THE SENSORY EVALUATION OF DAIRY PRODUCTS

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SECOND EDITION

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Second edition

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Preface

Cheese blocks are prepared for sensory assessment by graders at anAmerican Cheese Society Cheese Competition

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. The previous edition of *The Sensory Evaluation of Dairy Products,* published in 1988, has served as the primary reference on the topic until now. The first three editions of this book were published in 1934, 1948 and 1965, under the title *Judging Dairy Products*. We are pleased to present this newest edition to be (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.

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.

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 competent flavor evaluation of all dairy ingredients. Based upon sensory judgments, occasionally some milk, cream or other dairy ingredients may merit rejection. An important premise of the dairy industry is *dairy products quality can be only as good as the raw materials from which they are made*.

Technical and esthetic judges evaluate a variety of cheeses at a recent American Cheese Society Cheese Competition

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 de-emphasized 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 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 1988.

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 16 cover the sensory evaluation of several dairy products not included in the collegiate contest, but that are most assuredly evaluated in plants and may be judged at other various dairy products 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. The other products covered include concentrated and dry milk and whey, pasteurized process cheese and related products, sour cream and related products, Swiss cheese and related cheeses, Mozzarella and Hispanic cheeses. Chapter 17 is devoted to modern sensory evaluation practices, including an overview of modern affective and analytical sensory tests, as well as the application of sensory languages (such as the Cheddar cheese lexicon) to scientific and market research. An appendix section guides coaches or instructors through the preparation of samples and provides an overview of sensory panel methods.

In preparing this edition of *The Sensory Evaluation of Dairy Products*, authors from industry and academia have applied their philosophy and instructional techniques to convey their expertise at describing sensory 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 and Canada. For instance, cottage cheese curds that may be evaluated as "firm/rubbery" are familiar and desirable to consumers on the U.S. 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 U.S. 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. Ideally, definitions of attributes should not deviate from one coast to another. Furthermore, 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.

Quality in the eyes of official judges does not necessarily guarantee success in the marketplace

Many dairy products are defined in the U.S. 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 CFRs may occur at any time, only the latest edition of this official document should be consulted for purposes of legal compliance.

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.

Modern sensory analysis commonly relies on private sensory evaluation booths and computer software

The editors gratefully acknowledge the technical and creditable contributions by our chapter authors. Without their outstanding efforts and dedication to the field of the sensory evaluation of dairy foods, this book would not be complete. We also recognize the following individuals for their outstanding efforts and assistance in preparing this book by reviewing certain chapters: Rosyleen Aquino, Susan Duncan, Charlsia Fortner, Lisbeth Goddik, Jonathan Hopkinson, Luis A. Jimenez-Maroto, Robert T. Marshall, Tonya Schoenfuss and Bruce Tharp.

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 (1921–present; University of Illinois) and Dr. G.M. Trout, which has well-served many needs of dairy sensory scientists for two decades. May our newest volume serve you well as you contribute to the field of dairy sensory science.

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Chapter 1
History of Sensory Analysis

Mary Anne Drake, Stephenie Drake, Floyd Bodyfelt, Stephanie Clark, and Michael Costello

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., 1999). U.S. 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., 2008; Trout et al., 1981), and the original dairy products evaluation textbook (Nelson and Trout, 1964) was published in 1934. In the 1940s, the triangle difference test was developed in Scandinavia (Bengtsson and Helm, 1946; Helm and Trolle, 1946).

Sensory analysis became a focus of attention to the U.S. 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 U.S. government failed to conduct sensory evaluations on foods developed for malnourished people in several countries – the foods at issue were often rejected (Stone and Sidel, 2004). The food industry was quick to adopt

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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 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 U.S. 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
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
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 IV
1982	ISO 5492 Sensory analysis – vocabulary – Part V
1978	ISO 5492 Sensory analysis – apparatus – tasting glass for liquid product
1983	ISO 5495 Sensory analysis – methodology – paired comparison test
1988	First edition of *The Sensory Evaluation of Dairy Products* (Bodyfelt et al.) published
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)).
2008	Second edition of *The Sensory Evaluation of Dairy Products* (Clark, Costello, Drake, and Bodyfelt) published

sensory evaluation, quite possibly as a result of both the government's successes and most notable failures (Stone and 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 pace-setting food products and beverages.

