Basque region of northern Spain in different feeding seasons throughout lactation. From a sensory standpoint cheeses made from milk of mountain grazing sheep had lower overall intensity, buttery, toasty and nutty aroma, salty taste, and elasticity and moisture in the mouth than cheeses made from milk of indoor-feeding ewes (Valdivielso et al., 2016). Barlowska et al. (2018) conducted a related study in Poland, with four farms (two mountainous areas; two upland areas) raising Saanen goats and making artisan cheese during two production seasons. From a sensory standpoint, mountain cheeses were more firm, aromatic, less goaty, less sour, sweeter, and saltier than upland cheeses (Barlowska et al., 2018). Upland milk is also generally higher in PUFAs and MUFAs (Coppa et al., 2019). In a study done regarding the ability to differentiate feeding systems based on goat cheese aroma, 100% of the testers could distinguish both the taste and odor of 20-day-ripened cheese from a grazing herd compared to a hay/concentrate system. The fact that fewer testers could distinguish the same two systems in 1-day-ripened cheese highlights how aging generally increases the taste and odor of cheese (Fedele, 2008).

Vitamins and minerals also have an important role in milk and cheese quality. Potassium and calcium chloride contribute bitterness to chevre, while free amino acids, organic acids, and naturally present mineral salts all contribute to taste as well (Salles et al., 2002). In addition to influencing flavor, vitamins and minerals are important for milk quality. Deficiencies of zinc, selenium, manganese, and iron, as well as vitamin A, vitamin C, and beta-carotene, have all been shown to impact the health of the mammary gland and SCC (Nudda et al., 2020), thereby influencing cheese quality and yield.

18.5 Evaluating Goat and Sheep Cheeses

Understanding the source of the milk, making procedures, and intention of cheesemaker can all help during the evaluation of goat and sheep milk cheeses. At a minimum, it is essential for evaluators to know if the source of milk is from a sheep, a goat, or a mixture. With that base information, expectations for certain appearance and flavor characteristics come to mind. As noted previously, goat and sheep cheeses should be white in color. If goat milk is used, the caproic, caprylic, and capric acid "goat notes" should be observed but not be overbearing (dirty buck). Lanolin (wool-like) aroma/flavor should be noted in sheep cheeses but not remind the eater of old mutton. Evaluating additional appearance, body and texture, and flavor quality characteristics relies on some knowledge of intended cheese style. For instance, while a fresh chevre would be expected to have a closed body and a soft, smooth paste; mechanical openings and firm, crumbly body, and grainy texture would be more typical in an aged Romano. The present document summarizes some of the common flavor defects and body and texture defects that might be observed in goat and sheep cheeses (Tables 18.3 and 18.4). An example scorecard for evaluation of goat and sheep cheeses is included in Fig. 18.5. The reader is encouraged to view additional references for detailed appearance, body and texture, and flavor notes about goat and sheep cheeses. For instance, Talavera and Chambers (2016) further refined an existing lexicon (language) to describe flavor characteristics of artisan goat cheeses made in the United States. They worked with five highly trained descriptive sensory panelists to establish a lexicon of 39 flavor attributes to represent sensory characteristics for 47 artisan goat cheeses produced throughout the United States

Preparation of Cheese for Evaluation

When evaluating goat and sheep cheeses, tempering to room temperature is typically advised, as volatile components will become more prominent. An exception is ricotta and chevre, which may be served on the cooler side of room temperature. The cheeses should be sampled with tools that are appropriate to the style. For instance, ricotta is often spread, feta may be sliced or crumbled, and Manchego is commonly thinly sliced. For firm, large-format goat and sheep cheeses, triers should be used to penetrate the cheese and extract a representative sample to observe for mechanical openings or eyes. Cheese body can be examined by breaking the plug and working between the thumb, index, and middle fingers. Surface-ripened, mold-ripened, or washed-rind cheeses should be sliced open.

How to Evaluate

Similar to evaluation of all other cheese types, evaluation of goat and sheep cheeses begins on the outside with appearance, color ,and rind development, and moves inward. Since product evaluation typically involves comparison to a standard, any shortcoming characteristic or "out-of-balance" attribute is characterized as a defect. With respect to defects, the term "slight" refers to attributes that are only detectable upon critical examination, while "definite" is not intense but is detectable; "pronounced" defects are immediately noticeable and typically objectionable to most

Table 18.3 Common flavor defects in goat or sheep cheese, identification and their probable causes

Flavor	Identification	Probable cause
Bitter	A basic taste sensation, commonly on the back of the tongue, similar to the taste of quinine	Breakdown of proteins by proteolytic starter culture or microbial contamination
Flat/lacks flavor	Lacks characteristic piquant, lactic acid, or "goaty" free fatty acid aroma/flavor for goat or lanolin for sheep cheeses	Lower than typical level of short-chain volatile fatty acids in milk
Foreign	Atypical aroma or flavor for goat or sheep cheese	May be chemical (e.g., cleanser, sanitizer), enzymatic, or bacteriological in origin
High acid	Unbalanced, overly sharp, and puckery to the taste, characteristic of lactic acid	Excess lactic acid production; may be coupled with low salt
High animal flavor	Goaty, "buck", or mutton flavor is out of balance	Mishandling of milk promotes lipolysis that releases butyric, caproic, caprylic, and/or capric acid
High salt	Salt is out of balance, too high, off-putting	Over-salting
Lacks freshness	Staleness or "refrigerator aroma" noted in product	Stored improperly or too long
Low salt	Cheese lacks salt; may be coupled with high acid or goaty flavor	Under-salting
Metallic	A flavor having qualities suggestive of metal, imparting copper taste or a puckery sensation	Oxidation of ingredients (milk), contamination with free metals, or use of sea salt (certain minerals)
Musty	Atypical aroma of basement or mold	Contamination with mold spores; poor packaging
Oxidized	Wet cardboard aroma and/or mouth-drying sensation or aftertaste	Exposure to light and oxygen facilitates autoxidation of unsaturated fatty acids to produce aldehydes and ketones
Unclean	An undesirable dirty gym socks or dirty dishwater aroma/flavor; fecal aroma, flavor, aftertaste in extreme cases	Volatile compounds coming from fecal material or bacterial contamination
Yeasty	A flavor indicating yeast fermentation, may be appearance of gas eyes or slits	Contamination by yeast; poor packaging

observers. Each plant may determine and evaluate cheese quality based on methodology appropriate to the setting. To assist in the process of developing an evaluation criteria, an example scorecard is included in Fig. 18.5.

Appearance, Color, and Rind Development

Unripened goat cheeses are expected to be white; any discoloration in the form of yeast, mold, or bacterial spoilage should result in downgrading. Sheep cheeses may range from white to cream to slightly blonde color if aged. Surfaces of ripened cheeses or washed-rind cheeses should be properly colored (light browns, pinks, oranges) and uniform. A toad skin or rippled appearance is not unheard of. Blue-green mold-ripened cheeses should exhibit vivid blue-green well-veined interiors. Cheeses with ash may range from gray to black and must not be slimy or wet.

Table 18.4 Common body defects in goat and sheep cheeses[a], identification and probable causes

Body/Texture	Identification	Probable cause
Crumbly	Falls apart while cutting, working, or spreading	Low moisture retention; may be associated with high acid or high salt
Gassy	Eye or slit formation within body of cheese or packaging	Contamination with yeast or gas-producing microorganisms
Grainy	Atypical rough, mealy, gritty, or sandy feeling	Overcooking of curds
Pasty	Sticky and smears when worked or rubbed between the thumb and fingers	Excessive acid production, high moisture content, poor drainage of whey
Too firm	Atypical resistance to mastication or manipulation between thumb and fingers	Excess use of chymosin, too high cooking temperature and/or time, low moisture
Weak/Soft	Cheese compresses very easily between thumb and forefingers; may be difficult to plug cheese	Excess moisture or proteolysis
Weepy/Wet	Whey syneresis from cheese body	High moisture; poor drainage of whey; improper storage

[a]Defects are style-dependent (e.g., a brined white cheese would be expected to be crumbly; a fresh or soft-ripened cheeses would be expected to be weak/soft)

Aroma and Flavor

Goat and sheep cheeses should have pleasing and desirable aroma and flavor characteristics consistent with the source of the milk and the age of the cheese and should be free from undesirable aromas and flavors. A term that should come to mind is balance. Soft goat cheeses such as chevre are expected to be refreshing (fresh) with a slight tang (lactic acid), have recognizable goat flavor (characterized by caproic, caprylic, and capric acids), and be free from excessive goatiness or "dirty buck" notes. Talavera and Chambers (2016) reported that the most common attributes shared in U.S. goat cheeses included overall dairy (especially buttery, dairy fat, and dairy sour), goaty, astringent, biting, pungent, sharp, salty, sour, and bitter.

Goat cheeses should be downgraded if they lack typical goaty flavor, but goat flavor should not overwhelm. The same can be said for sheep milk cheeses (lanolin vs. mutton). A summary of the common off-flavors in goat and sheep cheeses is included in Table 18.3.

Body and Texture

The body and texture of most goat and sheep cheeses vary depending on cheese style, so a judge must be familiar with the intended style of the cheese to be a fair evaluator. Deviations in body and texture often result from improper acidification, moisture, salt balance, and/or proteolysis in aged cheeses. A summary of the common body and texture defects in goat and sheep cheeses is included in Table 18.4.

GOAT/SHEEP CHEESE
Iowa State Fair Judging Score Sheet
Judges: 0.5 to 1 point deduction for each defect (note that the minimum total score is 76 and maximum is 100)

Product identity: ______________________________

Packaging Appearance & Condition: 8 pt. min. 10 pt. max. total ______
Positive features:
Intact ☐ Factually informative ☐ Positive dairy image ☐ Protects product ☐ Visually appealing ☐
Deviations from ideal:
Cracked or disturbed ☐ Loose ☐ Confusing or misleading information ☐ Uneven shape/color ☐

Product Appearance: 12 pt. min. 15 pt. max. total ______
Positive features:
Consistent/Homogeneous ☐ Evenly firm ☐ Evenly moist ☐ Rustic, hand-made appearance ☐
Proper eye development ☐ Typical of product ☐ Visually appealing ☐
Deviations from ideal:
Atypical ☐ Cracked or disturbed ☐ Rough surface ☐ Uneven shape/color ☐ Excessive rind ☐ Free whey ☐
Mottled/Seamy ☐ Uneven mold ☐ Unexpected yeast/mold ☐

Aroma: 12 pt. min. 15 pt. max. total ______
Positive features:
Appealing ☐ Buttery ☐ Fresh ☐ Typical of product ☐ Earthy ☐ Nutty ☐ Pleasantly fruity ☐
Deviations from ideal:
Atypical ☐ Ammoniated ☐ Cooked ☐ Chemical ☐ Flat ☐ Fruity/fermented ☐ High goat/sheep ☐ Unclean ☐

Flavor: 22 pt. min. 30 pt. max. total ______
Positive features:
Appealing ☐ Fresh ☐ Nice balance of flavors ☐ Nice salt content ☐ Typical of product ☐
Deviations from ideal:
Atypical ☐ Bitter ☐ Cooked ☐ Chemical ☐ Flat ☐ High acid ☐ High goat/sheep ☐ High salt ☐ Fermented ☐
Fruity ☐ Lacks freshness ☐ Overly flavored ☐ Oxidized ☐ Rancid ☐ Unclean ☐

Body & Texture: 22 pt. min. 30 pt. max. total ______
Positive features:
Crumbly (feta) ☐ Firm but delicate ☐ Pleasant mouthfeel ☐ Smooth ☐ Spreadable ☐ Typical of product ☐
Deviations from ideal:
Corky ☐ Crumbly (atypical) ☐ Curdy ☐ Gassy ☐ Mealy/grainy ☐ Open ☐ Pasty/Sticky ☐ Short/Brittle ☐
Too firm/rubbery ☐ Weak ☐

Specific comments:

Fig. 18.5 Example scorecard, used in the Iowa State Fair Dairy Products Contest for the evaluation of goat or sheep cheese

Potential Defect Sources

Defects come from a variety of sources. Along with originating in the milk, defects may occur during harvesting, storing, or processing the milk or cheese. Animal nutrition contributes to flavors because consumed compounds can enter the mammary gland and be absorbed into the milk. Microbes produce distinct aromas and flavors by releasing enzymes that alter fats or proteins. If milk is stored too long before processing, cheese quality may suffer due to oxidation or hydrolysis of fatty acids. Despite pasteurization, microbes originally present in the milk or introduced during processing may contribute to defects prior to pasteurization; some spoilage microorganisms and their enzymes survive pasteurization and can cause degradation (defects) later. Cheese may experience oxidation if it is not stored properly. If utensils are unclean or if chemicals such as sanitizing agents are present on equipment, the cheese may exhibit chemical off-flavors. Probable causes of common flavor and body and texture defects of goat and sheep cheeses are included in Table 18.3 and 18.4, respectively.

18.6 Flavored Goat Cheeses

Goat cheeses are excellent carriers for a variety of added flavors (e.g., herbs, fruits, flowers) that are only limited by the imagination of the cheesemaker. The flavor and body and texture characteristics of a good cheese should be enhanced by characteristic and complementary flavor and body and texture characteristics of the flavoring component. Even distribution of condiments is essential and should effectively represent the name on the package without detracting from the underlying high-quality cheese flavor that should be noted by the judge, and ultimately the consumer.

18.7 Conclusion

Goat and sheep cheeses have unique appearance and flavor attributes which differentiate them from other types of cheeses. Understanding these characteristics, as well as the intention of cheesemakers, enables fair judgment of goat and sheep cheese to encourage consistent, high-quality cheesemaking. Using consistent lexicons and scorecards for the evaluation of cheese will enable processors to optimize products' body and texture, flavor, and appearance to not only monitor product quality but attract and keep consumers.

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Chapter 19
Washed-Rind Cheeses

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19.1 Introduction

Washed-rind cheeses are notorious for their pungent, strong aroma and flavor profiles. This family of cheese is heterogeneous and made up of different varieties that vary in firmness and overall sensory characteristics. Soft, semi-firm, and firm washed-rind cheeses have been in continual production in Europe for several centuries. Well-known examples include Brick, Limburger, Taleggio, Reblochon, Livarot, Munster (traditional), Port du Salut, Comte, Gruyere, and many others. Also known as smear-ripened cheeses or bacterial surface-ripened cheeses, they get much of their characteristic qualities from the formation of a red-orange microbial mat on their rind surface. This mat, or "smear," is formed by the washing action that takes place during the aging of these varieties. Brine or other washing solutions are scrubbed onto the surface, which encourages a complex ecosystem of microbes to take root and grow. The combination of bacteria, yeasts, and molds leads to the formation of diverse aroma/flavor compounds often described as "autumn-like," "sweaty sock," "pungent," or "sulfurous". The metabolism of the surface-situated microbes can also lead to a pronounced softening of the cheese body depending on the overall making process, with near complete liquefaction occurring in extreme cases.

This group of cheeses is a sub-set of surface-ripened cheeses, which also include mold surface-ripened cheeses such as Brie and Camembert styles. Although washed-rind cheeses also generally have molds colonizing their surface, they are distinct from surface mold-ripened cheeses due to the complexity of the microbial smear and the presence of a consortium of bacteria and yeasts in addition to molds. These cheeses still rely on starter cultures (lactic acid bacteria) for acid production during

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the making process, but their "identity" and dominant sensorial characteristics are created by the action of surface microbes (yeasts, bacteria, and molds).

This microbial growth, and the concomitant formation of unique colors, flavors, and textures, make this variety one of growing prominence in the artisanal cheese "renaissance" occurring in the United States. The distinctive flavor profiles associated with some of these cheeses can rise to the level of having a cult following, such as Rush Creek Reserve (Uplands Cheese, Dodgeville, WI), which often sells out within weeks of going on sale each fall. The smear (washing liquid) also allows for interesting inclusions of other flavors and sensory profiles. The use of beer, wine, and cider and other spirits is becoming increasingly common and can be a prominent marketing feature when advertised on the label. Willoughby (Jasper Hill Cellars, Greensboro, VT) is a soft washed-rind cheese that has often been washed with different alcohols via collaborations with local breweries, meaderies, distilleries, etc. These interesting selling points, when combined with the unique flavors and textures exemplified by cheeses in this family, have poised washed-rind cheeses to gain popularity and carve out a niche in the artisan cheese market.

19.1.1 Washed-Rind Cheese Prominence and Market

Washed-rind cheeses have emerged as a fast-growing segment of the cheese marketplace. The recent renaissance of artisanal cheese production in the United States, along with consumer demand for complex flavors and textures, has led to tremendous growth in the specialty cheese category. Annual sales in the specialty and natural cheese space are expected to top $21 billion by 2022, up from $15 billion in 2011. (Packaged Facts, 2016; Shoup, 2016) This increase in demand has resulted in a burgeoning specialty cheese marketplace with ample room for new players to enter the field. The number of artisanal cheese producers had risen to over 900 as of 2016, more than doubling from 400 in 2006. (Roberts, 2012; American Cheese Society, 2018; Fanning, 2020) At the vanguard of the growing U.S. artisan cheese movement is the request from consumers for bold, interesting flavors and textures. Several categories of cheese have distinguishing sensory characteristics that fill this niche. One such variety is soft washed-rind cheese (i.e., smear-ripened cheese, bacterial surface-ripened cheese). This type of cheese develops a very distinctive range of flavors and textures that are sought-after by cheese aficionados.

Soft washed-rind cheeses are now in widespread production across the artisan cheesemaking community. According to the American Cheese Society (2018), approximately 40% of artisan and specialty cheese producers in the United States sell washed-rind cheeses as part of their portfolio. This reflects the upward purchasing trend this variety has exhibited in the past decade. (Sakovitz-Dale, 2006; Packaged Facts, 2016) Washed-rind cheeses are particularly profitable due to the fact that they fully ripen within weeks as opposed to months or years. This allows for a quick turnaround time and frees up inventory/cash flow much more quickly than is possible with long-aged cheeses (Bouma et al., 2014; Durham et al., 2015). This creates an optimal economic environment where cheese producers can generate much-needed profit from products high in consumer demand. The logical next step is to further understand the crucial quality parameters associated with washed-rind cheeses. The sensorial characteristics of washed-rind cheese, and cheese/food in general, are often the major driver of liking for consumers.

19.2 Types of Washed-Rind Cheeses

A wide variety of washed-rind cheeses exist in the marketplace. This style of cheese has been in production in many European regions for hundreds of years. The differing ripening protocols, and subsequent varied microbiota, can yield a diverse array of colors, aromas, and flavors. Production location/geography, intensity of smear application, type of washing fluid, and other cheese making or ripening parameters can be used to help differentiate and categorize these cheeses. The most common method of classifying washed-rind cheeses is by cheese firmness (i.e., moisture content; Table 19.1). The most usual bifurcation is "soft" washed-rind cheeses (high moisture) and "firm" or "semi-firm" washed-rind cheeses (low/moderate moisture). Some sources indicate that the "smear-ripened" nomenclature refers to soft washed-rind cheeses and "washed-rind" refers to firmed varieties (Gremmels, 2016). However, the terminology is often used interchangeably with "washed-rind" and "smear-ripened" being synonymous, both referring to bacterial surface-ripened cheeses.

Table 19.1 General outline of the major types of wash-rind (bacterial surface-ripened, smear-ripened) cheeses

Cheese type	Typical moisture content	Typical fat content (FDM)	Examples	Characteristics
Soft	45–60%	≥50%	Limburger Epoisse Rush Creek reserve Winnimere Esrom	Very thin rind Complete softening and/or liquifaction of cheese body at advanced ages
Semi-firm	40–50%	≥50%	Fontina Taleggio Raclette Pont L'Eveque	Thin rind Elastic body Exhibit good melting and flowing characteristics
Firm	<40%	≥45%	Comte Beaufort Pleasant ridge reserve Gruyere	Thick, dry rind Firm cheese body that can become somewhat short at lower moisture or older ripening times

19.2.1 Soft/High-Moisture Washed-Rind Cheese

Soft washed-rind cheeses include cheeses such as Port Du Salut, Reblochon, Époisses de Bourgogne, Rush Creek Reserve, Red Hawk, and Winnimere. These cheeses have a very soft rind, which is usually very aromatic and high in red-orange coloration and is usually eaten as part of cheese evaluation. The moisture content of these cheeses can often range between 45% and 60%, leading to a cheese body that is very soft and often partially or fully liquified during the later stages of ripening.