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

One of the first tools developed for the instrumental evaluation of dairy products 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 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 and Simmonds, 1995; Ampuero and Bosset, 2003 and 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 and 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., 1956), sour cream and buttermilk (Lindsay, 1967; Law, 1981), butter and cultured butter (Stark and Forss, 1966), Cheddar (Marth, 1963; Morris et al., 1966; Day, 1967), Swiss (Langler et al., 1966), and blue cheeses (Anderson and 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, 1970b, 1976). The research area of flavor chemistry (identification of volatile and non-volatile 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. Sensory evaluation, alone or in combination with 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 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 sub-discipline 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 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

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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) difference tests, (2) ratings, and (3) thresholds. 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., 1999). 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 base 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. Fechner (1860) further refined the relationship between stimulus and response:

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

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

Stevens (1957) described 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. (1999). 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 3-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 hand-writing, 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 and Noble, 1993; Frank et al., 1989; Murphy and 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; Johnson and Clydesdale, 1982; Johnson et al., 1983 Norton and Johnson, 1987; Teerling, 1992). 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). 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.

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 and 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 and 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

Carolyn F. Ross

3.1 Introduction

Dairy product sensory evaluation includes the critical examination and interpretation of important sensory attributes of the given product. Examples are the observation 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 – all of the aforementioned are components of sensory evaluation.

Humans possess and utilize five primary senses for perceiving stimuli: sight, hearing, touch, taste and smell. Of these human senses, taste, smell and chemical/pain sense respond to chemical stimuli, with taste and smell considered to be the most primitive (Brown and Deffenbacher, 1979). Other human senses include temperature sensation (heat and cold), pain, visceral hunger, thirst, fatigue and balance. Consumption and appreciation, the study of their physiology and human reaction to stimuli is fundamental to sensory evaluation.

This chapter will commence with a general discussion of sensory attributes and perceptions. A more detailed discussion of physiology involved in sensory perception will follow, beginning with vision and concluding with chemesthesis (chemical mouthfeel). The final section will describe the sensory evaluation of dairy products.

3.2 Perception of Sensory Attributes

Our perception of the environment, including food, is through specialized sense organs, or sensory receptors. The eyes are used for determining appearance and color, the nose for the sense of smell, the tongue for taste, skin for touch and the ear for any possible sound effect. Stimuli are defined as factors from the

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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). When we perceive a stimulus, our response does not occur as a one-step process. The chain of sensory perception has been described as follows (Schiffman, 1996):

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

In this scheme, a stimulus generates a response via nerve signal to the brain. 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 nerve's electrical discharge; the higher the frequency, the stronger the sensation. All human sensory receptors vary in their sensitivity to stimuli (Amerine et al., 1965; Schmidt, 1981).

Sensory perception may be divided into either an objective or a subjective response. An objective response measures the intensity of both the stimulus and the sensation. The objective response arises from the relationship and physiological response of the central nervous system, which is a physical or chemical reaction within individuals. By contrast, the subjective response arises from the statements, either verbal or written, that the individual makes about the sensations that he/she perceives. In this chapter, the objective response of sensory perception will be emphasized.

3.3 Sensory Perception

The sensory perception of a food is not a simple process inasmuch as individuals are bombarded by a number of overlapping sensory attributes when a food or beverage is first approached. Generally, the appearance aspects of the food are first noticed, since this can be perceived quickly and non-invasively. The observation step is typically followed by ortho-nasal perception of the odor or aroma of the food. Upon ingestion of the food, retro-nasal (in-nose) perception of the aroma continues, as well as perception of the food's consistency and texture, taste, aroma and possibly sound. All of these attributes help us determine the quality of the food that is being consumed, which influences our enjoyment of the food. Each of these attributes will be briefly discussed below.

Food or beverage appearance is a critical feature as it is often the first attribute perceived by a consumer and serves as a primary deciding factor in so many purchasing decisions (McDougall, 1983). Appearance is composed of a number of characteristics of the food, including color, size and shape, surface texture, clarity and carbonation level. From *Spectrum Terminology* (Meilgaard et al., 2007), the terms used to describe color are

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

All of the above-listed factors combined suffice to define the evaluation of color of food and beverage products.

Odor or aroma is attributable to our 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 in order to perceive a taste solution.

Upon ingestion of a food, the sensors in the mouth detect food texture and consistency. Texture is a complex term and is defined by the structure of the food product. Components of texture include mechanical properties (including hardness, cohesiveness, adhesiveness, denseness and chewiness), geometrical properties (smooth, gritty, grainy, chalky and lumpy) and moisture properties (juicy, oily or greasy). Related to texture is the noise produced by the food product, either during the rupture or the mastication of the food. Within sensory evaluation of foods, measurements of noise include pitch, loudness and persistence of sounds.

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 aromatics released from the food product once in the mouth, the taste sensations (sweet, sour, salty, bitter and umami) released from the soluble substance in the mouth plus the chemical feel factors in the mouth (astringency, cooling, metallic, "spicy heat"). Flavor will be considered as the sum of the total sensory impressions or sensations perceived when a food or beverage is placed in the mouth.

3.4 Physiology of Sensory Perception

The five human senses are thoroughly covered in other textbooks (Piggott, 1984; Amerine et al., 1965) thus the following discussion will strive to provide an overview of the senses and their importance in sensory evaluation. 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. Human sensory reactions associated with stimuli and receptors are shown in Table 3.1.

Table 3.1 Human sensory reactions associated with stimuli and receptors. Modified from Bodyfelt et al. (1988) and Schmidt (1981)

General receptors	Stimulus	Specific receptor	Sensory reaction
1. Chemical receptors	Chemicals	Olfactory cells in uppermost portion of nasal cavity	
Gustatory	Soluble substances	Taste buds	Tastes
Olfactory	Volatile compounds	Olfactory mucosa	Odors
2. Somesthetic (body) receptors	1. Temperature changes	Cells in skin	Warmth, coldness,
	2. Mechanical	Cells in skin	Touch (light pressing)
	3. Extreme energy (i.e., intense heat, laser, etc.)	Free nerve endings	Pain
Cutaneous	Mechanical thermal energy	Skin – specialized and free nerve endings	Pressure, pain cold
Kinesthetic	Mechanical pressure	Cells in tendons, muscles and points	Active movement, weight, deep pressure
Vestibular (static)	Head movement (rectilinear or rotary)	Cells in semicircular canals and vestibule	Equilibrium (balance)
Organic	Chemical or mechanical action	Cells in visera	Pressure, visceral disturbance (i.e., hunger, nausea)
3. Distance receptors			
Visual	Radiant energy wavelength 10^{-4}–10^{-0} cm (light waves)	Rods and cones of the retina	Color, hue, brightness, contrast
Auditory	Mechanical vibrations of frequency of 20–20,000 eps (sound waves)	Hair cells of the organ of Corti	Pitch, loudness

3.4.1 Vision

Of all the human senses, vision has the longest and most persistent investigation into its mechanism. The terms vision and appearance are separated by their definitions. Vision may be regarded as the psychological response to the objective stimulus generated by the physical nature of the object viewed (MacDougall, 1984). Appearance refers to more than just color; it is the recognition and assessment of the properties (surface structure, opacity, color) associated with the object seen.

Vision is perceived through the eye (Fig. 3.1). The eye is virtually spherical, with muscles providing mobility of almost 100°. The retina is described as the