19.2.2 Semi-Firm/Moderate-Moisture Washed-Rind Cheese

Semi-firm washed-rind cheeses include cheeses such as Limburger, Brick, Pont l'Eveque, and Raclette. These cheeses are usually of moderate moisture content, often between 40% and 50%. These cheeses often share aroma and flavor qualities similar to that of soft washed-rind cheeses, although sometimes they are lower in overall intensity. A critical feature of these cheeses is their functionality *vis-à-vis* meltability. These cheeses are often used in cooked applications where appreciable melting and flow is desirable. For example, raclette is usually melted and scraped and poured over cooked potatoes or other vegetables. Brick cheese is the main cheese used in Detroit-style pizza and must exhibit properties similar to that of mozzarella (e.g., melt, flow, stretch, browning, and blistering).

19.2.3 Firm/Low-Moisture Washed-Rind Cheese

Firm washed-rind cheeses include cheeses such as Cantal, Comté, Gruyère, Beaufort, and Pleasant Ridge Reserve. These cheeses are usually relatively low in moisture (compared to the varieties described above), ranging between 30% and 40%. This lower moisture content usually confers a firm, elastic body to the cheese. The lower moisture content, combined with ripening conditions and surface treatments and washing, usually results in a rind that is not consumed as part of the eating experience (although it technically is edible). The typical washed-rind aroma characteristics associated with softer varieties can still be experienced in firmer types, although usually limited to the surface rind. The body of the cheese usually has flavor attributes that range from brothy/umami, nutty, sweet, and fruity.

19.3 Manufacture of Washed-Rind Cheese

Washed-rind cheeses have variable moisture contents (depending on firmness level), are relatively low in acidity, and are aged in humid environments for several weeks. During this aging time, a microbe-laden washing fluid is scrubbed into the surface; alternatively, a solution that encourages native flora to grow can also be used (e.g., brine, beer, etc.). This process leads to the formation of the characteristic red-orange smear at the cheese surface. The smear is composed of a menagerie of microbes that include *Brevibacterium, Corynebacterium*, *Micrococci* species, *Geotrichum* species, and others. (Bockelmann, 1999; Button & Dutton, 2012) This complex ecosystem that forms on cheese rinds is still being fully elucidated. The metabolism of each microbe, along with the interaction between them, can have dramatic effects on how a cheese ages and ripens (Wolfe et al., 2014).

For the above reasons, the production of these cheeses is often divided into two main phases: the production of the base cheese and the formation of the rind and smear community. A common practice (especially in traditional/historical environments) is for multiple farmstead creameries to produce wheels of cheese, which are then collected and aged in a centralized facility where the aging process occurs and the rind is formed. The series of practices associated with the formation of the rind and overall cheese care during aging is known as “affinage”.

19.3.1 Cheesemaking – Forming Cheese Body/Base

The production of soft washed-rind cheeses (e.g., Limburger, Reblochon) differs in several key ways from the production of hard/firm washed-rind cheeses (e.g., Comte, Gruyere; Fig. 19.1). In the United States, soft washed-rind cheeses are usually produced from pasteurized milk, whereas firmer cheeses are made with raw, heat-treated, or pasteurized milk, depending on the producer. This is due to the required 60-day aging rule being a quality-limiting factor for the sale of these soft cheeses. Many soft cheeses would experience too high levels of softening, proteolysis, and general ripening post 60 days to meet customer quality standards. Of note is that many European Protected Designation of Origin (PDO) washed-rind cheeses must be produced with raw milk in order to meet PDO specifications (e.g., Comte, Reblochon).

Another point of differentiation for soft and firm washed-rind cheeses is starter culture selection during the initial stages of cheesemaking. The former often use mesophilic mixed-strain cultures, and the latter often utilize thermophilic cultures along with the standard mesophiles. Not only does this affect acidification dynamics, it can also confer distinct flavors to certain varieties due to their proteolytic activity and complex metabolic activity. A possible example would include the sweet, caramelly notes associated with firm washed-rind cheeses such as Gruyere or Cantal.

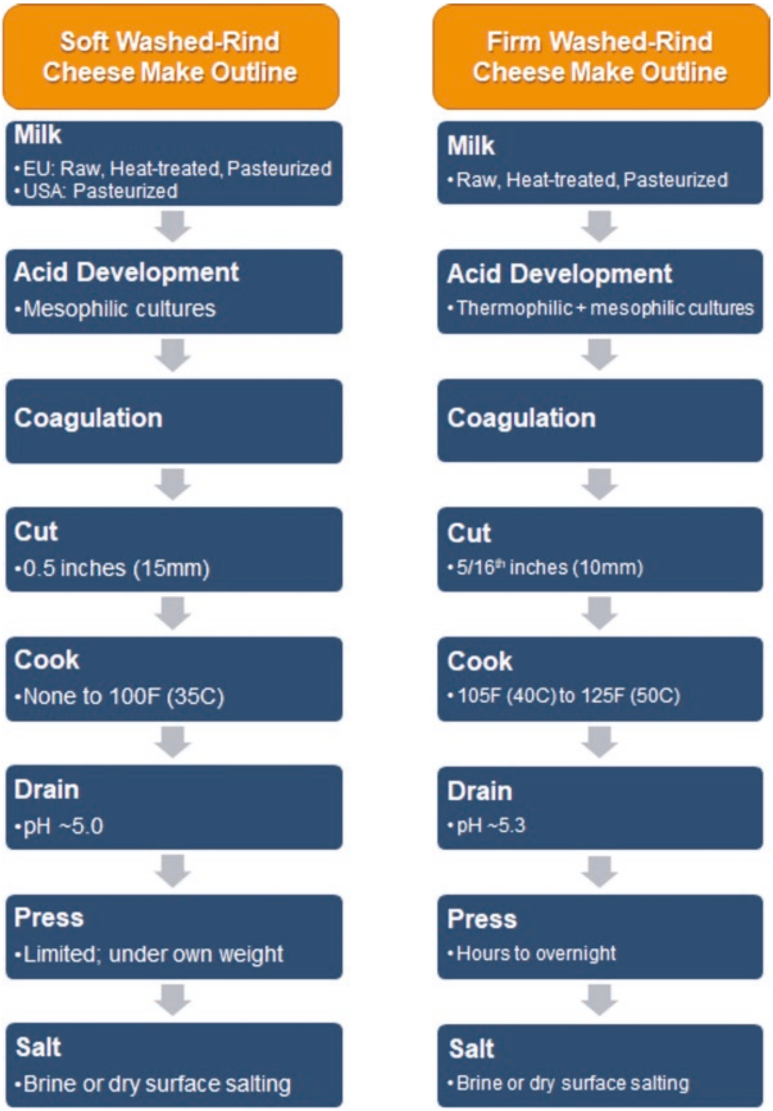

Fig. 19.1 General manufacturing steps and make procedure outlines for soft (left) and firm/hard (right) washed-rind cheeses (Provided by author)

Soft washed-rind cheeses usually follow an uncooked, unpressed make schedule, whereas firm varieties are usually cooked and pressed. During the coagulation and cutting phases, soft washed-rind cheese coagulum is often cut to a size roughly around 0.5 inches (~13 mm), with cooking ranging from no added heat to temperatures around 100 °F (~38 °C). Curds are drained under their own weight, often overnight, ending up at around pH 5.0. These are all critical factors yielding a higher moisture cheese, which confers the ultimate soft texture of the finished cheese. Hard washed-rind cheeses usually utilize a cut-size of around 5/16th inches (8 mm), with cooking temperatures ranging from 105 °F to 125 °F (~40 °C to ~50 °C). Drained curds are usually pressed anywhere from several hours to overnight. Both varieties can be brine salted or dry salted via application to the finished cheese surface. The amount/time of brining/salting varies widely depending on cheese size, shape, culture activity, desired flavor, and pH/moisture targets. (Jaeggi, 2019).

19.3.2 Affinage – Forming Cheese Rind

The ripening and aging process is critical for the final sensorial quality of washed-rind cheeses. Considerations such as smear application, ripening room (cave) temperature, relative humidity, air flow/exchanges, surface/rind scrubbing, and length of aging time are all parameters that must be accounted for and controlled. This process is holistically known as affinage; those who oversee this process are affineurs (masculine), affineuses (feminine), or affineux (gender neutral; preferred term).

A complex microbial menagerie is formed during the affinage process. This can either be accomplished: (1) deliberately, by applying a smear (brine-like solution) inoculated with commercial cultures (Fig. 19.2), (2) passively, by allowing native flora to get established on cheese rind (note that a brine or other solution is still usually applied to the surface to optimize growth conditions for aforementioned microbes, or (3) by using what is known as “back slopping” or the “old-young method,” where surface remnants of older cheeses are prepared into smear solution and applied to young cheeses.

The smear solution often consists of a dilute salt (~5% w/w) solution with the addition of yeasts, bacteria (*Staphylococci, Micrococcus, Coryneform, Brevibacteria, Arthrobacter*, etc.), and mold-type cultures. This smear solution can be rubbed on the surface (with a cloth, gloved hands, etc.), brushed onto the surface, and/or sprayed using an aerosolizing device. This can either be an automated process or a manual operation. The former utilizes cheese “robots,” which can take each wheel and simultaneously apply smear and turn the wheels before replacing them on the aging shelf. The latter is usually accomplished by trained staff who must touch each wheel, which often leads to a large number of labor hours being devoted to the affinage process for washed-rind cheeses.

The space in which the affinage process takes place is known as the aging space, ripening room, curing room, or “cave”. The actual ripening room may be as formal as a computer-control walk-in cooler or warehouse or as informal as an actual underground dwelling (e.g., Kaltbach caves in Switzerland used by Emmi, Fig. 19.3). The specific conditions and atmospheric parameters within the affinage space are dependent on the type of washed-rind cheese (hard vs. soft) and specific cheese in question (Limburger vs. Muenster). Air flow, humidity, temperature, native microbiota, foot traffic, physical size and volume of space, cleaning practices, and building materials such as wood board, heating, ventilation and air

Fig. 19.2 Example of an affineux applying a smear solution and turning blocks of Limburger cheese that are being aged on wood boards (Provided by author)

Fig. 19.3 The limestone Kaltbach caves in Switzerland (Photo by Emmi)

conditioning system, and wall/floor treatments are all parameters that can drastically influence the affinage process (Jaeggi, 2019).

Complementing the aforementioned aging space parameters and conditions, the ripening protocols usually include frequency of smear application and moving cheeses through a series of rooms in a stepwise fashion. Generally speaking, soft washed-rind cheeses will be ripened in a different manner than firm washed-rind cheeses. The soft variety is often ripened post-salting for 1–4 weeks, often in a single room at around 50–60 °F (~10–~16 °C) and ~98% relative humidity. Hard washed-rind cheeses are often moved through a series of ripening phases depending on the cheese type and other complexities (e.g., eye development). A simplified ripening schedule would move wheels of firm washed-rind cheeses through progressively cooler rooms with lower relative humidity (e.g., 60 °F (~16 °C) → 40 °F (4 °C); 98% RH → 60% RH) for a longer period of time (3–12 months). Not only is this important to attain the correct surface conditions for microbe growth progression and rind formation, but it also minimizes the chances for case hardening to occur. Case hardening refers to an external layer of cheese dehydrating too quickly, forming a non-permeable "case" around the wheel/block, thereby preventing external moisture migration from the rest of the cheese body. Table 19.2 summarizes soft vs. hard washed-rind ripening conditions.

19.4 Physical and Microbiological Characteristics of Washed-Rind Cheese

Washed-rind cheeses undergo complex chemical, physical, and microbiological changes during the cheesemaking and ripening process. The final appearance, taste, aroma, and texture of the cheese are influenced by the interconnected nature of the surface rind microbiota and the chemical nature of the cheese body that was established during the cheese making procedure. Acid development during the make, moisture content, ammonia, and carbon dioxide production during ripening, and many other physiochemical factors can determine if the final cheese undergoes complete liquefaction or retains a firm and chalky core. A thorough description of rind ecology and chemical changes during ripening is outside the scope of this

Table 19.2 General outline of the ripening conditions for wash-rind (bacterial surface-ripened, smear-ripened) cheeses

Ripening parameter	Soft-type	Firm-type
Number of ripening rooms	1	2 to 4
Residence time in ripening	1 to 4 weeks	3 to 12 months
Ripening room humidity	~98% RH	~60% RH to 98% RH
Ripening room temperature	50 °F to 60 °F	40 °F to 60 °F

Adapted from Jaeggi (2019)

chapter, but several key points will be highlighted below as these reactions dramatically influence the final sensorial attributes of the cheese.

19.4.1 Rind Ecology

The main attributes that are distinctive characteristics of many washed-rind cheeses are: bright surface coloration (red/orange), various degrees of radial softening, and a complex bouquet of aromas and flavors that can range from subtle to highly pungent. Each of these attributes is either a direct or an indirect action of the microbial metabolism of the surface smear organisms. Until recently, only a very rudimentary understanding of the surface microbes was available within the washed-rind cheese industry. *Brevibacterium linens* was often touted as being the main, if not sole, source of many of the distinctive colors and flavors of washed-rind cheeses. The true complexity of the surface ecology is now being better elucidated due to improved molecular genetic techniques. These new insights have identified numerous genera of molds, yeasts, and bacteria that colonize cheese rinds – many never previously associated with cheese rinds (Quigley et al., 2012; Wolfe et al., 2014). Table 19.3 lists some of the main microbial genera found within the rinds of washed-rind cheeses.

At the onset of ripening, washed-rind cheeses are usually acidic (pH ≈ 4.7–5.2, depending on exact type; Brennan et al., 2004). This, combined with the high salt content of these cheeses, usually prompts the growth of yeast species such as *Debaryomyces hansenii* or *Geotrichum candidum*, to name a few. This genus, and

Table 19.3 Example microbes isolated from rinds of smear-ripened cheeses*

Bacteria genera	Fungi Genera (yeast/mold)
Arthrobacter†	*Aspergillus*
Brevibacterium†	*Acremonium*
Brachybacterium	*Candida*†
Corynebacterium†	*Chyrsosporium*
Halomonas	*Debaryomyces*†
Microbacterium	*Fusarium*
Pseudomonas	*Galactomyces*
Psychrobacter	*Geotrichum*†
Serratia	*Kluyveromyces*
Sphingobacterium	*Penicillium*†
Staphylococcus†	*Saccharomyces*
Vibrio	*Scopulariopsis*

Adapted from Wolfe et al. (2014) and Cogan et al. (2014)
*Not an exhaustive list; alphabetical order.
†Major genera

other related microbes, consume lactic acid and deacidify the surface of the cheese. A gaseous by-product of this reaction can include carbon dioxide. Many of these surface microbes are also strongly proteolytic and can create large amounts of ammonia. This creates a less acidic environment and pH-sensitive microbes like *Corynebacterium* can grow and proliferate. Generally, the pH at the cheese surface can increase from approximately ~4.8–~5.5. The proteolytic reactions occurring during the early phases of the ripening process can also free up nutrients (amino acids) that allow other microbes to grow and proliferate. Eventually, the rinds of smear-ripened cheese become fully colonized with a menagerie of microbes, quite often reaching a pH near 6.0 or even 7.0 (Irlinger et al., 2015). Figure 19.4 outlines this process visually.

19.4.2 Texture Development and Softening

While the softening process and exact chemical mechanisms of softening and texture development in soft washed-rind cheese have only been studied briefly (Tansman et al., 2017), a similar process has been studied at some length in surface mold-ripened cheeses, such as brie and camembert. Similar chemical and physical phenomena are occurring, although due to different types of microbes (i.e., molds vs. yeasts, bacteria, etc.). As discussed in the previous section, the surface microbes

Fig. 19.4 Schematic outline of microbe growth during ripening (Image provided by author)

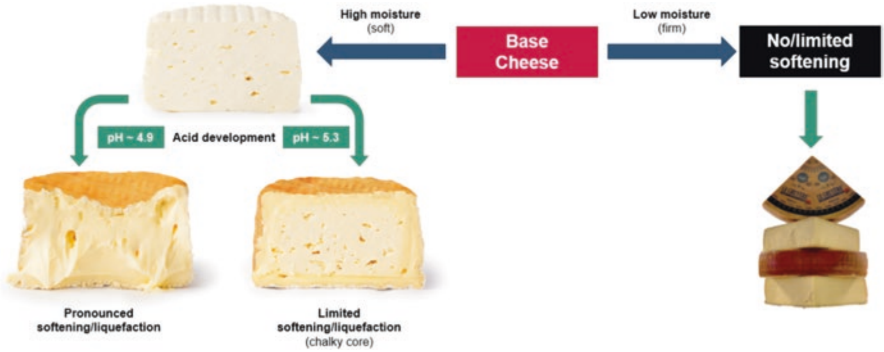

Fig. 19.5 Schematic view of softening potential based on cheese moisture and extent of acid development. Cheese images courtesy of Cowgirl Creamery (Emmi AG, Point Reyes Station, CA) and Columbia Cheese (New York, NY)

cause the cheese surface's pH to rise via lactate metabolization and ammonia production due to proteolysis. The gradient of high pH at the surface and low pH within the cheese body initiates a series of reactions that result in the radial softening of washed-rind cheeses (note: this softening/liquification is experienced in the soft-type cheeses, not in the hard-type cheeses; refer to Fig. 19.5).

The high surface pH values cause minerals such as calcium and phosphate to precipitate and crystallize at the surface, forming crystals like brushite (calcium phosphate), ikaite/calcite (calcium carbonate), and struvite (magnesium ammonium phosphate). This surface crystallization phenomenon establishes a concentration gradient, which prompts the migration of minerals from the cheese center toward the surface in a radial fashion. The high pH environment, coupled with this demineralization, shifts the dominant interactions within the cheese from the type casein-casein to the type casein-water. Water is absorbed by the casein matrix, which swells and leads to characteristic softening and liquefaction. Although proteolysis is a critical reaction occurring during ripening, it has minimal direct effects on the radial softening process. The proteolytic-derived products, such as sulfur compounds and ammonia, have the largest impact on the sensorial attribute of washed-rind cheese. Figure 19.6 summarizes the texture-related reactions occurring during ripening.

During ripening, metabolism by surface flora results in an increase in pH. The pH increase is in part due to lactic acid metabolism but to a greater extent due to the leaching of ammonia into the cheese. Ammonia is produced via proteolysis by the surface microorganisms and leaches into the cheese (serum) and converts to ammonium hydroxide. The increase in pH will solubilize the casein. However, the extent of solubilization depends on the initial demineralization of the casein. The greater the extent of demineralization prior to growth of the surface microorganisms, the greater the degree of solubilization (hydration) of the casein. Thus, the main corrective action that is taken to alter the body characteristics is to change the rate and

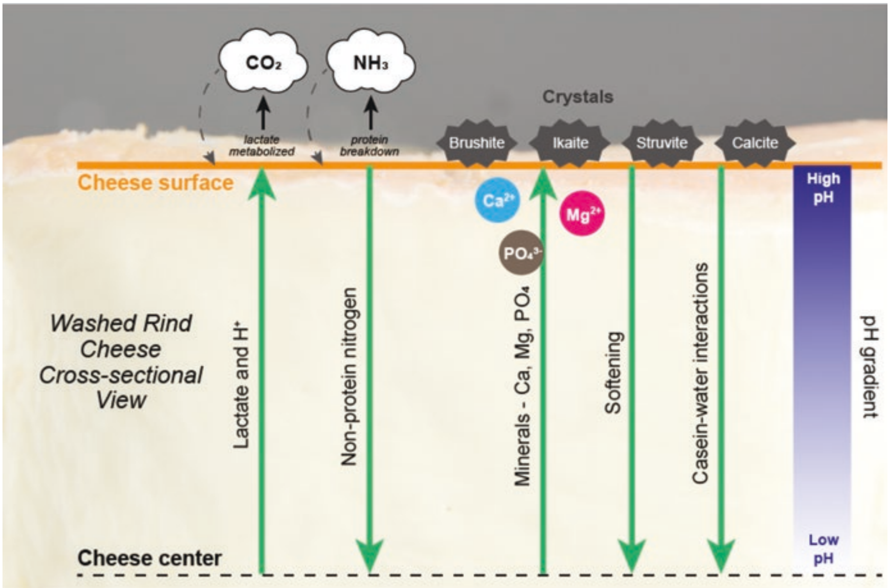

Fig. 19.6 Schematic view of reactions occurring in washed-rind cheese during ripening

extent of acidification and not just rely on duration of ripening to do so. At very low initial pH (<4.8) the caseins are not well hydrated and remain as small aggregates that are not linked extensively to other aggregates, resulting in a white, brittle body that will disperse light. This is often seen as a white core in cheeses. This may or may not be a fault in ripened cheeses. In cheeses that are usually retailed at a state of complete liquefaction (such as Winnemere and Rush Creek Reserve), a solid/chalky white core is considered a fault. However, many soft washed-rind cheeses may not be ripened to such a degree and a solid core is common in cheeses such as Oma (Jasper Hill Farms) or Red Hawk (Cowgirl Creamery).