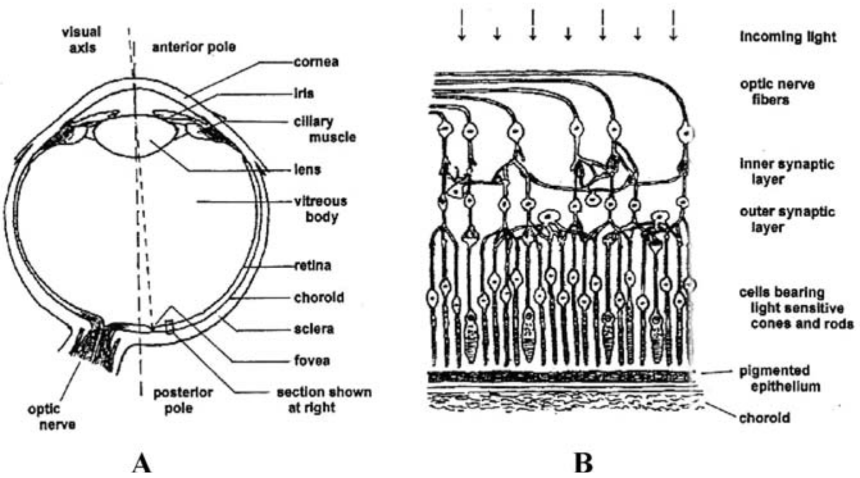

Fig. 3.1 **Part A**: The human eye – including the retina, fovea, lens and optic nerve. **Part B**: The organization of the olfactory system
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innermost lining of the eye and contains light sensitive nerve tissue. During perception, light is either reflected from an object or the light passes through an object, the light then enters the eye and is focused onto a depression in the retina (the fovea). The fovea is approximately 1.5 mm in diameter and is the region where vision is most acute. The fovea is located in a 2–3 mm diameter yellow pigmented area, but the central area of the foveal pit is non-pigmented and free of blood vessels. Located on the fovea are two types of photoreceptor cells, rods and cones. Cones are responsible for detecting color while rods are responsible for low intensity and/or colorless vision. Cones are exclusively and most densely packed in the center of the fovea while the rods increase in density to 20° from the fovea and then decrease toward the periphery of the eye. The rods and cones contain photosensitive pigments that bleach upon exposure to light. The subsequent electrical neural impulse generated travels to the brain via the optic nerve and the brain interprets the signal.

The measurement of appearance, particularly color, is regarded as a two-stage process, composed of a physical stage and a psychological stage. From a physical standpoint, color is defined as the perception that results from the detection of light as it has interacted with an object (Lawless and Heymann, 1999). The perceived color is affected by three factors: (1) 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 and Heymann, 1999). The color of an object can vary in three dimensions: hue (color), lightness (brightness) and saturation (the purity of the color).

Also critical during the physical evaluation of appearance are individual differences reflected in the spectral sensitivity of the viewer's eye. Cone vision is trichromatic and contains three color-sensitive pigments, responding to red, green and blue light. Color blindness results if the individual lacks any of these pigments, with the most common type being red/green color blindness. Color blindness afflicts about 8% males and 0.44% females (Lawless and Heymann, 1999). Therefore, if sensory evaluation activities involve color evaluation, panelists should be screened for color blindness.

Appearance evaluation is accomplished through the psychological step of translating reflectance or transmittance to trichromatic values and then to an appropriate color space. Aside from color, foods and beverages have a large variety of appearance characteristics. Other properties include gloss, transparency, haziness and turbidity. All of these properties can be attributed to the geometric manner in which light is reflected and transmitted.

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

3.4.2 Hearing

It has long been assumed that the sound emitted when certain foods are bitten and chewed are a reflection of the texture of these foods. Although hearing and/or sound is frequently excluded from sensory evaluation panels and ballots, the contribution of this sense to the enjoyment of food and the evaluation of food quality should not be minimized.

Figure 3.2 shows the structure of the human ear. Sound is perceived through the vibrations conducted through the air, which subsequently cause the eardrum to vibrate. Via the small bones in the middle ear, the vibrations are transmitted to create hydraulic motion in the fluid of the cochlea in the inner ear. The cochlea is a spiral canal covered in hair cells. When sympathetically agitated at their individual harmonic frequency, these hair cells send neural impulses to the brain.

Crispness and crunchiness are two noise-producing mechanisms of food, and within each of these categories, differentiation is made into wet and dry foods. Crunchiness and crispiness 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) (Vickers, 1985; Seymour and Hamann,