As the pH increases and the casein becomes more hydrated, the interior of the cheese changes to a straw color (i.e., translucent appearance). This is not a fault but an indication of normal ripening events. As the pH increases the body becomes very spreadable and gel-like, and in very ripened cheeses the body becomes more fluid. This change is progressive. The evaluator must be aware that not all varieties of soft-ripened cheeses desire a cheese that easily disperses when eaten but prefer the gel-like body, and that some styles desire a residual white core. The later cheeses are usually formed as thicker blocks or wheels. Those varieties that require full fluidity are usually only about 1 inch (~2.5 cm) in height, and the cheese is often wrapped in spruce cambium or placed in a ceramic form so the cheese does not flow during storage and it provides a convenient form to serve the cheese. The most common body fault with soft wash-rind cheeses is a gummy, gelatinous mouthfeel. This indicates that the cheese was insufficiently demineralized initially (pH prior to rennet addition or ripening was too high). The defect has been most noticeable in stabilized varieties.

19.5 Sensory Evaluation of Washed-Rind Cheese

Wash-rind cheeses are perhaps the most demanded cheeses to be evaluated due to the wide range in the manufacturer's desired body, flavors, and aromas. Many are manufactured by artisanal cheese makers who produce distinct flavor profiles due, in part, to feeding regimens and the diversity in the microflora of milk, cheesemaking space, and ripening environment. Even if manufacturers use the same commercial starters and ripening strains, passively contaminating microorganisms, often referred to as native microflora, unique to a cheese plant (and milk) may eventually become the dominant strains involved in producing distinctive flavors.

There are no standards of identity for body, flavors, textures, or aromas in these types of cheeses. In fact, in order to differentiate their cheese from other wash-rind cheeses, cheese makers often set their own criteria and then produce products to meet those specifications. Consequently, sensory evaluators (e.g., quality control professionals, contest judges, etc.) are met with tough decisions. A perceived defect or fault may actually be a desired attribute the cheese maker wanted to develop. In addition, there are categories in contests for type of milk used, (cow, sheep, or goat and blends of two or more), age, firmness (low vs. high moisture), and even categories regarded as "open class". The grader/judge must be aware of this diversity and be prepared to assess a cheese based on its own unique attributes.

At the heart of the matter is the manufacturer's expectations for their cheeses. Of predominant influence is the diversity of microorganisms growing on the surface of the cheeses and the complexities of their metabolic activities, which lead to a heterogeneity of flavors, aromas, and surface colors. A list of representative chemical compounds responsible fot the general sensory properties of washed-rind cheeses are shown in Table 19.4. For consistency in flavor, some manufacturers may use strains of microorganisms purchased from companies that have isolated and selected them specifically for washed-rind cheeses. However, since these cheeses are ripened in an open environment, there is a likelihood that there will be strains of microorganisms growing on the cheese that are passive contaminants, not intentionally introduced to the cheese.

Contaminants may be unique to the milk and/or facility; some may be undesirable and others welcomed. At times, the contaminants may become the dominant flavor-producing microorganism. Most common undesirable contaminants are molds and gram-negative bacteria such as E*nterobacteria*, *Pseudomonas,* and *Proteus* species. Occurrence of other contaminants, such as non-starter lactic acid bacteria (i.e., heterofermentative and/or with decarboxylase activity) can develop undesirable compounds, including gas defects. Some manufacturers have established their own unique blend of strains and thus a unique flavor and aroma, and this approach is becoming popular, especially amongst craft cheese makers.

There is a succession of growth of the different microorganisms on the surface of washed-rind cheeses, leading to a progression of body softening and intensity of flavors from the outside to the core as the cheese ages. However, slight variation in initial acidity and water activity of the cheeses can have a major impact on the succession of growth of microorganisms and therefore flavor characteristics of the cheese. These factors are under control of the cheese maker and they are often the first place to scrutinize to ascertain the source of undesirable attributes of a cheese unless microbial contamination is obvious.

19.5.1 Visual Characteristics

Appearance is what first attracts a cheese to a consumer and is the first attribute to be graded or evaluated in professional settings. Appearance includes: color, evenness of the microbial mat on the cheese surface (i.e., outer rind), obvious undesirable mold, slimy/sticky surface, cracked surface, and evenness of the shape of the cheese. Color of the cheese surface is most likely to draw criticism where it is often not warranted. Color will vary from yellow to pink to red to light brown (Table 19.4) and there may be adventitious molds and bacteria of various colors present. Individual strains of microorganisms may produce pigments, but the color may depend upon the cheese environment (i.e., water activity, acid development; Mounier et al., 2017), as well as the symbiotic relationship between microorganisms. For example, the interaction of certain yeast and bacteria strains have been shown to produce characteristic red-orange color in washed-rind cheeses (Wolfe et al., 2014). What stands out as an undesirable attribute is unevenness of color (i.e., splotches of red on one side but not the other, or dark brown splotches in an otherwise light pink surface; Table 19.4). If washed-rind cheeses are ripened with commercially obtained strains of microorganisms, then the cheese surface generally has shades of red to orange, and any deviation in the continuous, even color is easily observed. Colonies of mold (most common are blue, black, or grey) are a source of color variation (Fig. 19.7e–h). These are generally contaminants, although colorful molds are sometimes found on specific varieties (e.g., many tomme-styles or some firm washed-rind cheeses). In this case, it is evenly distributed throughout the cheese surface. Another example of desirable mold presence is that of *Fusarium domesticum*, which can impart a "frosty" white appearance to some washed rind cheeses (Fig. 19.7a–d). In addition, *Fusarium* can also help aid in rind stability by limiting excessive stickiness, although the mechanism is unknown (Bachmann et al., 2005).

The entire surface of the cheese should be of similar overall color, but often the bottom and top of the cheese are not the same even color due to uneven drying and exposure to air. This is a fault due to mishandling of the cheese during ripening. Blue- and purple-colored rinds are not desirable and are the result of growth of *Pseudomonas* and *Proteus* species. The shape of the cheese should not be lopsided, but the surface may have patterns, ridges, or wrinkles and it does not have to be smooth, but the patterns should be consistent over the cheese surface (excluding sides). Lopsided cheese may be a result of poor workmanship or cheeses may distort during shipping and handling.

Soft cheeses tend to flow or slightly distort if allowed to sit too long without being turned. This can also lead to the surface layer sticking to the boards the cheese

Table 19.4 Example of reported chemical compounds[a] found in washed-rind cheeses responsible for color, aroma, and flavor attributes/defects

	Chemical compound	Characteristic	Origin	Reference
Color	Carotenoids	Yellow-red rind appearance. These compounds can also contribute to inner core color	Biosynthesized mainly by *Arthrobacter* sp., *Brevibacterium* sp., *Corynebacterium* sp., *Dietzia* sp., *Glutamicibacter* sp., *Micrococcus* sp., *Staphylococcus* sp. and others	Galaup et al. (2007), Sutthiwong et al. (2014), Giuffrida et al. (2020), Yeluri Jonnala et al. (2021)
	Pyomelamin	Brown rind defect	Metabolism of tyrosine by *Y. lipolitica*	Williams and Withers (2007)
	Indirrubin and indigo	Purple rind defects	Catabolism of tryptophan by *Proteus* sp. and *Psychrobacter* sp.	Kamelamela et al. (2018)

	Chemical compound	Characteristic	Origin	Reference
Flavor and aroma	Short-chain free fatty acids (<4 carbon atoms)	Acid (all of them), sour (formic, acetic acids), and nutty notes (propionic acid)	Lactate fermentation	Thierry et al. (2011)
	Short-medium and long free fatty acids (between 4 and 20 carbon atoms)	Variable, depending on lipase activity and specificity, fatty acid chain length and others (e.g., butyric acid, rancid; octanoic acid, goaty; stearic acid, soapy)	Lipolysis of milk fat. Breakdown of amino acids	Mounier et al. (2017)
	Methyl ketones: 2 – Octanone, 2 – Nonanone, 2 – Decadone and 2 - undecadone	Fruity, floral, and musty notes	Oxidation of free fatty acids by enzymatic activity of *G. candidum.*	Mounier et al. (2017)
	Sulfur compounds: *S*-methyl thioesthers (i.e., *S*-methyl thioacetate, *S*-methyl thiopropionate, *S*-methyl thiobutyrate, *S*-methyl thioisobutanoate, *S*-methyl thioisovalerate, *S*-methyl hexanoate) and sulfides (i.e., dimethylsulfide and dimethyltrisulfide)	Complex cheesy, cabbage, and cowshed notes	Possibly by catabolism of L-methionine, branched-chain amino acids (i.e., leucine, isoleucine, and valine) and/or short-chain fatty acids by several bacteria and yeasts	Mounier et al. (2017), Berger et al. (1999), Jovillet et al. (1992)
	Sulfur compounds: Ethyl thioesthers (i.e., ethyl 3-Mercaptopropionate)	Sulfur, fruity, grapy, rhubarb, and empyreumatic notes at low concentrations. Skunky notes at high concentrations	Catabolism of sulfur amino acids (presumably L-methionine).	Sourabie et al. (2008)
	Biogenic amines (i.e., putrescine, cadaverine, histamine, and tyramine are more relevant amines in cheeses; others are tryptamine, 2-phenylethylamine, spermine, and spermidine)	Tingling and burning mouth sensation (mainly histamine and tyramine), as well as unclean/putrid notes (putrescine and cadaverine)	Decarboxylation of free amino acids by bacteria, yeasts, and fungus with decarboxylase activity	Benkerroum (2016), Mounier et al. (2017)

[a]Not an exhaustive list

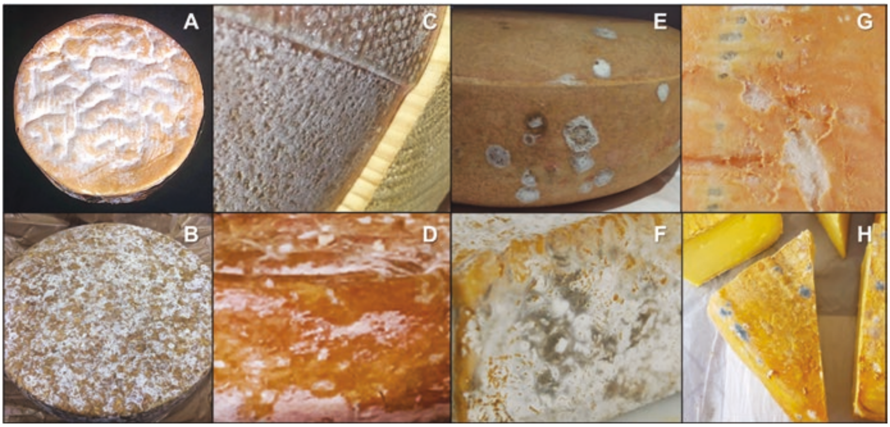

Fig. 19.7 Examples of rind diversity among washed-rind cheeses. Presence of mold (**a–d**) is not necessarily a defect if coverage is consistent and/or homogeneously covers rind and neutral in color. Mold can be considered a defect (E-H) when it has inconsistent presence on cheese surface and/or has strong coloration (e.g., dark blue-green). (Images courtesy of Uplands Cheese, Jasper Hill Farm, Josh Windsor, Kathleen Cotter, and Heather McDown)

sits on during the ripening process and, therefore, an uneven or pitted surface. Some varieties of soft-wash rind cheeses will flare out during aging and are held into shape by strips of bark or ceramic molds. The cheese should not be huffed up or puffy as this would indicate gas production by contaminants within the cheese. In hard washed-rind cheeses, the surface should be checked for cheese mites (Fig. 19.8). Mites are detected with a mite light (small flashlight with a magnifier) and mite colonies often make the cheese surface appear pitted and may leave small anthill-like residue. In some cheese contests, if a cheese has visible mites, the evaluation stops and the cheese is wrapped and thrown out so as not to allow the mites to contaminate other cheeses.

The surface of washed-rind cheese may exhibit crystals, but they are not considered a fault unless excessive and would result in rejection by the consumer. The evaluator must be able to differentiate between mold and crystals. However, crystals may indicate excessive drying of the rind or over ripening. If so, the associated fault of excessive rind will be obvious once the cheese is cut into. At the surface, the crystals are generally fine-grained, somewhat shimmery in appearance, and at first glance, may give the impression of residual salt or dried brine solution. They are neither and have been identified by Polowsky et al. (2018) as brushite (calcium phosphate), ikaite (calcium carbonate), and struvite (magnesium ammonium phosphate; Fig. 19.9).

In hard washed-rind cheeses, there may be larger crystals of either tyrosine, leucine, or brushite. Tyrosine crystals may be indicative of the use of *Lactobacillus helveticus* as a starter or flavor adjunct. They are firm, crunchy, and very white and may appear as distinct white solid or slight diffused areas called star bursts within the body of the cheese. They are rarely considered a fault but rather seen as

Fig. 19.8 An example of cheese with an extreme mite infestation

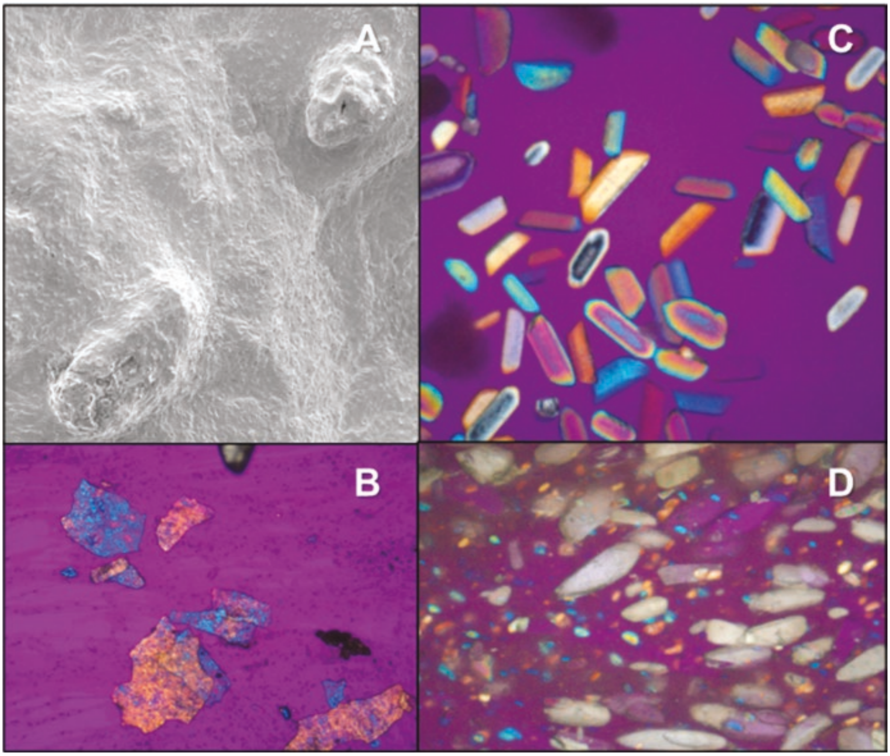

Fig. 19.9 Crystals embedded in the surface smear of a washed-rind cheese (**a**). Examples of surface entities extracted from washed-rind cheese (**b**) remnants of wax-lined cheese paper, (**c**) struvite crystals, (**d**) ikaite crystals (white) and struvite (colors) (colored; color due to microscope filter)

harbingers of anticipated sweet, fruity, and butterscotch flavors. Calcium phosphate crystals are generally more numerous when present in the interior. However, they are very hard, gritty, with a mouthfeel of fine-grained sand. They are generally considered a fault, especially when numerous and contrasting the otherwise smooth mouthfeel.

19.5.2 Aroma Characteristics

One of the very first things an evaluator does is pick up the cheese and smell it, sometimes even disregarding appearance. The best means to assess aroma is to smell the cheese after it has been cut into and not to rely on the aroma of the surface. Surface aroma may or may not be indicative of the quality of the cheese. Some evaluators will not smell the cheese directly but will wave the aromas toward their nose in a wafting motion. Undoubtedly, the most often quoted response of wash-rind cheeses by consumers is that the cheese “stinks” or has a very “smelly” aroma, especially soft and semisoft washed-rind cheeses. This is characteristic of these cheese varieties and expert evaluators must further define the aroma attributes associated with washed-rind cheeses. Examples of commonly acceptable aromas include yeasty, sulfury, mushroomy, and earthy. In some cases, expect the aroma to be reminiscent of fermented fruit; sweet with a bit of alcohol and/or yeasty notes (Table 19.4). Mild ammonia aroma is often common as well. It is not considered a defect when present in low levels and is not the most dominant aroma attribute. As this category of cheeses grows, more diverse aromas become present in the marketplace. Cruciferous-like (broccoli, cauliflower) or allium-like (oniony) aromas are increasingly common. These could be considered a subset of the “sulfur” aroma attribute (Table 19.4). Biogenic amines, such as putrescine and cadaverine, impart putrid notes into the cheese (Table 19.4), which is often considered as a defect. Unacceptable aromas often include strong barny, cowy, and fecal notes. These undesirable aromas are usually produced by contaminant microorganisms. If the evaluator/grader notices these aromas the evaluation often stops, especially if there is indication of gas production. These are both signs of microbial species present that are atypical of washed-rind cheeses.

Aroma plays a major role in cheese flavor evaluation; however, the aroma of a non-cut wheel or block may not be identical to the aroma of the interior of the cheese. This is not a fault. The exterior and interior of washed-rind cheeses are usually evaluated separately. If there is a fault with the aroma of the cheese, it can sometimes be pinpointed as to the cause by doing the evaluation in a zonal manner. The initial aroma of an uncut piece of washed-rind cheese may vary widely depending upon the microorganisms present and the age of the cheese. Also, expect the aroma of the wash liquid if the cheese has been washed with fermented beverages (beer, whiskey, wine).

19.5.3 Textural Characteristics

Texture is the term used to describe the manner of union of the particles of cheese. If there are very few openings within the cheese body, it is called "closed" or "closed bodied". If there are numerous openings, it is called "open" or "open bodied". Openness can be either mechanical (i.e., mechanical openings) or caused by gas-producing microorganisms (i.e., gas holes, splits, cracks). Mechanical openings are naturally occurring areas where the curds have not knit together. This is often due to the curds not being pressed with great force, often deliberate in nature. These should not be considered a fault unless the openness is unevenly distributed (i.e., one side of the cheese has a much more open body than the other side of the cheese). Unevenly distributed openings can occur due to a lack of turning the cheese in a periodic nature or adding more wet curd to the curd already in the cheese form after the whey has drained (Fig. 19.10).

19.5.3.1 Texture Evaluation of Soft Washed-Rind Cheese

Although mechanical openings are very rare in soft washed-rind cheeses due to the very soft, collapsible body of the cheese, many semi-firm and firm washed-rind cheeses will have numerous mechanical openings, which may have been expanded by carbon dioxide produced by the starters used (*Leuconostoc* sp.). The openings may have uneven or smooth surfaces, with shiny or dull interiors. In firm washed-rind cheeses, gas production may lead to formation of small round eyes or splits/cracks in the cheese. Splits are considered a fault (Fig. 19.11). The grader should be made aware of whether a gas-producing microorganism has been used in the

Fig. 19.10 Examples of open-bodied cheeses formed via gas production (left) and mechanical openings (right)

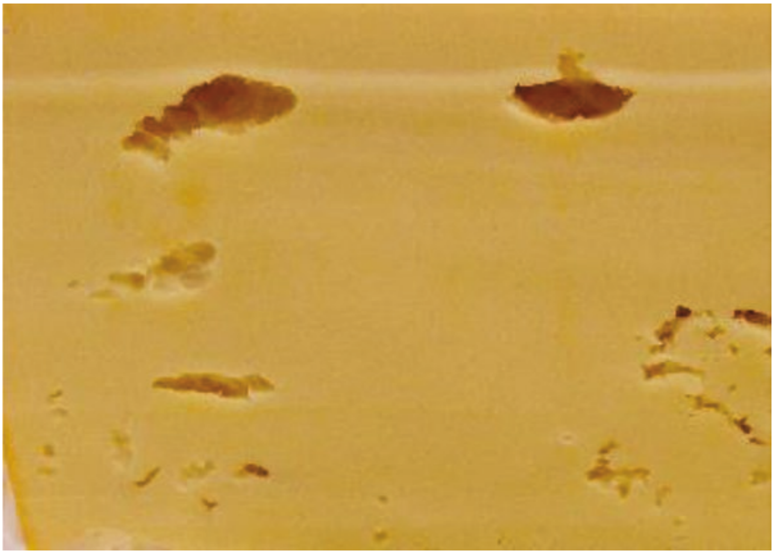

Fig. 19.11 Splits, cracks, and excessively large openings in the body of a firm washed-rind cheese (Beaufort-style)

production of any washed-rind cheese. The formation of gas may not be accompanied by any detectable off-flavors, but occasionally the cheese may develop a fruity or sulfury note, or more pungent aromas in the case of butyrate-forming microorganisms (e.g., late blowing defect caused by *Clostridium* species, discussed further below).

The difference in formation of round eyes or a split is due to the elasticity of the cheese at the time gas was formed. The gas is usually carbon dioxide which is odorless and is derived from the metabolism of residual sugar or citric acid by either starter bacteria, coliforms, yeasts, or heterofermentative lactobacilli. Clostridia sp. will often produce a sulfur note along with slits. Gas produced by the added surface microorganisms is not the cause of gas within the cheese. If gas is caused by yeast, the associated flavor or odor of alcohol (raw bread dough) is observed. If the cheese maker used a gas formed as part of the starter, the cheese would exhibit gas formation (splits or round holes) but a distinctive flavor may not be noticed, or it will be slightly buttery if the cheese is very young.

19.5.3.2 Evaluation of Body Characteristics of Washed-Rind Cheese

Body refers to several attributes: firmness, cohesiveness, elasticity, and smoothness (plasticity). These attributes are governed by cheese composition, rate/extent of acid development during cheese making/at onset of ripening, metabolism of surface microorganisms, and residual coagulant. Many soft-ripened cheeses are high in fat (>55% FDB) and moisture (>45%). The fat content of cheese, often expressed as fat in dry matter or fat on a dry basis (FDM or FDB), is determined by the casein to fat ratio (c/f) of the milk. Cheese makers can select milks (often dictated by seasonality) with the appropriate c/f ratio or they can add cream (fat) to lower the c/f ratio and increase the FDB. The moisture content of cheese is determined by the manufacturing and ripening practices. The rate and extent of acidification during manufacture will determine the initial level of demineralization of the casein. The extent of initial demineralization will eventually influence the body of the cheese as it ripens. As with all cheeses, proteolysis induced by residual coagulant, native milk proteinases, and proteinases of starter and non-starter bacteria will eventually result in a smoother body, decreased curdiness, and more flavor. Lower moisture cheeses may develop a short body (i.e., brittle, inflexible), whereas higher moisture cheeses may become pasty or sticky. Higher fat cheeses may have a weak body. However, in soft washed-rind cheeses, this can be an advantage when coupled with high moisture; as it may result in cheeses with the desired viscous body after ripening, resulting in a pleasing mouthfeel.

19.5.3.3 Evaluation of Body Characteristics of Soft Washed-Rind Cheese

Body evaluation in soft washed-rind cheeses is best evaluated by mouthfeel of a small slice of cheese. In the case of cheeses that experience pronounced liquefaction by the time of consumption (e.g., Winnemere, Rush Creek, Vacherin Mont D'Or) the top of the rind is often removed or peeled away and the cheese body is then spooned out for evaluation (Fig. 19.12). This also allows for evaluation of the rind and cheese body to occur in separate tastings. The rind includes the microbial mat and the portion of cheese immediately below the surface. In soft rind cheese, it should usually be less than 1/16 inch (~16 mm) and it is edible, although some evaluators and consumers might refuse to taste it due to intense aromas/flavors. A firm or thick rind indicates excessive growth of microorganisms or drying, and a cracked rind may also indicate excessive ripening.

The body of soft washed-rind cheeses is influenced most strongly by the metabolism of the surface microflora and without it the cheeses will not obtain their soft, smooth, fluid body. Neither the microorganisms nor the enzymes released by them will penetrate the cheese. Instead, the softening of washed-rind cheese is due to the interplay of retained calcium, pH changes, and casein water interactions (as described above in Sect. 19.4.2 Texture Development and Softening).

The rind in soft washed-rind cheese refers to the microbial mat and for most varieties, should be very thin, although there are exceptions as a thick mat of microorganisms may be desirable in some specific cheeses.

The rind may have a slight sandy crunch or mouthfeel due to the presence of calcium phosphate, ikaite, or struvite crystals but this is not considered a fault unless the crystals are excessively large and detract from the cheese body. Much of the calcium and phosphate in soft-ripened cheeses is solubilized and will diffuse through the cheese to the surface. The diffusion initially is due to differences in water activity that develops (i.e., surface drying and application of salt to the cheese

Fig. 19.12 Rush Creek Reserve (Uplands Cheese, Dodgeville, WI) (left) is often consumed and evaluated by first peeling back the top portion of its rind (right)

surface). As the pH increases at the surface and with sufficient concentration of minerals, crystals will form. With the reduction in soluble minerals at the surface due to crystallization, diffusion of more minerals from the interior of the cheese occurs. This starts the cascade of softening reactions already described.

19.5.3.4 Evaluation of Body Characteristics of Semi-Soft and Firm Washed-Rind Cheese

In semi-soft and firm washed-rind cheeses, a plug is pulled from the cheese using a cheese trier. Pressure is exerted on the plug by slowly bending the plug. If the plug breaks quickly the cheese is called short. If the plug cannot be broken until it is fully or almost fully bent it is called long (Fig. 19.13). Semi-soft washed-rind cheeses are slight to definite long but since hard washed-rind cheeses are usually evaluated after considerable aging, (>6 months) a slightly short body may be observed. However, attributes often accompanying a short body may not be acceptable. A lot of information can be gleaned from the assessment of the plug, either through rubbing it between the fingers or chewing the cheese. Short body may often be accompanied by mouthfeel attributes of grainy, mealy, or curdy. Body firmness can also be evaluated at the same time. Excessive firmness is a common fault in both semi-hard and hard varieties.

Short body can be due to excessive acidity (low pH) which can also lead to a grainy but easily broken-up paste when chewed or rubbed between the thumb and index finger. Other sources of short body and mealy, curdy mouthfeel include excessively dry cheese, insufficient loss of calcium during manufacturing (as indicated by high initial pH of the curd prior to aging), and the curd may have been too dry or low in fat or too high in salt at hooping. Curdiness is expected in semi-hard and hard cheeses but the body should be cohesive. The curdiness may also result in mechanical openings.

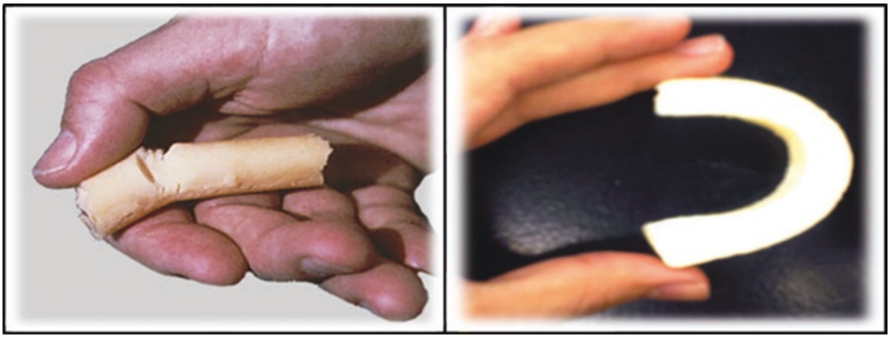

Fig. 19.13 Examples of short (left) and long (right) body cheese

19.5.4 *Flavor Characteristics*

The aforementioned breakdown of protein (casein), fat, and carbohydrate (lactate/citrate) result in a wide array of flavor compounds within the many varieties of washed-rind cheeses. (Table 19.4 and Fig. 19.14) Most cited faults in flavor of washed-rind cheeses are bitter, ammoniated, lacks salt, lacks characteristic flavor, acid, unclean (barney, cowy, catty), as well as a tingling/burning mouthfeel caused by the presence of biogenic amines (i.e., histamine and tyramine). If the cheese is labeled as having been washed with these beverages (e.g., beer, cider), the cheese should have that flavor present. The penetration and overall impression of any added flavor(s) are important criteria during evaluation. The flavor of the wash or added flavor is expected to be sensed throughout the cheese even if the intensity is only slight. Consequently, cheeses with added flavors either in a wash or introduced via added ingredients are usually evaluated in a manner where the interior is tasted first, then the exterior rind, so as not to have the intense exterior flavor of carryover to the interior. A piece of cheese with both interior and exterior is then evaluated for flavor to form a holistic impression of the cheese. More research is needed to fully develop an understanding of the spectrum of possible flavor molecules present in washed-rind cheese. There is a critical dearth in published literature as it relates to formal descriptive or affective evaluation of this variety. However, the complexity of the flavors these cheeses exhibit implies that any further formal sensory evaluation of these cheeses will add much-needed knowledge to the washed-rind consuming zeitgeist.

19.5.4.1 Evaluation of Flavor in Soft Washed-Rind Cheese

Expected flavor of soft and semi-soft washed-rind cheeses is cheese specific. Some may have a slight yeasty note, especially if the surface microflora is only yeast. If the variety uses *Brevibacterium* and *Micrococcus* species, a slight sulfur note should be detected. Excessive sulfur or eggy flavor is considered a fault when not in

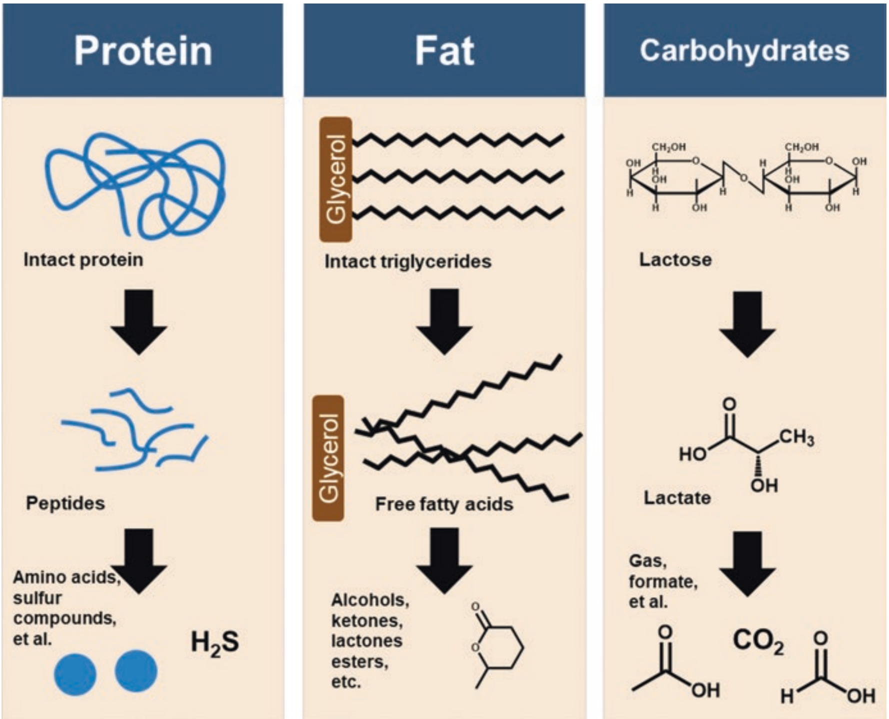

Fig. 19.14 Schematic view of flavor-generating reactions in washed-rind cheeses (Not exhaustive)

balance with other flavors. The complex metabolism and resulting array of flavors make evaluation of these cheeses difficult for untrained judges.

Soft washed-rind cheeses are evaluated by cutting the cheese in half and then if doable, by removing a slice. Some cheese may be so fluid that a spoon may be used to dip into the cheese. It is the choice of the evaluator whether to eat the rind and many evaluators do so. If the rind is not eaten, the evaluator must take cheese from as near the surface as possible. If the rind is tasted, the most common defects in the rind are excessive salt, bitterness, and ammonia "burn". If the paste is bitter but the rind is not, it is indicative of the coagulant and starter culture used. The cheese may still have a white center. This portion is expected to be acidic and will lack salt. These are not faults in this portion. It simply indicates that the cheese has not yet reached full maturity. In some cases, this is desirable but in others, it may be a fault. In contests, some evaluators will find fault if the cheese contains a white center, while others will not fault the cheese either for the white center or the associated acid flavor and lack of salt. However, if the center is bitter or has other off-flavors they should be considered as faults.

19.5.4.2 Evaluation of Flavor in Semi-Hard and Firm Washed-Rind Cheese

Flavor is evaluated by plugging the cheese or cutting a wedge from the cheese. The microbial mat (exterior rind) is not usually tasted, but the layer of cheese directly beneath it should be. Evaluate flavor from middle of the cheese separately from the exterior portion. The flavor of a properly aged semi-firm/firm washed-rind cheese should have consistent flavor throughout the cheese albeit progressively less in the interior. The outer portion of the cheese will be stronger than the middle due to the nature of the ripening process and faster migration of flavors produced at the surface, along with penetration of salt/brine. The flavor components diffuse through the cheese with time, however, the microorganisms do not. Expected flavor of hard washed-rind cheeses can include earthy, salty, sulfury, sweet, umami/brothy, and others (see Table 19.5). The flavor is contributed both by the surface microorganisms and, in large part, to either native microflora or added flavor adjuncts. A very common adjunct is *Lactobacillus helveticus* and results in a sweet, fruity note reminiscent of cooked pineapple or butterscotch. Excessive aging in these cheeses may result in harsh cooked notes, which are not desired. Unclean off-flavors are often described as chemical (phenolic, band-aid), cowy, barney, or catty. Given the distinctive names, these imply that they are usually considered as faults in contests, but there are some manufacturers who strive to achieve these notes due to customer

Table 19.5 An example of a washed-rind sensory lexicon developed for descriptive analysis, which encompasses soft, semi-firm, and firm washed-rind cheeses

	Term	Definition
Basic tastes	Sweet	Basic taste sensation elicited by sugars
	Salt	Basic taste sensation elicited by salt
	Acid	Basic taste sensation elicited by acids
	Bitter	Basic taste sensation elicited by bitter compounds
	Umami	Basic taste sensation elicited by peptides & nucleotides. Appetitive taste. Savoriness. Induces salivation and furriness sensation on tongue, throat, roof, and back of the mouth
Dairy flavors	Cooked	Aromas and flavors associated with heated milk. Includes sulfurous, sweet, and browned notes
	Cowy/Barny	Aroma associated with barns and barn animals, indicative of animal sweat and waste
	Butter (diacetyl)	Aromatics commonly associated with natural, fresh butter
	Milky (lactones)	Aromatics and flavor commonly associated with milk or fresh cream
	Scorched	Aroma associated with extreme heat treatment of milk proteins
	Caramelized	Aroma associated with caramelization of sugars
	Whey	Aromatics associated with cheese whey

(continued)

Table 19.5 (continued)

	Term	Definition
Aged dairy flavors	Animal/wet dog	Aromas and flavors associated with gelatin or wet dog
	Butyric (rancid)	Aroma and flavors associated with butyric acid, cheesy, baby-breath/vomit
	Cucumber	Aroma and flavors associated with cucumbers
	Goaty	Aromatics associated with C6–C10 fatty acids
	Waxy/crayon	Aromatics associated with medium-chain fatty acids
	Soapy	Aromatics associated with long-chain fatty acids, saponification
	Malty	Sweet, slightly fermented/sour grain note associated with freshly kilned malt
	Oxidized	Aroma associated with oxidized fat
	Cardboard	Aroma associated with wet cardboard
	Feed	Aromatics and flavor commonly associated with cow feed, Alfalfa, hay
	Fruity	Aromatics associated with different fruits
	Rosy/floral	Aroma associated with flowers
	Sulfur	Aromatics associated with sulfurous compounds
	Brothy	Aromatics associated with boiled meat or vegetable soup stock
	Green	Aroma associated with freshly cut green vegetables
	Nutty	Nut-like aromatic associated with different nuts
	Metallic	Aromas and flavors associated with metal, copper pennies.
	Methyl ketone (bleu)	Aroma associated with blue-veined cheeses
	Medicinal/phenolic	Disinfectant-like
	Moldy	Damp, mildewy aromatic associated with mold growth
	Musty	Aromatics associated with closed air spaces, dry
	Mushroom	Aroma associated with raw mushrooms, damp humus
	Sour (dairy)	Aroma reminiscent of acid fermentation, associated with organic acid notes not pertaining to lactic acid, a dirty fermentation aroma. Not related to the taste acid
	Earthy	Aromatic characteristic of damp soil, wet foliage
	Yeasty	Aromatics associated with fermenting yeast
	Catty	Aroma associated with tom-cat urine
	Soy/soy sauce	Aromatics associated with soybeans or soy sauce
	Fecal	Aroma associated with complex protein decomposition
Chemical feeling factors	Prickle	Chemical feeling factor of which the sensation of carbonation on the tongue is typical
	Pungent	Chemical feeling factor of a hot, burning sensation in the mouth caused by chiles
	Metallic	Chemical feeling factor of metallic sensation in mouth
	Burn	Chemical feeling factor associated with high concentrations of irritants to the mucous membranes of the oral cavity
	Bite	Chemical burning sensation felt in the mouth caused by spices
	Astringent	Harsh, drying, puckering sensation on the surfaces of the mouth

Adapted from the Center for Dairy Research Internal Descriptive Lexicon demand. They do have niche markets. Rancidity (butyric acid) is usually not a welcomed flavor and may be due to use of mastitic milk or poor handling of milk. It is not a common defect in washed-rind cheeses and is atypical of the variety.

19.6 Conclusion

Washed-rind cheeses are perhaps the most diverse cheese family in terms of cheese appearance, texture/body, and aroma/flavor. With moisture content varying up to 30% across this category of cheeses, sensory evaluation must be carried out with as much contextual and background information as possible. It is important to remember that judging at a contest is distinct from evaluating a cheese during the quality control process. Context is often lacking as to what the cheese is "supposed to be" and the consumer expectations of that cheese. As with many areas of the food industry, the overall consumer acceptance of a product may be distinct from the traditional criteria in which the product was initially developed and evaluated. In other words, consumer tastes often evolve at a quicker pace than the standards and protocols for sensory quality control. Each evaluation of washed-rind cheese should be approached with an open mind and the judge must know the ultimate goal of the sensory critique in question.