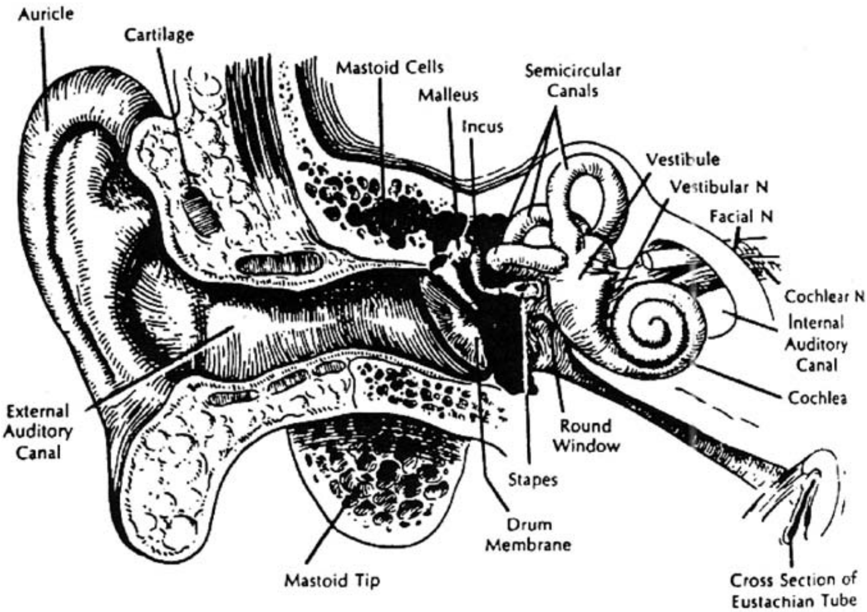

Fig. 3.2 The organization of the human ear
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1988). Crisp foods break in a single stage while crunchy foods break in several successive stages of applied pressure (Szczesniak, 1991). The intensity and pitch of crispiness and crunchiness can be measured in terms of decibels.

3.4.3 Olfaction

Mammals possess an olfactory system of incredible discriminating power and people are known to be able to distinguish among thousands of distinct odors (Amoore, 1970). It is estimated that humans can recognize an estimated 10,000 odors while over 900 genes encode the structure of the olfactory receptors (Young and Trask, 2002). Even odorants with nearly identical structures can elicit different odor perceptions.

Olfactory stimuli contribute a significant proportion of the experience of flavors for the majority of foods. Thus the sensory and hedonic evaluations of most food-related flavors are dependent on olfactory perception. In order to perceive the odor of a chemical compound, the compound must be volatile. The volatility of the compound depends upon its molecular weight and molecular bonding properties. It has been reported that in order for compounds to be perceived via the olfactory system, the upper limit of molecular weight (MW) needs to be within the range of 300 Da or less (Moncrieff, 1967).

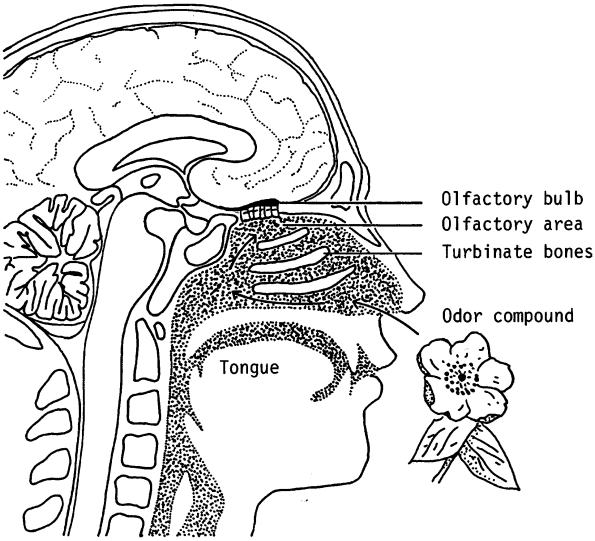

Fig. 3.3 A cross-section view of the head indicating the olfactory area
From: Amoore, J.E. et al. 1964. The stereochemical theory of odor; and Bodyfelt et al., 1988. *Sensory Evaluation of Dairy Products*.Van Nostrand Reinhold, New York. Copyright © 1964 by Scientific American, Inc.

Airborne odorants are sensed by the olfactory system that is located in the nasal cavity (Fig. 3.3). The olfactory receptor area is located in the roof of the nasal cavity and is lined with the olfactory epithelium (Fig. 3.4). The surface of the olfactory epithelium is coated by a layer of mucous and embedded in this

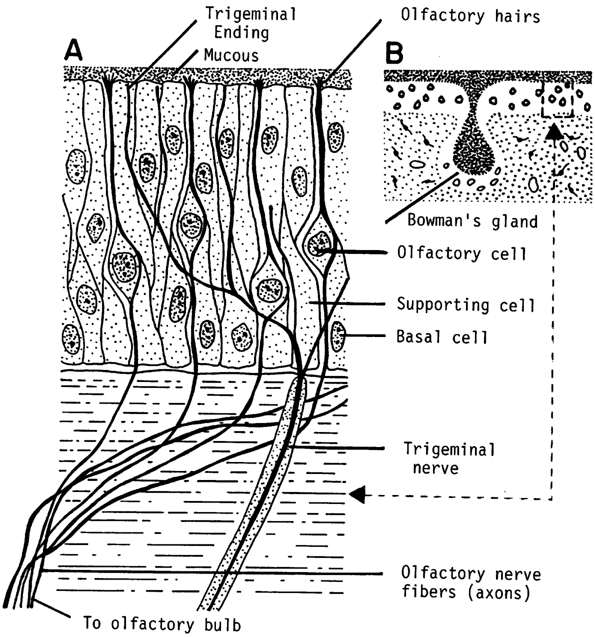

Fig. 3.4 Elements of the human olfactory epithelium. **Part A** – Microscopic diagram of the various cells that compose the olfactory mucosa (epithelium); **Part B** – The mucous membrane in the olfactory region
From: Bodyfelt et al., 1988. *Sensory Evaluation of Dairy Products*.Van Nostrand Reinhold, New York

mucous are several million receptors coated with cilia, or fine hairs. The function of these cilia is to provide a greater surface area for receptors to interact with odorants. The olfactory receptors 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 to the olfactory receptors with the neurons in the olfactory pathway.

In order for the odorants to adsorb to the chemoreceptors in the nose, which is necessary for perception, the odorant must be soluble in the receptor cell membrane and partition from the air into the watery mucous medium. This membrane is composed of lipids, proteins and water and most volatile organic compounds are soluble to some degree in these constituents. Different molecules will partition at varying rates and in various patterns (Lawless and Heymann, 1999). The receptors are broadly tuned in and respond to the specific odorants present.

Numerous theories of odor recognition and perception have been developed over the years. Chemical, physiological and anatomical studies have suggested that the chemical or physical attributes of the odorant molecule causes a response in the olfactory receptor in the olfactory epithelium, which in turn leads to the experience of odor. In other words, odorant character is encoded by broadly responsive receptors whose responses create patterns that are interpreted by the brain as "odorant quality."

An early hypothesis of odor recognition was named the vibrational theory (Wright, 1954). This theory suggested that odors of given chemicals are a function of their intrinsic vibrational frequencies. The stereochemical theory (Amoore et al., 1967) proposed that olfactory receptors are sensitive to size, shape and electronic status of the odorant molecule. Amoore et al. (1967) observed a strong correlation between the psychophysical assessment of odor quality for 107 odorants and the size and shape of the odorant molecule. Amoore's theory was based on the lock and key theory of enzymology and proposed that all key odorants are based on a combination of a limited number of primary odors and specific nerve receptor site cavities. Beets (1978) theorized that two molecular attributes were important in odor determination: (1) the form and bulk of the molecule and (2) the nature and disposition of the functional groups of the molecule. Odorous molecular compounds within the incoming air occur in many orientations and conformations, and are attracted to and briefly interact with particular sites in the pattern.

In the late 1980s, evidence mounted that olfactory transduction used a G-protein-coupled pathway. Several genes encoding G-protein-coupled receptors were cloned and these receptors were found to have common motifs in their amino acid sequences (Jones and Reed, 1989). Using molecular genetic techniques, the researchers Buck and Axel (1991) identified a large family of approximately 1000 genes that encoded for the same number of different G-protein-coupled receptors (odor-sensing proteins) in the rat olfactory epithelium. In subsequent parallel and complementary research publications, Buck and Axel described the expression patterns of odorant receptor genes in the olfactory epithelium and showed that the axons of neurons expressing the same odorant receptor converged in the olfactory bulb on the same loci (glomeruli). The Axel research group (Columbia University College of Physicians and Surgeons) reported that each olfactory neuron was found to express one receptor protein and the neurons that express a given protein terminate in two of the approximately 2000 glomeruli in the olfactory bulb (Axel, 1995). This research indicated that the receptor was involved in the process of axonal convergence. Axonal convergence showed that the axons of neurons expressing the same odorant receptor converge in the olfactory bulb on the same loci (glomeruli).

Buck's research group went on to find further evidence indicating that one receptor can recognize multiple odorants. They 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 odor receptors, 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. Notably in 2004, Buck and Axel were each awarded the Nobel Prize in Medicine for their discoveries of odorant receptors and the organization of the olfactory system.