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Chapter 20
Modern Sensory Practices

Mary Anne Drake

20.1 Introduction

When dealing with dairy foods, sensory quality is always involved on some level. The best raw materials and ingredients produce the best products; hence, sensory quality is a crucial consideration for finished product ingredients such as fluid and dried milk. The sensory perception of finished products such as ice cream and cheese is also critical. In many instances, a general measurement of product quality or consistency may be all that is required. For the majority of product and market research endeavors, more detailed and complex information on sensory properties is required. The application of sensory perception is one of the keys to the nearly ubiquitous, wholesome, and flavorful image that dairy foods continue to enjoy with consumers. Due to the pivotal role that sensory perception occupies in the marketing of dairy foods, some means of sensory measurement are often a final step in product development.

Sensory science is a relatively young discipline, which has been in formal existence for roughly 60 years. Many food technologists attribute its birth as a science in the 1940s with the development of "consumer" or hedonic food acceptance methodologies by the US Army Corps of Engineers. However, its scientific roots trace back to the 1800s with the development and application of psychological theories to measure and predict human responses to external stimuli (Lawless & Heymann, 2010a). Certainly, the importance of sensory quality is ageless, with basic capitalism driving individuals to market and sell the best and freshest products. As with other fields of science, sensory science has progressed with time and continues to evolve. Specific scientific methods have been developed to accurately, reproducibly,

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and either objectively or subjectively measure or estimate human responses to stimuli. Sensometrics is a field of sensory science that is specifically devoted to development of tests to accurately measure human responses.

Sensory science is widely applied across many categories of consumer goods, ranging from personal care products to pharmaceutical products to foods. For all of these product categories, sensory perception must be considered. The degree of “like” and “dislike” is not the only question answered by sensory analysis. Trained panelists can be used to generate data that are objective and analogous to instrumental data. Threshold tests can be used to estimate sensory thresholds and qualitative tests can be used to determine consumer emotional responses to products. Consumer perception, as well as the degree of like and dislike, can be addressed; the impact of storage, ingredient substitution, packaging, and process variability can be quantified; and relationships can be established between instrumental tests and sensory perception. Dozens of types of sensory tests exist and can be fine-tuned to meet a specific objective. Too often in sensory studies, a sensory test may be an afterthought to an experiment or alternatively, an inappropriate test is used or an appropriate test is selected but somehow misused. When these unfortunate sensory study situations occur, pragmatic results and conclusions cannot be drawn, just as the same situation would apply to any other scientific test inappropriately selected or conducted. Prior knowledge of which tests are available and when and how to use them will yield powerful results.

20.2 Types of Sensory Tests

The sensory analysis of dairy products can be categorized into three basic categories or groups of tests (Fig. 20.1). The first group of tests is traditional tools, which are comprised of USDA grading and ADSA scorecard judging. These are sensory tools that were developed in the early 1900s by the dairy industry to ensure product quality and consistency and to encourage and train students (Bodyfelt et al., 1988). By these techniques, a product is assigned an overall quality score or grade based on a designated list of defects. These techniques are still used today to troubleshoot product quality problems, to train students, and to ensure baseline quality of government commodities. However, they suffer from several scientific shortcomings that make them entirely unsuitable for use in product or market research. Many of the designated defects are dated and not well defined, which makes identification and scoring subjective at best, rather than specific and clearly defined. Quality downgrades for defects are not consistent (different declared defects are assigned varied point deductions) and furthermore, within a specific defect, the point deductions are not consistent. These varying point deductions ultimately mean that score assignment is not linear, which precludes the use of parametric statistics. Finally, the process of quality perception is not associated with consumer acceptance or preference; nor are quality-based results actually descriptive of the total sensory profile of the product. These issues are reviewed in detail elsewhere (Singh et al., 2003; Delahunty

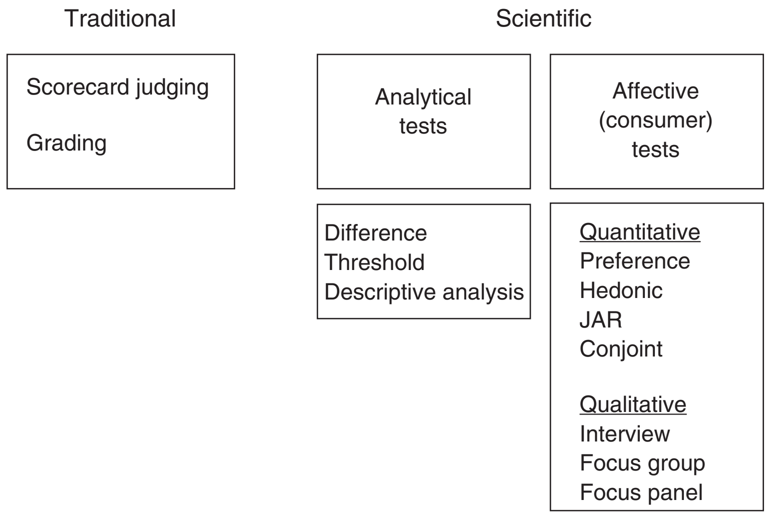

Fig. 20.1 Groups of sensory tools available for dairy foods

& Drake, 2004; Bodyfelt et al., 2008). These tools are dated at best and flawed at worst and should not be used in research endeavors for any reason. There are numerous mainstream sensory tools (ranging from very simple to complex) based on the psychological, physical, and physiological science of human responses to external stimuli – sensory science that can readily be applied to meet any specific sensory research objective in dairy foods. Mainstream sensory tools are comprised of two basic groups of tests: analytical tests and affective or consumer tests (Fig. 20.1). Within each of these categories are groups of sensory tools for specific objectives.

20.2.1 Difference Tests

The best-known analytical sensory test is the *difference test*. The sole objective of a difference test is to determine if panelists can detect whether a difference exists between two or more products. The most common types of difference tests are the *triangle* and *duo trio tests*, although there are several others. More recently, the tetrad test has emerged as a powerful non-directional difference test (Ennis et al., 2014). The selection of which difference test to use is often determined by the amount of sample, number of samples, testing conditions, and specific test objectives. These tests are relatively easy to set up and administer and the results are easily computed using a simple binomial calculation or published tables (Lawless & Heymann, 2010a). The number of panelists required varies depending on the specific goal. Generally, 25–50 panelists are recommended. Other subcategories of difference tests, such as a *degree of difference* (DOD) *test*, can be used to quantify the degree of difference among samples, but this more advanced test generally requires fewer, more experienced, or trained panelists. In contrast, another type of test similar to but distinct from difference testing is *similarity testing*; this test is conducted similarly to a difference test, but generally requires larger numbers of panelists (>75) (Meilgaard et al., 2016).

Difference tests are generally quite simple, but there are numerous different types and subcategories of these tests, and they can fulfill a wide variety of functions. Difference tests are less often used in sensory research than *acceptability* or *descriptive* tests, but they can suffice as a preliminary test to determine if more advanced or detailed sensory tests are required. The impacts of process changes and ingredient substitutions can all be determined by this simple test. Jiamyangyuen et al. (2002) used paired comparison tests (a type of difference test) to confirm that wooden ice cream sticks from different wood types resulted in different perceived flavors in ice cream mixes. Yeh et al. (2017) used triangle tests to determine if the addition of vitamin premixes to fluid milk impacted consumer perception. It is important to keep in mind that the sole purpose of this test is to determine if a difference exists. The nature of the difference, the degree of difference, or consumer preference cannot be determined using this test, nor can these questions be asked of panelists when undertaking a difference test. If those questions need to be answered, a different or an additional sensory test is required (Lawless & Heymann, 2010a; Meilgaard et al., 2016).

20.2.2 Threshold Tests

Threshold tests are another category of analytical sensory tests with a specific function: to determine thresholds. A threshold is defined as the lowest concentration at which a sensory response is detectable (Lawless & Heymann, 2010a; Meilgaard et al., 2016). There are other types of thresholds, such as absolute threshold (previously defined), recognition threshold (lowest concentration at which a compound can be recognized), difference threshold (concentration at which differences in stimuli can be detected), terminal threshold (concentration above which there is no perceived increase in sensory stimulus), orthonasal threshold (threshold of volatile compound perceived orthonasally), and retronasal threshold (threshold of volatile compound retronasally). The latter is determined by having subjects wear nose clips when taking a mouthful of the sample, followed by removal of the nose clip once the compound is in the mouth. Thresholds are often applied to undesirable and desirable components in foods. For example, at what concentration is dimethyl trisulfide (DMTS), an off-flavor in whey protein isolate [WPI] identified? Such a question can be answered only by (1) quantification of DMTS in WPI to determine the concentration(s) of this compound in the product, followed by (2) threshold testing of DMTS in water and WPI to determine what concentrations are detected by humans (Wright et al., 2006). Thresholds can thus provide a powerful tool in relating sensory perception to instrumental analysis of volatile and nonvolatile compounds (Carunchia Whetstine et al., 2005; Robinson et al., 2004, 2005; Jo et al., 2019).

A search through the literature for ascertaining a threshold of a compound can be confusing. Indeed, ranges of more than 1000-fold are reported for many compounds throughout the literature (Rychlik et al., 1998; van Gemart, 2003). Several issues must be addressed to determine an accurate and reproducible threshold value. Thresholds are impacted by several things, and perhaps the most significant element is a proper and consistent testing procedure. This includes an appropriate threshold test method, an appropriate number of panelists, and a consistent methodology. The two most common threshold procedures are the ascending forced choice or 3-AFC method (method of limits) and the R-index method (signal detection theory) (ASTM, 1992; Lawless & Heymann, 2010b). These tests were developed from some of the original and historical tenets of sensory and psychological science (Fechner's law, discussed in previous chapters). An appropriate number of panelists is the key to a reliable threshold determination. Thresholds are by their very nature estimates at best since the population varies widely in sensitivity to compounds, and a given individual, when tested multiple times, will also be variable. The value obtained from threshold testing is referred to as a best estimate threshold (BET) and that is the reason why. The goal is to obtain a reasonable estimate of the threshold. As such, a large number of individuals need to be tested in order to obtain a reliable threshold. The minimum recommended number of individuals is frequently noted as 75–100, although testing 30–40 individuals on multiple days can also approach a sound BET. Thresholds obtained from fewer individuals should be considered suspect. Finally, the testing procedure can also be a source of variability. Temperature and headspace volume will both impact threshold. Panelist training and/or experience also has an impact – generally, training can increase threshold sensitivity by as much as 1000-fold for an individual. It is also important to note that thresholds are based on consistent identification of a signal in a series of coded samples. One must ensure that the signal detected is caused by the compound tested. When conducting thresholds on nonvolatile compounds (such as bitter or umami compounds), nose clips are often worn by panelists to ensure that the signal detected is the nonvolatile component and not some volatile flavor or aroma inherent to the source of the nonvolatile compound.

20.2.3 Descriptive Tests

The third general group of analytical sensory tests is descriptive analysis. Descriptive analysis consists of training a group of individuals (generally 6–12) to identify and quantify specific sensory attributes or all of the sensory attributes of a food. This sensory tool, unlike the previous analytical tests that use untrained or instructed/screened individuals, requires training of the panelists. The extent of the training is dependent upon the complexity of the sensory attributes that are to be profiled. Training may be as brief as a few hours if there are only a few attributes and the attributes are distinct in the samples. On the other hand, a significant amount of time and/or financial commitment is required if flavor profiling of 16 attributes (or more) of Cheddar cheese is desired. The simplicity of descriptive analysis is that the panel and its training can be adjusted to meet the specific project goals. The panel can be trained on a few attributes or a large number of attributes. The panelists are trained (sometimes for several hundred hours) to operate in unison as an instrument, and each individual panelist serves a function analogous to an individual sensor on an instrument. The panel replicates measurements analogous to replication of instrumental measurements and the data collected are analogous to instrumental data. There are different approaches and training techniques for undertaking descriptive sensory analysis, but the primary goal is the development of a powerful instrument to document sensory properties. The various techniques and approaches for the conduct of descriptive analysis are reviewed elsewhere (Lawless & Heymann, 2010a; Murray et al., 2001; Delahunty & Drake, 2004).

Relevant to the objective of this book, it is worthy to address and demonstrate how trained panel results differ from dairy product judging. Figures 20.2, 20.3, 20.4 and 20.5 demonstrate this point with cheese and skim milk powder. The reader will note that the products are actually quite distinct from each other in their sensory properties, although their assigned grades are not different. Thus, using judging or grading would not differentiate these products and potentially valuable information would be overlooked. Grading and judging protocols were designed to provide quality scores based on predetermined defects. These tests were not designed to generate sensory profiles of products, which is the goal of descriptive analysis. The *trained descriptive sensory panel* functions as a qualitative and quantitative instrument used to document sensory properties of different foods. Figures 20.6, 20.7 and 20.8 demonstrate application of a trained panel with a defined sensory language to document differences in whey protein flavor and cheese texture, respectively.

For comparison of relatively few samples or few attributes, a means table or figure is advisable (Figs. 20.3, 20.4 and 20.5). However, when multiple samples (>6) and/or multiple attributes are evaluated (>6), a multivariate analysis and presentation of the data may assist with simplification and clarification of differences among products. These techniques are essentially data compression procedures and can be extremely useful for characterization of how products differ relative to one another across all attributes or parameters evaluated. *Principal component analysis*

Fig. 20.2 Grades of two 16-kg blocks of 3-month Cheddar cheese. Grades were provided by a licensed USDA grader

Cheese 1	A	Sl. Bitter Sl. flat
Cheese 2	A	Sl. Bitter Sl. flat

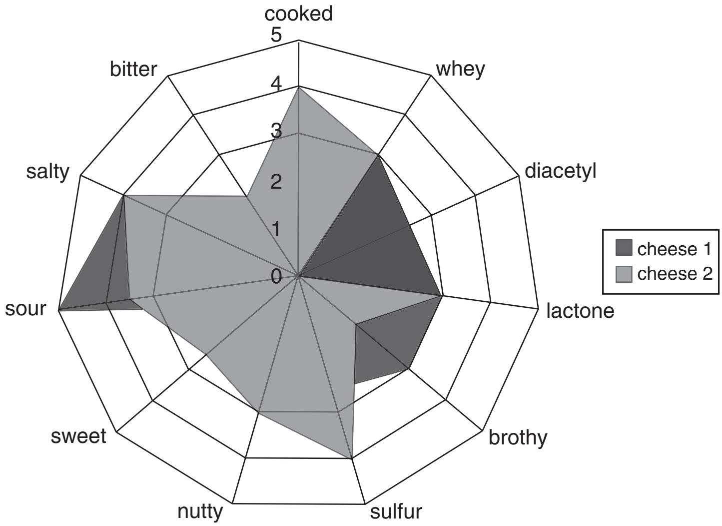

Fig. 20.3 Descriptive sensory profiles provided by a trained descriptive panel for the two 16-kg blocks of Cheddar cheese in Fig. 20.2

Fig. 20.4 Grades for two skim milk powders (SMP) within 1 month of production. Grades were provided by a licensed USDA grader

Powder 1	US Extra	Sl. Cooked
Powder 2	US Extra	Sl. Cooked

(PCA) is the most commonly applied multivariate approach in sensory analysis, although there are several techniques available. By this method, linear combinations of variables (principal components – PCs) that explain the most variability within the sample set are generated. A biplot of the samples and how they are differentiated on the principal components is then generated. The variables that comprise each PC can be ascertained from the statistical program and by viewing an overlay of the vectors on the biplot (Figs. 20.6, 20.6 and 20.8). For example, Figs. 20.6 and 20.7 address the PCA for the descriptive analysis of a set of whey proteins (WPC80 and WPI). PC1 explained 42% of the variability among the samples and was characterized by opacity, color, sweet aromatic, cereal, cardboard, soapy, metallic, astringency, and viscosity (Russell et al., 2006). PC1 primarily differentiated WPC80 from WPI while PC2, 3, and 4 differentiated individual whey proteins from one another. A quick glance at Fig. 20.6 tells us that WPC80 and WPI were differentiated from each other as groups (exception – WPC7) and that the differences between

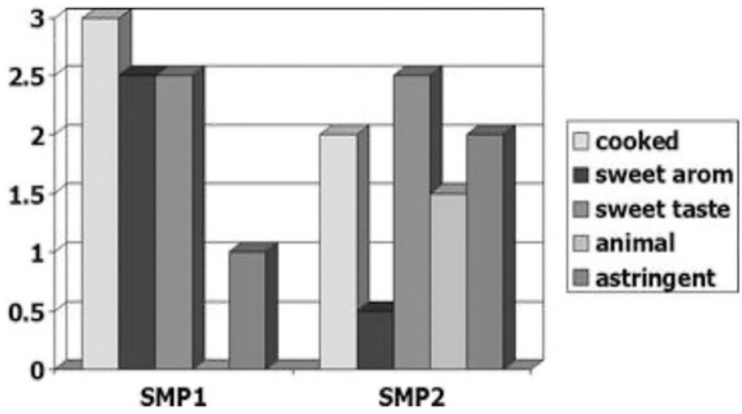

Fig. 20.5 Descriptive sensory profiles provided by a trained descriptive panel for the two SMP in Fig. 20.4

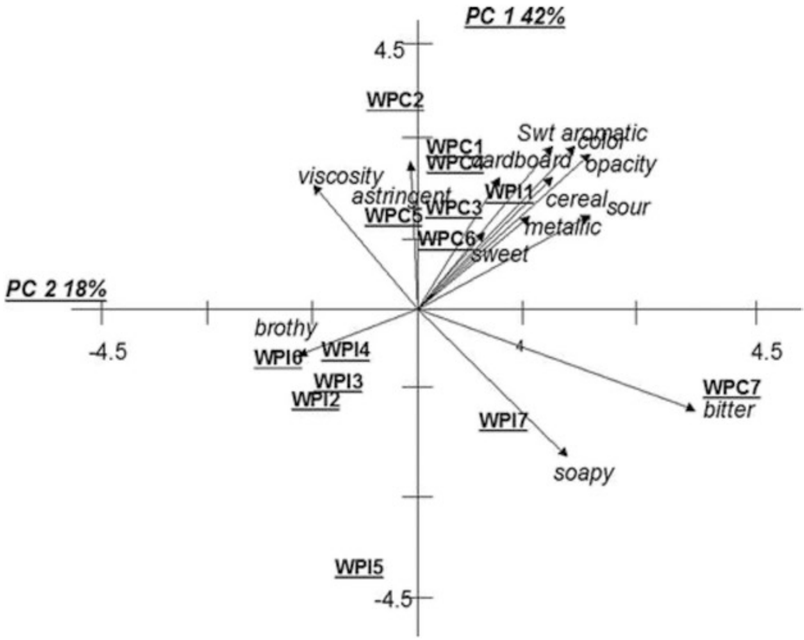

Fig. 20.6 Principal component biplot of descriptive analysis of whey proteins (PC1 and PC2). (Taken from Russell et al., 2006). *PC* principal component, percentage following PC in parenthesis explains amount of variability depicted by each principal component on each axis, *WPC* whey protein concentrate, *WPI* whey protein isolate, *Swt aromatic* sweet aromatic

these products explained the most variability in the data set (42%). The WPC80 samples were generally characterized by high viscosity, sweet aromatic, cardboard, cereal, and metallic flavors and sour taste and astringency compared to WPI. As a

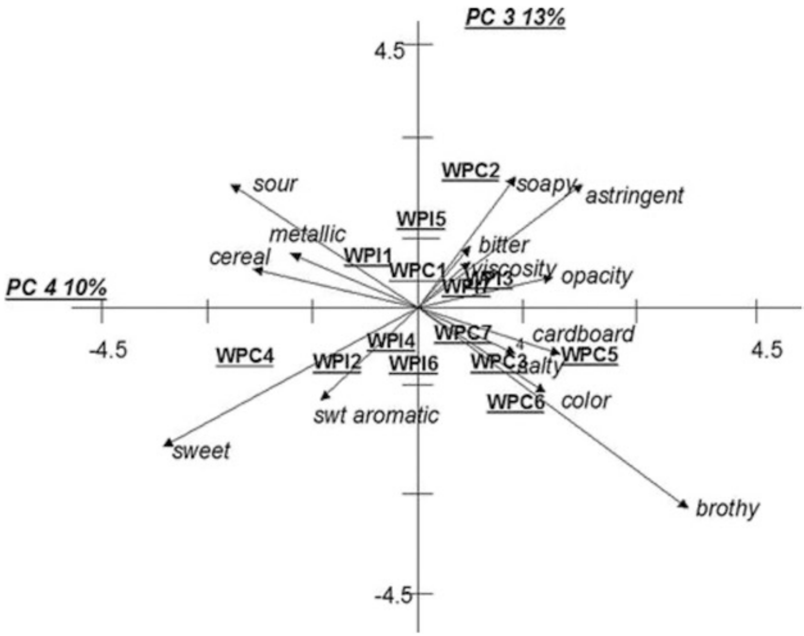

Fig. 20.7 Principal component biplot of descriptive analysis of whey proteins (PC3 and PC4). (Taken from Russell et al., 2006). *PC* principal component, percentage following PC in parenthesis explains amount of variability depicted by each principal component on each axis, *WPC* whey protein concentrate, *WPI* whey protein isolate, *Swt aromatic* sweet aromatic

whole, the WPI are more distinct from each other than the WPC80. WPI 7 and 5 are distinct from the other WPI while WPC7 is distinct from the other WPC80. Similarly, Fig. 20.8 documents trained panel texture differences among 20 Gouda cheeses of different ages (Yates & Drake, 2007). The reader is referred to Lawless and Heymann (2010a) or Meilgaard et al. (2016) for a more detailed discussion of the statistical theory of this technique and other alternative approaches.

A key aspect of a trained sensory panel is that the results are analogous to instrumental data. As such, the sensory instrument should be as precise and reproducible as possible. Training with defined sensory languages and replication of panel measurements are used to achieve this goal. One way of minimizing variability is through focused panel training where panelists are presented with the sensory language (or lexicon) and then discuss these attributes as they relate to the products that will be evaluated. However, a crucial step for facilitating panel training and panel performance and establishing any relationship to physical or instrumental measurements is to have clearly defined terms for sensory attributes (Drake & Civille, 2003; Lawless & Civille, 2013). Defined terms facilitate panel training and minimize variability, but they also set the parameters for understanding instrumental measurement of the sensory attribute. For example: Is cheese firmness measured by compression with fingers, bite force with incisors, the molars, or compression

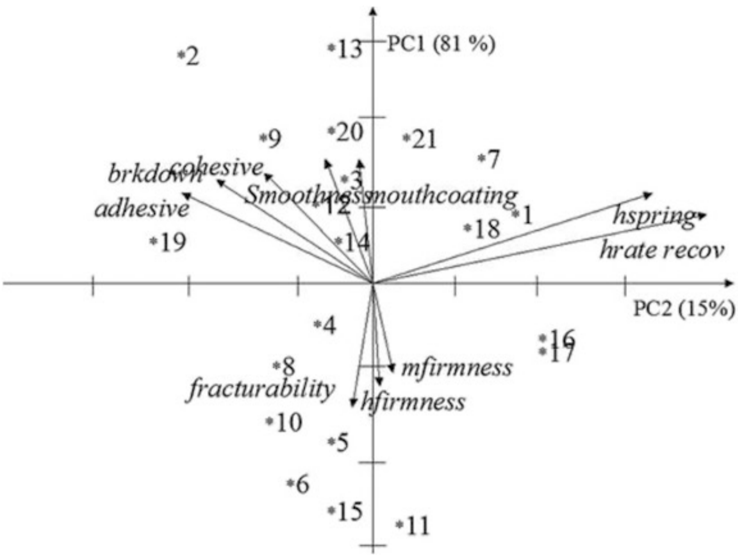

Fig. 20.8 Principal component plot of descriptive texture attributes of Gouda cheeses. *PC* principal component. *Numbers* represent cheeses, mfirmness – firmness in the mouth, hfirmness – firmness by hand, hrate recov – rate of recovery determined by hand, hspring – springiness determined by hand, smoothness – smoothness of the chewed mass, cohesive – cohesiveness of the chewed mass, brkdown – degree of breakdown

between the tongue and the hard palate? Is free fatty acid flavor defined as the aroma or a flavor reminiscent of hexanoic acid, butyric acid, methyl octanoic acid, or any free fatty acid? In the case of texture: What is the defined size and shape of the sample? Cheese firmness might be measured by the fingers, tongue, incisors, or molars depending on the type of cheese. Many cheese texture attributes, in addition to firmness, can be evaluated by hand manipulation in a specific manner (Drake et al., 1999; Sandra et al., 2004). Ideally, references (food or chemical examples) are also provided in addition to attribute definitions to aid panelists in training and attribute identification and scale usage. Delahunty and Drake (2004) reviewed sensory lexicons for cheese flavor and texture. Tables 20.1 and 20.2 demonstrate published lexicon examples for cheese texture and Cheddar cheese flavor with definitions and references. Similar languages have been identified for dried dairy ingredients, chocolate milk, and butter (Drake et al., 2003; Thompson et al., 2004; Krause et al., 2007). As previously addressed, the *sensory language* can be simple or complex depending on the specific test objective(s). Furthermore, sensory languages can be expanded and/or modified and clarified with time and usage. Figure 20.9 demonstrates this issue with a graphical representation of the cheese flavor lexicon initially developed by Drake et al. (2001). The first layer in the wheel represents the basic language, which in most cases is all that is needed to document flavor differences in Cheddar cheese. The second layer of the wheel represents the more advanced version of the language with subdivisions of descriptors in the basic language.

Table 20.1 Descriptive sensory language for cheese texture

Hand evaluation terms	Definition	References
Hand firmness	Press fingers completely through the sample. Evaluate the force required to completely compress the sample	Velveeta™ = 3 Muenster = 7 Sharp Cheddar (Kraft) = 10 Parmesan = 15
Hand springiness	Depress sample 30% between thumb and first two fingers. Evaluate total amount of recovery of sample. (if sample fractures as it is depressed, it is not springy)	Parmesan = 1 Velveeta™ = 4 Sharp Cheddar (Kraft) = 7 Muenster = 13
Hand rate of recovery	Depress sample 30% between thumb and first two fingers. Evaluate rate of recovery (how long it takes to recover to the original shape)	Feta = 1 Velveeta™ = 3 Sharp Cheddar (Kraft) = 6 Muenster = 9
Mouth evaluation terms – First bite	Using molars, take one complete bite through the sample	
Firmness	The amount of force required to completely bite through the sample	Velveeta™ = 2 Muenster = 6 Sharp Cheddar (Kraft) = 9 Parmesan = 14
Fracturability	The amount of fracturability in sample after biting	Velveeta™ = 1 Sharp Cheddar (Kraft) = 5 Feta = 14
Mouth evaluation terms – Chew down	Chew the sample 5 times and evaluate the chewed mass	
Degree of breakdown	Evaluate how much the sample has broken down during mastication	Parmesan = 1 Muenster = 9 Sharp Cheddar (Kraft) = 11 Velveeta™ = 14
Cohesiveness	The degree to which the chewed mass sticks together in the mouth	Parmesan = 1 Feta = 3 Muenster = 7 Sharp Cheddar (Kraft) = 11 Velveeta™ = 14
Adhesiveness	The degree to which the chewed sample sticks to the surfaces of the mouth and teeth	Parmesan = 1 Muenster = 7 Sharp Cheddar (Kraft) = 10 Feta = 12 Velveeta™ = 14

(continued)

Table 20.1 (continued)

Hand evaluation terms	Definition	References
Smoothness of mass	Evaluate the smoothness of the chewed mass	Parmesan = 1 Feta = 3 Muenster = 8 Sharp Cheddar (Kraft) = 10 Velveeta™ = 14
Mouth evaluation – Residual	Expectorate the sample: Evaluate the residue in the mouth	
Smoothness of mouth coating	Evaluate the degree of smoothness felt in the mouth	Parmesan = 1 Feta = 5 Muenster = 10 Sharp Cheddar (Kraft) = 11 Velveeta™ = 14

Source: Brown et al. (2003)

Clear definitions and references for attributes also facilitate comparison with other studies and instrumental analyses and provide a platform that can be further expanded and applied. The sensory instrument then becomes applicable to a wide array of applications. Drake et al. (2001) developed a sensory language for cheese flavor. The language was developed specifically for Cheddar cheese but once the base language was identified, it was subsequently applied to other cheeses including Swiss, Mozzarella, Parmesan, and Gouda with minor modifications (Liggett et al., 2008; Jo et al., 2018 Table 20.3). Drake et al. (2002) demonstrated that the defined language could be used by panels at multiple locations to provide identical results for the same samples. This same defined language has also been used for comparison and calibration with other descriptive panels (Drake et al., 2005) and interpretation of instrumental volatile analysis (Suriyaphan et al., 2001; Avsar et al., 2004; Carunchia Whetstine et al., 2005; Carunchia Whetstine et al., 2006a, b; Carunchia Whetstine and Drake, 2007; Drake et al., 2010; Jo et al., 2018). In the latter cases, the trained descriptive panel played a critical role in elucidating flavor chemistry. Many volatile component peaks generated on a detector are neutral or not aroma-active and do not play crucial roles in flavor because either the compound has no odor or its concentration is below human sensory detection (Drake et al., 2006). For this reason, coordinating instrumental analysis results with sensory analysis by using a trained sensory panel is an absolute requirement in flavor chemistry to appropriately interpret instrumental results (Drake, 2004; Drake et al., 2006; Cadwallader, 2007). Without accompanying sensory analysis, there is no relation to flavor and thus, instrumental volatile analysis is simply a list of volatile organic compounds present in the sample. Similar work with sensory analysis can be used to interpret instrumental measurements of physical properties and determine exactly how they relate to sensory perception of texture (Foegeding & Drake, 2007).

Another important application of descriptive analysis, other than enhanced product understanding and identification of relationships to instrumental analyses, is to

Table 20.2 Basic Cheddar cheese flavor language

Descriptor	Definition	Reference
Cooked/ milky	Aromatics associated with cooked milk	Pasteurized skim milk heated to 85 °C for 30 min
Whey	Aromatics associated with Cheddar cheese whey	Fresh Cheddar whey
Diacetyl	Aromatic associated with diacetyl	Diacetyl, 20 ppm
/lactone	Aromatics associated with	Fresh coconut meat, heavy cream, δ-dodecalactone, 40 ppm
Fruity	Aromatics associated with different fruits	Fresh pineapple, ethyl hexanoate, 40 ppm
Sulfur	Aromatics associated with sulfurous compounds	Boiled egg, H_2S bubbled through water, freshly struck match
Free fatty acid	Aromatics associated with short-chain fatty acids	Butyric acid, 20 parts per thousand
Brothy	Aromatics associated with boiled meat or vegetable	Canned potatoes, Wyler's low soup stock, sodium beef broth cubes, methional, 20 ppm, 2-methyl-3-furanthiol
Nutty	The sweet roasted aromatic associated with various germ, nuts, and unsalted wheat thins	Lightly toasted unsalted nuts, wheat roasted peanut oil, 2/3-methyl butanal, 500 ppm
Catty	Aroma associated with tom-cat urine	2-Mercapto-2-methyl-pentan-4-one, 20 ppm
Cowy/ barny	Aroma associated with barns and animal sheds, reminiscent of ruminant sweat and urine	Mixture of isovaleric acid and *p*-cresol, 100 ppm
Mothball/ feed	Aroma associated with mothballs or protein catabolism, sometimes reminiscent of silage or grass compost	Mothballs, indole or skatole, 50 ppm
Sour	Fundamental taste sensation elicited by acids	Citric acid (0.08 g/100 mL in water)
Salty	Fundamental taste sensation elicited by salts	Sodium chloride (0.5 g/100 mL in water)
Sweet	Fundamental taste sensation elicited by sugars	Sucrose (5 g/100 mL in water)
Bitter	Fundamental taste sensation elicited by caffeine or quinine	Caffeine (0.08 g/100 mL in water)
Umami	Chemical feeling factor elicited by certain peptides and nucleotides	MSG (1 g/100 mL in water)

Source: Drake et al. (2001)

gain an understanding of the consumer. Consumer or *affective tests* are addressed later in this chapter, but generally these tests tell us what consumers "like." In many cases, why consumers like or prefer a product is not clear unless descriptive analysis is applied to the same set of products. By descriptive analysis, we know the specific sensory or texture profiles of the product; however, with consumer tests, we know which product(s) consumers like or prefer. For a small number of products or treatments, we can closely examine the sensory profiles of well-liked products and can

Fig. 20.9 Graphical representation of the basic and advanced levels of the Cheddar cheese flavor lexicon (Table 20.2)

infer "why they are liked." Often, the goal is larger than simply understanding why a specific product is preferred over a few others. Instead, the identification of the drivers of consumer liking is desired. For this specific goal, a wide range of a particular product is profiled by a trained sensory panel. Selected products are then presented to consumers to obtain liking information. The two sets of data are combined in a multivariate statistical technique generally called *preference mapping*. A minimum of eight products with variable trained panel profiles is generally recommended in order to obtain a robust statistical model. For example, if all products are liked, it would not be possible to identify drivers of liking. This approach has been applied to identify specific consumer likes and dislikes with many dairy products (Jack et al., 1993; Hough & Sanchez, 1998; Krause et al., 2007; Thompson et al., 2004; Young et al., 2004; Lawlor & Delahunty, 2000; Xiong et al., 2002; Murray & Delahunty, 2000a, b; Richardson-Harmon et al., 2000; Drake et al., 2009; Shepherd et al., 2013; Desai et al., 2013; Jo et al., 2018). The power of these studies is that specific consumer groups with specific likes and dislikes are identified. Figures 20.10 and 20.11 demonstrate the application of this technique to Cheddar cheese and butter, respectively.

Table 20.3 Swiss cheese descriptive analysis lexicon adapted and modified from the Cheddar cheese lexicon

Descriptor	Definition	Reference
Cooked/ milky	Aromatics associated with cooked milk	Skim milk heated to 85 °C for 30 min
Whey	Aromatics associated with Cheddar cheese whey	Fresh Cheddar whey
Diacetyl	Aromatic associated with diacetyl	Diacetyl
Milkfat	Aromatics associated with milkfat	Fresh coconut meat, heavy cream, δ-dodecalactone
Vinegar	Aromatics associated with vinegar	Distilled white vinegar, acetic acid
Dried fruit	Aromatics associated with dried fruits, specifically peaches and apricots	Dried apricot half
Fruity	Aromatics associated with different fruits	Fresh pineapple, ethyl hexanoate
Sulfur/eggy	Aromatics associated with cooked eggs	Hard-boiled egg, mashed
Sulfur/ cabbage	Aromatics associated with cooked cabbage	Boiled cabbage, dimethyl trisulfide
Cheesy/ butyric acid	Aromatics associated with butyric acid	Butyric acid
Brothy	Aromatics associated with boiled meat or vegetable stock	Canned potatoes, Wyler's low sodium beef broth cubes, methional
Nutty	The nut-like aromatic associated with different nuts	Lightly toasted unsalted nuts, unsalted cashew nuts, unsalted wheat thins
Sweaty	Aromatic associated with human sweat	Hexanoic acid
Cowy/ phenolic	Aromas associated with barns and stock trailers, indicative of animal sweat and waste	Band-aids, *p*-cresol, phenol
Sour	Fundamental taste sensation elicited by acids	Citric acid (0.08% in water)
Bitter	Fundamental taste sensation elicited by various compounds	Caffeine (0.08% in water)
Salty	Fundamental taste sensation elicited by salts	Sodium chloride (0.5% in water)
Sweet	Fundamental taste sensation elicited by sugars	Sucrose (5% in water)
Umami	Chemical feeling factor elicited by certain peptides and nucleotides	MSG (1% in water)
Prickle	Chemical feeling factor of which the sensation of carbonation on the tongue is typical	Soda water
Metallic	Chemical feeling factor elicited by metallic objects in the mouth	Aluminum foil

Source: Drake et al. (2001) and Liggett et al. (2008)

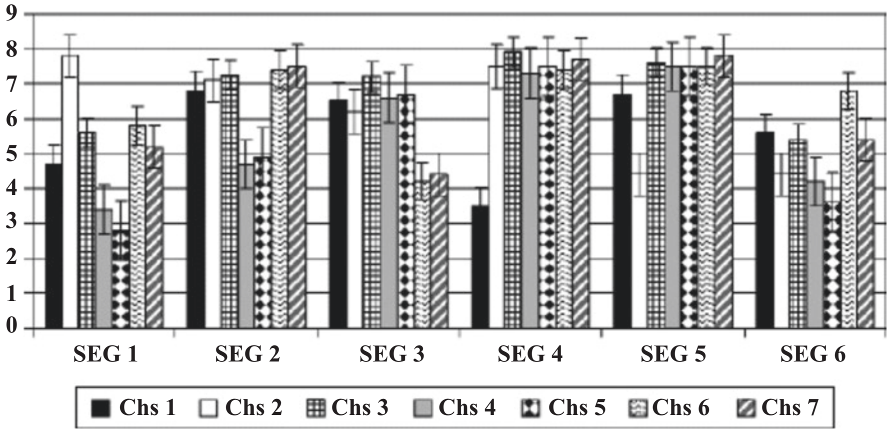

Fig. 20.10 External preference map of combined consumer data ($n = 240$) with descriptive analysis results for 7 different Cheddar cheeses. Six consumer segments with distinct liking profiles for 7 selected Cheddar cheeses were identified. (Taken from Young et al., 2004)

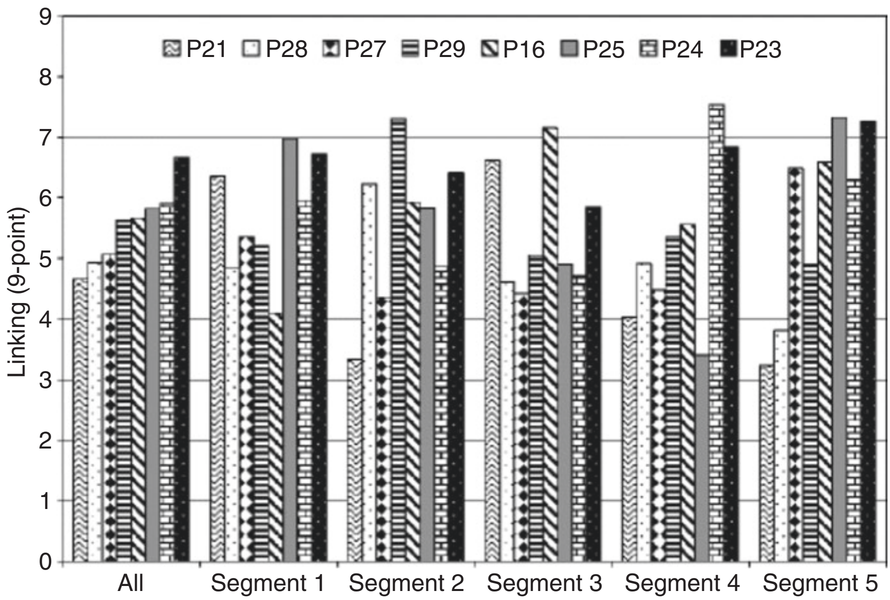

Fig. 20.11 Overall acceptability scores for 6 butters (P16, P21, P23, P24, P25, P27) and 2 spreads (P28, P29) within different identified consumer segments. Liking profiles for the 8 products are distinct for each consumer segment. (Taken from Krause et al., 2007)

20.2.4 Affective or Consumer Tests

20.2.4.1 Quantitative Consumer Tests

The third group of sensory tests is affective or consumer tests. Similar to analytical sensory tests, there is a large array of specific and sensitive tests in this category. To the beginner, this group of tests seems to just measure preference and liking. In contrast, this group of tests is like a glassy lake that looks shallow and smooth but is in fact deep and quite complex. Qualitative and quantitative tests are available. Consumer tests involve testing with consumers. This issue may seem obvious, but the primary objective of these tests specifies that trained panelists *should not* be used. Once individuals are trained to identify and quantify attributes of a product(s), they cease to be typical consumers. Further, when quantitative consumer tests are conducted, their objective is to determine or infer consumer likes and dislikes. Consumers are highly variable and constantly changing due to age, advertising, new experiences, new products, etc. For this reason, large and successful companies have large sensory and/or market research departments that conduct these tests regularly and with *large* numbers of representative consumers. Demographic information (age, gender, product usage rate) is generally collected from consumers to determine if these variables influence product liking. Additional information (income, ethnicity, product perceptions/attitudes) can also be probed in the screener if desired (Fig. 20.17). For this reason, these screeners are sometimes called usage and attitude screeners (or U & A information). Even for small research projects or objectives, a minimum of 50 consumers is recommended in order to make any conclusion(s) about product liking or preference – and these should be product consumers, not trained panelists (IFT/SED, 1981; Resurreccion, 1998; Meilgaard et al., 2016; Hough et al., 2006). In-house employees are also suspect since they are generally familiar with the company's product(s) and tend to be biased. Certainly, they can be and are used for "first pass" or preliminary assessment of product quality, but they should not be used for decisions that impact new or improved products. The reader is referred to several textbooks that address these issues in detail (Lawless & Heymann, 2010a; Meilgaard et al., 2016; Resurreccion, 1998).

Quantitative tests are the best-known group of tools, with preference and acceptance testing the most used subset within this classification (Lawless & Heymann, 2010a; Meilgaard et al., 2016). *Preference and acceptance testing* are often used interchangeably, but they are two distinct test methods. In preference testing, consumers are presented with two or more samples and asked to indicate which sample they prefer. If more than two samples are presented, consumers can also rank their preferences (preference ranking). The test is generally a forced choice – that is a preference must be indicated. A preference test is easy to conduct and the question is readily understood by consumers of all ages, even those with minimal understanding of English. Nonparametric statistical analysis can be applied to determine differences. However, a primary drawback is that the degree of liking is not determined. Consumers can dislike products and still have a preference for one when forced to choose. Further, other consumer questions, besides overall liking, can be asked with acceptance testing, and preference can be inferred from acceptance testing. In short, with acceptance testing, more information along with preference can be obtained.

Acceptance testing is also called "degree of liking." Consumers are presented with products and asked to indicate their degree of liking on a scale. The most commonly used scale is the 9-point hedonic scale (Fig. 20.12). This scale is bipolar – the anchors are dislike and like – and has been widely used since its invention in the 1940s (Schutz & Cardello, 2001). In this sense, it has certainly stood the test of time. The scale can be presented numerically or verbally, horizontally or vertically (Schutz & Cardello, 2001) and is used to effectively indicate differences in consumer liking of products. Other adaptations of this scale include a 7-point scale and a smiley face scale that can be used with children or those that do not speak/read English (Fig. 20.13). Research has suggested that issues of central tendency and unequal scale intervals are shortcomings of this scale and other scales such as labeled affective magnitude scales (LAM) have been proposed as more sensitive alternatives (Schutz & Cardello, 2001; Greene et al., 2006) (Fig. 20.14). More recent research has suggested that liking and disliking are actually completely different thought processes and should not be scaled on the same continuum (Herr & Pages, 2004). Instead, degree of liking and/or degree of disliking should be scaled on distinct unipolar intensity scales (Fig. 20.15). The 9-point hedonic scale will certainly continue to be a mainstream quantitative consumer research tool. Indeed, while studies have suggested that the LAM scale or nonpolar like and dislike scales may be more sensitive in certain situations, in a vast majority of studies the 9-point hedonic scale has proven to be a robust and perhaps more conservative estimate of consumer liking. As with any sensory test, it is important to remember that specific situations may call for a more specialized scale than the traditional 9-point hedonic

OVERALL LIKING

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

OVERALL LIKING

Like extremely
Like very much
Like moderately
Like slightly
Neither like nor dislike
Dislike slightly
Dislike moderately
Dislike very much
Dislike extremely

Fig. 20.12 Numerical and verbal representations of the 9-point hedonic scale

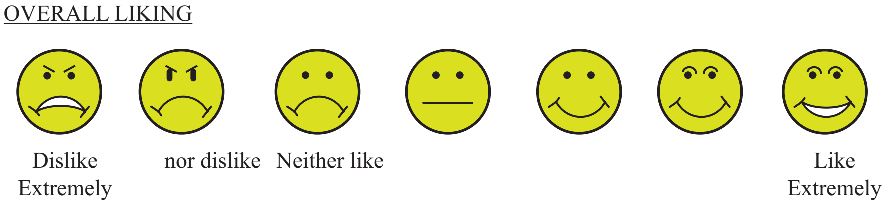

Fig. 20.13 Seven-point smiley face scale used with children or with individuals that do not speak or read English. Faces are converted to numerical values (1–7) for data analysis

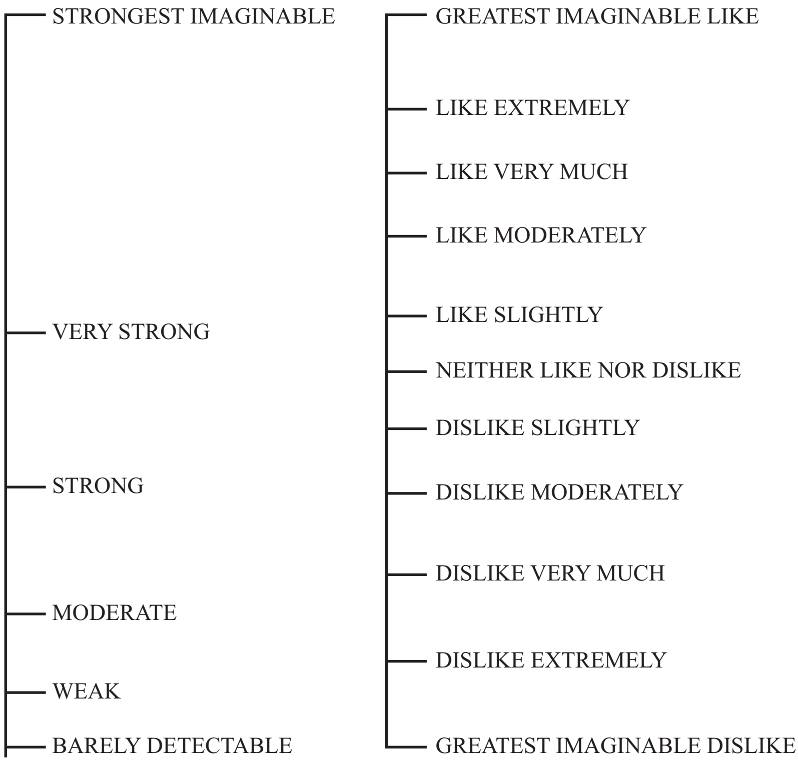

Fig. 20.14 Labeled affective magnitude (LAM) scales for measuring intensity and liking

scale. Such situations would potentially include testing with children, non-English speaking populations, or different (non-US) cultures. For most situations, or the standard research project where the goal is simply to determine if differences exist between products in consumer acceptance, the 9-point hedonic scale is the scale of choice.

The *just-about-right* or JAR scale is another often-used scale that is a subcategory of acceptance testing (Fig. 20.16) (Lawless & Heymann, 2010a). This test is often used in product development or optimization studies since the experimenter

Overall Liking

1	2	3	4	5	6	7	8	9
No Opinion								Like Extremely

Overall Dislike

1	2	3	4	5	6	7	8	9
No Opinion								Dislike Extremely

Fig. 20.15 Unipolar scales for scoring liking and disliking separately

JAR scale for sweetness

Much too little	Somewhat too little	Just right	Somewhat too much	Much too much

Use of category scales to infer if sweet taste is optimal

Sweetness Intensity

1	2	3	4	5	6	7	8	9
Low			Moderate					High

Sweetness Liking

1	2	3	4	5	6	7	8	9
Dislike Extremely			Neither like nor dislike					Like Extremely

Fig. 20.16 An example of a just-about-right (JAR) scale for sweetness intensity followed by an example of obtaining similar information using category scales

can probe if a specific product attribute (such as sweetness or chocolate flavor) is "just about right." There are a limited number of categories and only nonparametric statistical analysis is appropriate. Nine-point category scales can also be used to obtain the same information, and parametric statistics (ANOVA) can be applied (Fig. 20.16). By this approach, the attribute liking is probed, followed by the perceived intensity of the attribute. Whether or not the attribute intensity is "right" or "liked" can then be inferred.

Maximum difference scaling and Conjoint analysis are another group of quantitative approaches that can be applied to consumer tests, usually surveys, and that can be used to probe consumer perceptions. Unlike preference and acceptance tests that generally deal with actual products that are tasted/evaluated by the consumer, neither maximum difference scaling or conjoint analysis require actual products. The premise of maximum difference (Maxdiff) scaling is that consumers are not

1. Gender: _______ female _______ male

2. Age:
_______ less that 20
_______ 20 – 24
_______ 25 – 29
_______ 30 – 34
_______ 35 – 39
_______ 40 - 45
_greater than 45

3. What is your yearly income?

_$0 – 10,000
_$10,000 – 20,000
_$20,000 – 40,000
_$40,000 – 60,000
_greater than $60,000

4. What is your education level?

_Did not finish High school
_High School Diploma/GED
_College Degree
_Advanced Degree beyond undergraduate
_Trade/professional school (i.e. community college, etc.)

5. Are you a U.S. citizen? Yes No

6. Do you shop for the household, even if it's you alone? Yes No

7. Do you have allergies to dairy beverages? _______Yes _______No

8. Do you purchase DRINKABLE yogurt? Yes No

9. If you purchase DRINKABLE yogurt, how often do you consume them (any type)?

_______ never
_______ a few times per year
_______ at least once per month
_______ at least 2 – 3 times per month
_______ at least once per week
_______ two or more times per week

10. If you consume DRINKABLE yogurt, what product brands do you purchase? (check all that apply)

_______ Dannon
_______ Stoneyfield Farms
_______ Yoplait
_______ Store brands (Food Lion, Harris Teeter, etc.)
_______ Other brands

11. What general factors influence your purchase of DRINKABLE yogurt? (check all that apply)

_______ Price
_______ Flavor
_______ Color
_______ Texture
_______ Sweetness
_______ Availability

Fig. 20.17 An example of a demographic screener used with consumer acceptance testing of drinkable yogurts

inherently good at ranking a list, but they can easily determine the "best" and "worst" option from a list. As such, MaxDiff can be applied to assess key intrinsic or extrinsic product properties. Maximum difference scaling has been applied to identify key consumer attributes for fluid milk, cheese shreds, and protein products (Harwood & Drake, 2018; Speight et al., 2019; Harwood & Drake, 2019). Schiano et al. (2020) utilized Maxdiff scaling to identify key aspects of food sustainability.

Conjoint or trade-off analysis is a technique that takes into account the fact that consumers make choices or trade-offs between independent (yet conjoined) attributes in a product when making a purchase decision (Orme, 2006). Consumers are presented with a list of product attributes and are then asked to go through a series of trade-offs. Quantitative data are generated, which can be subjected to traditional statistical analyses. The end-product is the determination of which product attribute(s) are most important to the consumer – without having to manufacture prototypes. For example, Jones et al. (2008) used conjoint analysis to determine which aspects of meal replacement bars were most crucial to consumer selection and purchase. Similarly, Childs et al. (2008) used this approach to probe consumer perception of whey and soy proteins in meal replacement products. Kim et al. (2013) identified desirable package claims for chocolate milk and Oltman et al. (2015) identified key consumer attributes for protein beverages.

20.2.4.2 Qualitative Consumer Tests

The final group of consumer research tools are qualitative instruments. Using these tools, insights into consumer perceptions, needs, and desires can be probed for product development, advertising, and development of quantitative screeners and questionnaires. The primary tests in this group are the *focus group* and the *interview*. Focus groups are a qualitative research tool where an experienced moderator leads a group of 8–12 participants through a guided discussion. The conversation typically lasts for 1.5–2 h. The session is tape-recorded or video-taped or external individuals may observe the session and record common themes. A *focus panel* is similar except that the participants know each other and participate in these group sessions regularly. The potential advantage of the focus panel over a focus group is that you have a group of consumers that are familiar with each other as well as the focus group process and potentially more ground can be covered and more group interaction achieved.

Subjective information about product attributes, preferences, and motivations can be gained in this manner (Lawless & Heymann, 2010a; Meilgaard et al., 2016; Kreuger & Casey, 2000), and this tool is widely used in market research. Focus groups have been used in various food studies examining a number of issues including food preference, safety, and usage (Cotunga & Vickery, 2004; Sherlock & Labuzza, 1992; McNeill et al., 2000; Kosa et al., 2004; Boon et al., 2005; Keim et al., 1999; Jo et al., 2018; Speight et al., 2019; Rizzo et al., 2020). Optimally, a focus group is conducted in triplicate with a target sampling of consumers. Common themes and consensus opinions should be consistent among the three groups (similar to replications) in order for the results to be considered sound or valid (Kreuger & Casey, 2000). The interview tool is conducted similarly except that it is generally a one-on-one exercise. Although more time-consuming, more personal or detailed information may be obtained in this manner. Because these tools are qualitative in nature and generally low numbers of consumers are polled, results must be interpreted with caution. Ideally, a quantitative test would be conducted as a follow-up to confirm or expand findings.

20.3 Common Misuses and Abuses of Sensory Tools

Sensory analysis is often written-off by individuals and companies as a subjective or hit-or-miss tool due to unsatisfactory results. Generally, the source of said dissatisfaction is ignorance of the array of sensory analysis tools, which results in selection of the wrong tool/test or misuse of the right tool. The following represent some common mistakes and misuses of sensory analysis:

1. Trained panel results not replicated – The trained sensory panel is an analytical instrument. As with any instrument, results are replicated to ensure reproducibility. This means that each panelist must evaluate each sample a minimum of twice. In some cases, more replications are conducted by each panelist. More replications are generally conducted when there are very small differences between samples, when the panel is not highly trained, or when the nature of the modality or parameter measured is variable or fatiguing.
2. The sensory language used is not defined or referenced. A well-defined sensory language is crucial not only to have a sensitive and reproducible panel but also for interpretation and/or replication of the results or for establishing relationships with consumer liking or instrumental measurements. A given word can mean different things to different people. It is crucial to define lexicon terms (Drake & Civille, 2003; Foegeding & Drake, 2007).
3. Dairy judges are used in place of analytical or affective sensory testing. Dairy judging was designed historically to provide a rapid measurement of general quality based on predetermined (and common at the time) defects. It was not designed to be an analytical research tool. The defects and their intensities are not well defined, and thus quite variable and difficult to reproduce. Point deductions from quality are not equivalent for different defects and parametric statistics are not possible. Defects are not necessarily objectionable to the consumer and the quality score generated does not necessarily have any relevance to consumer acceptance. Only predetermined defects are scored, not the entire flavor or texture profile of the product, as would be the case with descriptive analysis. The net result is that little relevant information to a research or marketing project or objective is obtained. The solution is to select a modern sensory test appropriate for the research or marketing objective.
4. A trained panel is used to measure liking, acceptance, or preference. Once panelists are trained to identify and quantify attributes in products (or grades and defects such as with product judging), they are no longer typical consumers. As such, what they like or prefer generally is no longer relevant or comparable to those of the average consumer. A further issue addressed below is that a minimum of 50 consumers is needed to determine preference or acceptance of a product with any degree of certainty.
5. Low numbers of individuals are used for consumer testing. When preference or acceptance (liking) tests are conducted, the objective is to determine or infer consumer liking or preference. Consumers, by their very nature, are highly variable based on product usage, geographical location, ethnicity, nationality, etc. As

such, a large number of measurements are necessary to have any degree of confidence in the results. Testing with 100–500 consumers at multiple locations is conducted by large companies seeking to make sound market decisions. Obviously, research studies do not always have the luxury, due to finances or simply available samples, of testing large numbers of consumers. However, it is widely agreed that a minimum of 50 consumers of the product, and in recent years, a minimum of 75–100 consumers of the product, should be polled to make sound conclusions regarding liking or preference (Lawless & Heymann, 2010a).

6. "Industry does it, so it must be okay." This statement is widely used as a fail-safe excuse for any manner of mistakes. This is an invalid issue for several reasons from the old jump-off-the-bridge adage to the issue that not all companies conduct sound product development and research, much less sound sensory analysis. The largest and most successful food (and nonfood) companies have large sensory and market research divisions and/or make use of any of a large number of sensory consulting firms. Clearly, much attention is given to appropriate selection of sensory tools/tests and appropriate use of the selected tools.

20.4 Conclusion

Sensory quality is the ultimate measure of product quality and success. Modern sensory analysis comprises a wide variety of powerful and sensitive tools to measure human responses to foods. Selection of the appropriate test, appropriate test conditions, and data analysis results in reproducible, powerful, and relevant results. Knowledge of product variability, stability, comparison to competitor product(s), relationships to instrumental analyses, and consumer understanding are all requirements for a successful food product or beverage. Application of appropriate sensory analysis is the only set of techniques that can provide the answers to all of these questions.

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Appendices

Appendix A. Preparation of Samples for Instructing Students and Staff in Dairy Product Evaluation

A glossary of descriptive terms that help convey the sensory attributes or defects known to occur in dairy products is an invaluable tool for communication between food technologists or to "prime the pump" so that the learning curve for students or trainees may be shortened. But nothing can substitute for actually experiencing the attributes with our own senses. And while some attributes may be found reliably in just about any dairy case, instructors will find it helpful to actually provide students with examples of dairy products that possess the attributes described within the context of the dairy product's natural sensory matrix.

A.1 Milk

Since milk provides the basis for all dairy products and happens to be the most subtly and delicately flavored dairy product (and ingredient), it makes the natural medium for introducing off-flavors or attributes to the student of dairy foods sensory evaluation. Milk has the additional merit that the imparting of "sought" attributes to it requires nothing more than the simplest "doctoring" step, with no time-consuming product manufacture required.

Currently, all milk samples for the Collegiate Dairy Products Evaluation Contest are 2% milk, so training should begin with 2% milk. The ideal first step is to find an example of milk worthy of a "10" on the scorecard. But this can be difficult, as the subtle flavor matrix of milk cannot hide even slight imperfections and defect-free milk is quite rare. This qualification immediately excludes two of the more common examples of milk found in the dairy case, ultra-pasteurized milk (cooked) and milk marketed in plastic jugs (light oxidized). It is also important to note that milk

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packaged in paperboard (gabletop) cartons frequently is also subject to flavor defects (cardboard flavor, refrigerator/stale, lacks freshness). Ideally, high temperature short time (HTST) pasteurized milk packaged in amber glass or in a large volume (e.g., bag in box) that has been shielded from light is most likely to have an "ideal" flavor profile.

The instructor may find it useful to adulterate milk samples to the intensity level of "pronounced" (Table A.1) for the introductory student and then reduce this concentration once the student's palate has been trained to identify the given attribute.

A.2 Ice Cream

Ice cream judging involves the evaluation of body and texture as well as flavor. Initially, the instructor will find it useful to try to isolate the flavor attributes from the texture attributes. Beginning students frequently find that the coldness of ice cream numbs the palate, and this may pose as an obstacle to mastering some of the subtleties of most effectively sorting out and evaluating the body and texture features of this frozen product. Consequently, introducing flavor attributes to students by means of using unfrozen ice cream mix is most helpful (Table A.2). The basic mix described provides a suitable foundation for highlighting or focusing on flavor attributes.

Basic Mix Recipe A basic mix can be made to contain a standard fat level (12% fat), low sweeteness (10% sugar, 4% high fructose corn syrup), and a low intensity of vanilla flavor by combining 620 g whole milk, 180 g heavy cream, 60 g sugar, 25 g corn syrup solids (CSS) or 25 mL high fructose corn syrup (HFCS), and 0.5 mL vanilla extract. Alternatively, 800 g light cream can be blended with 60 g of sugar, 25 g CSS or 25 g HFCS and 0.5 g vanilla extract.

Care must be taken when presenting ice cream purchased at the store for student evaluation, as not only must the brand name be concealed but possibly even the shape of the carton. By ice cream industry marketing trends, cylindrical cartons have primarily become associated with "premium" ice creams, while straight-edged, rectangular, or the occasional square cartons are more commonly viewed or associated with the so-called "economy" brands. These visual cues lead to bias.

For unbiased judgment, it is best to transfer ice creams from their original retail containers into plain, white "deli" cartons for students to sample. This must be done with care, as forcibly pressing the ice cream into the container will alter the ice cream's body and texture. However, a simpler approach for maintaining anonymity is to pre-dip the ice creams from the original containers onto heavy-duty paper or plastic plates and cover with plastic wrap within 1–2 h of the sensory training session. This approach also has the advantage of minimizing heat exposure to the ice cream samples.

Table A.1 Recipes (per ~600 mL) for producing off-flavors in milk

Off-flavor	Procedure for producing the sought off-flavor
Acid (sour)	Add about 2% volume of cultured buttermilk to fresh milk. Please note that diacetyl present in most commercial buttermilk may be confusing to new tasters. Alternatively, add 6–7 mL of a 10% lactic acid or a 0.5% citric acid solution to the milk
Bitter	Add 2–2.5 mL of a 0.1% quinine sulfate solution milk, which will yield milk with a bitter taste within the range of "pronounced"
Cooked	Cooked milk samples can easily be found within most store dairy cases. Ultra-pasteurized milk will typically exhibit a pronounced cooked flavor. Note that certified organic milk (often ultrapasteurized) will likely *also* have the "feed" flavor. Conventionally HTST pasteurized milk will often exhibit a slightly cooked flavor A cooked flavor may be produced by heating a working quantity of milk in a vessel to 80 °C (176 °F) and holding for 1 min. Be aware that elements of the cooked attribute are volatile and will evaporate shortly after the container is opened
Feed	Adding 4–7 mL of a prepared "tea" (from brewing alfalfa or timothy hay in water) to milk will impart a pronounced feed flavor on the milk. An expanded intensity range is a result of variability in the strength quantity of the tea Most "grass-fed" and certified organic milk varieties will manifest the feed flavor. However, they often also exhibit the "cooked" flavor as well (because they are commonly ultrapasteurized) Concentrate grain, distillers grain, molasses, and silage-related feed flavors may also be encountered in milk. They exhibit more sweet than grassy notes
Flat	Add about 20% water to 2% milk An alternative is to serve nonfat or skim milk and compare it to 2% fat milk
Foreign/ chemical	Add about 2 mL of a 200 ppm chlorine solution to the milk immediately before presenting to the student. This off-flavor does not remain "stable," so it cannot be prepared far ahead of time Foreign is anything that should not be present in 2% milk, so addition of a flavoring (e.g., vanilla) is another good example of foreign Serving lactose-free milk (enzyme-modified) is another option since the sweetness is intensified Serving milk with DHA or fish oil are other alternatives
Fruity/ fermented	The fruity/fermented defect can be closely approximated by using a mixture of six parts pineapple juice (fruity) and one part vinegar (fermented). Add 3–4 mL of this mixture to the milk to yield a pronounced defect Add 1 mL of a 1% stock solution of food-grade ethyl hexanoate to the milk
Garlic/ onion	Add 2 mL of a 1% garlic powder (or 1% garlic or onion juice) mix (in water) to the milk Add a clove of garlic to infuse for about 2 h; then either decant the milk or retrieve the clove using sanitized cheesecloth or a coffee filter
Lacks freshness	Open a carton of milk and store in the refrigerator for ≥7 days, or alternatively, use an unopened carton of milk that is 1 week beyond the pull date The lacks freshness attribute may be approximated by adding 10–15 g of skim milk powder to the milk

(continued)

Table A.1 (continued)

Off-flavor	Procedure for producing the sought off-flavor
Light oxidized	Examples of light-oxidized milk can usually be purchased right off the grocery store shelf. Exposing milk in transparent and/or translucent plastic jugs to fluorescent lighting or sunlight will quickly produce light-oxidized milk (15–30 min) Milk can be transferred into a clear glass milk bottle and placed on a windowsill exposed to direct, bright sunlight for the following results: (1) 7–10 min = slight intensity; (2) 10–15 min = definite, and (3) 15–10 min = pronounced
Malty	Add 1–3 g of malted milk powder to warm milk and swirl until thoroughly dissolved. Add this mixture to the milk Use an extract of Grape Nuts® cereal (add 15 g Grape Nuts® to 100 mL of milk and allow the flavor to infuse for 20–30 min). Then decant or filter out cereal bits, and add ~10,~20, and~ 30 mL aliquots to each volume of milk to produce a range of intensities (i.e., slight, definite, and pronounced) of malty milk
Metal oxidized	Immerse a sanitized copper penny or a copper wire in milk overnight About 8–12 h before use, add one or two drops of a 1% solution of copper sulfate to milk and leave in a refrigerator. This attribute takes about 4–8 h to develop
Rancid	Add ~0.5 g of lipase powder to milk, agitate and hold at 21 °C (70 °F) for an hour Add ~20 mg lipase to the same volume of milk and store at refrigerator temperature for ~48 h A quick resort technique is the addition of a few drops of a dilute solution of butyric acid to milk
Salty	Dissolve 0.25–0.5 g of table salt into 600 mL of milk
Unclean (spoiled)	Combine rancid, fruity, and bitter milks. Most commercial milks will eventually become naturally “spoiled” or unclean (≥7–10 days beyond the sell-by date). Small quantities of such “out-of-date” samples can then be used to “doctor” fresh milk to simulate a range of intensities of the unclean defect. Additionally, the source of “lacks freshness” milk examples can be left in extended storage for an additional 1–2 weeks – which will generally evolve into the unclean or spoilage stage of milk deterioration

A.3 Butter

As previously noted in Chap. 6, butter making automation has sufficed to improve both the quality and the uniformity of butter. Currently, many of the attributes listed on the USDA scorecard are encountered only infrequently, if at all, in North American butter. Even when observed, the beginning student will find that many of these butter attributes are actually too delicate to detect or identify. The instructor will therefore find it helpful to hand-make or purposely adulterate stock butters purchased directly from either butter manufacturers or retail sources (Table A.3).

Since butter is relatively easy to prepare in the laboratory or kitchen setting, other attributes may be introduced by simply manufacturing butter from adulterated cream. Butter exhibiting the “cheesy” or “old ingredient” attribute may be produced by churning expired or “treated” cream in a countertop kitchen mixer. Similarly, acid, bitter, feed, scorched (cooked), etc. “defects,” may be produced by adulterating the cream as described for milk in Table A.1 and churning that cream into butter.

Table A.2 Recipes for off-flavors in ice cream mix (standard mix is composed of 620 g whole milk, 180 g heavy cream, 60 g sugar, and 0.5 g vanilla extract)

Off-flavor	Procedure for producing off-flavor
Acid	Add 10 mL of buttermilk to 200 mL of the basic mix
Cooked	Heat basic mix in a double boiler to 80 °C (176 °F) for 15 min. Filter through sanitized cheesecloth if any particles or chunks result
High flavor	Add 1 mL vanilla extract to 200 mL of basic mix
High sweetness	Add 5–7.5 g of sugar to 200 mL of basic mix, depending on intensity desired
Low sweetness	Use the basic mix to illustrate
Lacks fine flavor	Add 25 mL whole milk to 200 mL basic mix
Low flavoring	Use the basic mix
Old ingredient	Add up to 10 g of “old” (aka >12 months old) skim milk powder (NFDM) to 200 mL of basic mix. This amount of skim milk powder addition should be approached carefully since the flavor character of long-stored skim milk powder deteriorates with age; thus the age and flavor character of the skim milk powder must be carefully considered. In fact, the flavor of long-stored NFDM (>9–12 months) can be quite overpowering. As little as 1 g of aged NFDM added to 200 mL of mix might be more than enough for some dry milk powder sources
Oxidized	Utilize light-oxidized or metal oxidized milk (see Table A.1) or cream as the base
Salty	Add 1 g of table salt to 200 mL basic mix
Syrup flavor	Add 5–10 g of HFCS to 200 mL basic mix, depending on intensity desired
Whey	Add 10 g of whey powder to 200 mL basic mix

A.4 Cottage Cheese

Unlike butter, automated approaches to cottage cheese manufacture have not particularly improved cottage cheese in terms of either quality or uniformity (Rosenberg et al., 1994). There are few attributes listed on the Collegiate Dairy Products Evaluation Contest scorecard that are not found routinely in cottage cheeses conveniently purchased at either the supermarket, neighborhood grocery store, or the specialty or organic food store. Nevertheless, commercial cottage cheese samples may be easily adulterated to highlight specific attributes for student instruction (Table A.4).

Regarding the appearance, color, and/or body and texture attributes of creamed cottage cheese, most of them can be observed in commercial products.

Cottage cheese is presented in two forms to student contestants: it must be judged on a plate (untouched) and evaluated in the mouth.

The appearance attributes “free whey” and “free cream” are easily produced within the laboratory if not readily found in commercial products. Free cream may

Table A.3 Recipes for off-flavors in butter

Off-flavor	Procedure for producing off-flavor
Feed	Certified organic butter or butter made from cream from "grass-fed" cows will exhibit feed flavor. Kerrygold butter commonly has a feed flavor
Garlic/onion	Store a stick of butter in a closed container with a clove of garlic for ~6 h. Remove the garlic, re-close the container and refrigerate the butter and allow time for the garlic aroma to penetrate the butter's center mass
Musty	Store the butter in a closed container beside an agar slant of the yeast microorganism *Streptomyces odorifer*
Oxidized	Store aliquot sticks of butter, lightly wrapped in paper, in a refrigerator for several weeks to a month. The surface of the butter will undergo oxidization and the distinct off-flavor will, in time, diffuse into the butter's interior, although most of the oxidized flavor will be surface concentrated
Rancid	Place a stick of butter in a closed container with a small jar containing butyric acid for about 6 h. Remove the butyric acid, re-seal the container and permit the butyric acid to equilibrate throughout the butter for a week or more Alternatively, butter may be stored for a few days in an enclosed container with a slice of Asiago or Romano cheese
Storage	Select grocery store "house brand" butters to either refrigerate for 4–6 months or freeze for 8–12+ months, and then examine for a range of storage-like flavors
Whey	"Whey butter" may not often be available in many parts of the United States or Canada under that label. However, it can occasionally be found in specialty food stores, neighborhood grocery stores, or online. It may be labeled as "Old Fashioned" butter

be replicated by simply spooning enough cream onto the curd on the plate to create a so-called cream halo of varying intensities (slight, definite, or pronounced).

The free whey defect can be simulated by removing enough cottage cheese from the container such that a moderate well is formed. The container with the remaining cottage cheese is returned to the refrigerator for a day or two. Typically, whey will seep into the formed space and this liquid exudate may be spooned onto the observation plate, which will form a greenish-yellow thin liquid around the curds (Fig. A.1). Alternatively, pineapple juice can be used to simulate the appearance of free whey on a plate. Pineapple juice is also good at replicating the fruity off-flavor. Combining pineapple juice with vinegar works well for fruity/fermented and free whey.

Per all products used as "demonstration" samples, care should be taken to not prejudice students by directly revealing the brand name of the various products evaluated. Cottage cheese needs to be removed from its original container or else the label should be entirely obscured (Fig. A.2).

A.5 Yogurt

Unless you have the facilities and are comfortable with yogurt making, you will be best served by surveying the yogurts available in your area and identifying those with distinct and repeatable sensory attributes.

Table A.4 Recipes for off-flavors in cottage cheese

Off-flavor	Procedure for producing off flavor
Bitter	Add 2–3 mL 0.1% quinine sulfate to a pint of cottage cheese to yield a pronounced bitter taste.
Cooked	Heat ingredients to be used for dressing to 80 °C (176 °F) for 15 min in a double boiler Add 5–7 mL shelf-stable (UHT) milk to the creamed curds
Fruity/ fermented	The fruity/fermented defect can be closely approximated by using a mixture of six parts pineapple juice and one part vinegar. Add 3–4 mL of this mixture per pint of cottage cheese
High acid	Add approximately 2% buttermilk to a pint of cottage cheese Titrate cottage cheese to the desired acidity by using a 10% lactic acid solution
High diacetyl	Add sufficient diacetyl to a pint of cottage cheese to achieve a concentration of approximately 0.01%. As an advisory, diacetyl in water solution (~5–10%) should be easier "to control" the sought range of diacetyl intensities, than the use of the pure compound. (The pure compound should be handled with the greatest care, with appropriate personal protective equipment, under a fume hood as degenerative pulmonary diseases have been linked to chronic exposure to diacetyl)
Rancid	Treat cottage cheese with 0.5 g of lipase per pint and allow it to react at room temperature for an hour or in the refrigerator for 24–48 h Alternatively, for "last-minute preparation," finely ground Romano, Cotija or Kasseri cheese can be incorporated into the cheese sample to simulate rancidity
Salty	Add 0.5 g of table salt per pint
Unclean (spoilage)	Store commercial cottage cheese samples for 7–14 days beyond the sell-by date. Use these samples directly; or alternately, use sample portions to "doctor" fresher products to simulate the spoiled consequence of aging product. Alternatively, blend bitter, fruity/fermented, and rancid examples together
Whey	Acquire sweet liquid whey from a hard cheese manufacturer and use to "doctor" cottage cheese samples "to taste" Alternatively, add reconstituted (1:9 dilution) whey powder to achieve the desired whey flavor intensity
Yeasty	Add baker's yeast to cream dressing and hold at room temperature overnight, and then add the "treated" dressing to dry cottage cheese curds

Yogurt is presented for evaluation in three forms. First, yogurt must be presented in its original cup so that the evaluator may look for the "free whey" and "shrunken" attribute. No other attribute may be judged in the cup.

Secondly, the yogurt must be judged on a plate for "atypical color," "color leaching," "excess fruit," "lacks fruit," and "lumpy ".

Finally, a third container should be provided for the students to evaluate in the mouth.

Of all the attributes listed on the scorecard, only the free whey attribute may be easily replicated by the instructor or judge. This is achieved by simply dripping water onto the surface of the yogurt in the cup used for judging free whey or shrunken.

As with other products, you will need to conceal the brand name of the yogurt from your students to preempt preconceptions. This is a particular problem with yogurt, as its appearance is judged while in its original container. The most

Fig. A.1 Creating an observation plate of cottage cheese that exhibits "free whey"

Fig. A.2 Cottage cheese prepared for tasting by transfer to a secondary container

convenient solution is to save empty containers and wrap them with either aluminum foil or duct tape, then drop the container to be judged into the container you have obscured (Fig. A.3).

To present the yogurt on the plate for visual evaluation, it is best to disturb the curd as little as possible, and in a manner that can be easily replicated. Inverting the container and puncturing the bottom releases the yogurt onto the plate without breaking the curd (Fig. A.4). The curd that releases should then be cut into quarters and allowed to fall away in a manner that reveals the yogurt's body.

Fig. A.3 Yogurt placed inside taped container to conceal brand

A.6 Cheddar Cheese

It is difficult to adulterate cheddar cheese for taste/flavor and body/texture. However, gassy (tiny eyes or slits) and open (jagged openings) might be creatively reproduced in visual plugs. Usually, an assortment of cheddar cheese brands and varied degrees of aging (maturing) can be purchased within the local marketplace (e.g., supermarkets, grocery stores, delicatessens, cheese markets (shops)), out-of-state mail order/online supply businesses, and/or direct order from the sales departments of larger-sized cheese manufacturers and cooperatives. Some Collegiate team coaches have been known to purchase cheddar cheese samples (as well as other dairy product samples, with the exception of ice cream) when traveling out of state, in order to expand student (team members) exposure to a "much wider set" of product attributes from other marketplaces.

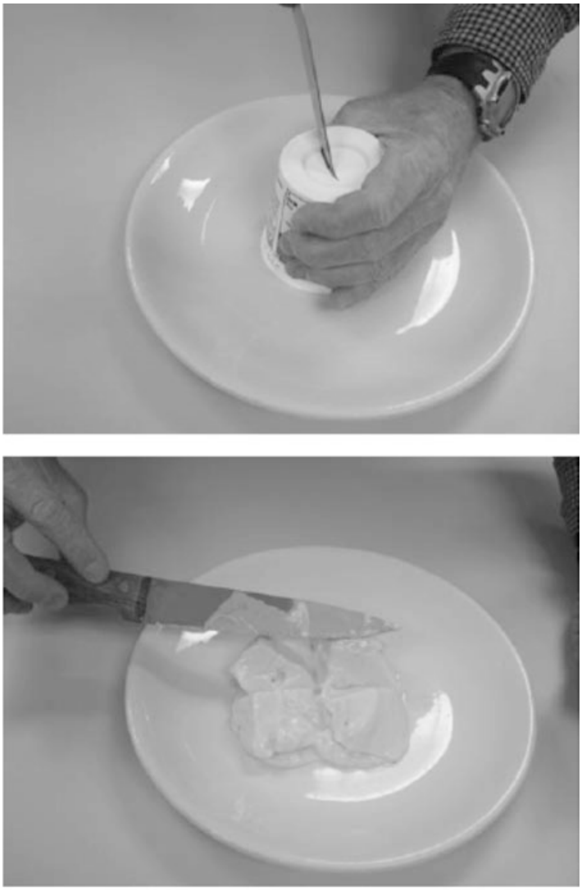

Fig. A.4 Preparing yogurt for visual evaluation on the plate

Appendix B. Resources

The following names and addresses and websites are included to enable the reader to quickly access organizations that are involved in assessing, regulating, understanding, or promoting dairy products.

Agricultural Marketing Service (AMS): http://www.ams.usda.gov

American Dairy Science Association (ADSA): 1111 B, Dunlap Avenue Savoy, IL 61874 217-356-5146 http://www.adsa.org

Center for Food Safety and Applied Nutrition: 5100 Paint Branch Parkway College Park, MD 20740-3835 https://www.fda.gov/about-fda/fda-organization/center-food-safety-and-applied-nutrition-cfsan

Centers for Disease Control and Prevention (CDC): 1600 Clifton Road Atlanta, GA 30333 1-800-311-3435 https://www.cdc.gov/

Code of Federal Regulations, Electronic (CFR): https://www.ecfr.gov/cgi-bin/ECFR?page=browse
Collegiate Dairy Products Evaluation Contest (CDPEC): https://www.dairyproductscontest.org/
Dairy Management, Inc.: https://www.usdairy.com/
Department of Health and Human Services (HHS): 200 Independence Avenue, S.W. Washington, DC 20201 https://www.hhs.gov/
Food Processing Suppliers Association (FPSA): 1451 Dolley Madison Blvd., Suite 200 McLean, VA 22101 http://www.fpsa.org
Institute of Food Technologists (IFT): 525 W. Van Buren, Suite 1000 Chicago, IL 60607 312-782-8424 https://www.ift.org/
International Dairy Foods Association (IDFA): 1250 H Street, N.W., Suite 900 Washington, DC 20005 202-737-4332 https://www.idfa.org/resource-links
National Conference on Interstate Milk Shipments: 123 Buena Vista Drive Frankfort, KY 40601 502-695-0253 https://ncims.org/
National Dairy Council: https://www.usdairy.com/about-us/national-dairy-council
National Dairy Shrine: https://www.dairyshrine.org/
National Milk Producers Federation: https://www.nmpf.org/
Pasteurized Milk Ordinance (PMO): https://www.fda.gov/media/114169/download
U.S. Dairy Export Council (USDEC): https://blog.usdec.org/usdairyexporter/us-dairy-exports-hit-all-time-record-in-march-0?_ga=2.109036802.1404793352.1620699825-432021467.1620150806
U.S. Food and Drug Administration (FDA): 5600 Fishers Lane Rockville, MD 20857-0001 1-800-463-6332 https://www.fda.gov/
U.S. Public Health Service (PHS): https://www.usphs.gov/

Reference

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