Perceptually, when a person sniffs a cheese sample, the mix of volatile compounds flows over the receptors in the olfactory region in the nose. This activates an array of olfactory receptors, but only those specifically responsive to the compounds present. The G-proteins initiate a cascade of intracellular signaling events, which are propagated along the olfactory sensory axon to the brain.

The anatomy of the nose is such that only a small fraction of inspired air reaches the olfactory epithelium via the nasal turbinates. The olfactory receptors in people are located in the upper recesses of the nasal cavity, away from the major flow of inspired air. Under normal breathing conditions, about 5% of respired air reaches the olfactory receptors. However, during sniffing, the amount of respired air reaching the receptors increases to about 20%, reflecting the importance of sniffing to increase odorant transport to the olfactory epithelium (DeVries and Stuvier, 1961).

Optimal odorant contact is achieved by sniffing for 1–2 s (Laing, 1983). 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 full-strength sensation. Adaptation, or the tendency to become unresponsive to stimuli that are stable in space and time, is an important phenomenon in odor perception (Lawless and Heymann, 1999). Practically, one may experience this when entering the home of another person. Initially, the smells of the home, including cooking and cleaning smells, are noticed. However, after several moments, one no longer detects these odors due to adaptation. In sensory panels, this may manifest itself in increasing thresholds (Chapter 2) or "zero" ratings for certain attributes. The phenomenon of adaptation also reinforces why sensory testing should be conducted in an odor-free environment.

The sensitivity of the olfactory receptors varies with the compound and the individual and may vary over a range of 10^{12} molecules/mL of air or more (Meilgaard, 1975). Odor thresholds (Chapter 2) 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 means or tool for detecting odor substances and still surpasses the sensitivity of instrumental means of chemical detection. Using analytical instruments such as gas chromatography, 10^{9} molecules/mL air are capable of being detected. The human nose is 10–100 fold more sensitive than this instrumentation, thus highlighting and emphasizing the importance of sensory evaluation in the analysis of odors.

Threshold values for odors are highly variable both within and across individuals. The condition known as "anosmia" describes a person's inability to detect odor compounds. "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 and Forrester, 1976), and diacetyl (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.

While the number of odor families that people can recognize is large, labeling given odors is not an easy task. Often one can recognize a smell but cannot seem to 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. People tend to perceive odors as whole patterns rather than individual components, often making odor profiling difficult (Engen, 1982).

Over the years, many odor classification schemes have been proposed to assist with classification of odor. Linnaeus proposed seven categories of odor: aromatic, fragrant, musky, garlicky, goaty, repulsive and nauseating. In 1916, the Olfactory Prism was proposed as a six-odor grouping for fundamental odors. The odors included: spicy, flowery, foul, fruity, resinous and burnt. In 1970, Amoore developed an odor classification system based on specific anosmias as they may represent a lack of a specific receptor type for a group of compounds. In Amoore's system, he proposed eight classes: ethereal, camphoraceous, musky, floral, minty, pungent, putrid and sweaty. Historically, the challenges with odor classification lists have been the use and application of broad, associative and subjective descriptors (Moncrieff, 1967).

The vast majority of the contributions to and diversity of flavors comes from the compounds sensed by human olfactory receptors. The greater part of what we have come to known as food flavor is mediated by smell. Retro-nasal odors are those odors detected "in mouth" via transportation of the stimulus up from the back of the throat and into the region of the olfactory receptors. Orthonasal odors are those that are perceived through the nostrils.

Specific food and beverage products and related industries now have their own systems for 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 semi-hard cheeses (Berodier et al., 1997).

3.4.4 Taste and Gustation

Like olfaction, gustation (or taste) is a chemical sense. Taste involves the detection of stimuli dissolved in water, oil or saliva by receptors within taste buds. The most commonly accepted number of taste categories has been four: sweet, sour, salty, bitter, with a more recently added fifth category, umami (savory, meaty and broth-like), as advocated by Yamaguchi and Ninomiya (2000). Specific receptors have been identified for these five basic tastes. Other sensations, such as metallic, have also been proposed to join the group of primary sensations (Stevens et al., 2006). Controversy does exist regarding the present status of taste quality classifications, as some believe these classifications limit panelist response to these classifications (Delwiche, 1996). However, these basic tastes do sufficiently describe most taste experiences and have convenient taste standards available (Lawless and Heymann, 1999). Individuals often have difficulty differentiating between taste sensations and other chemical feeling sensations. A chemical feeling factor is defined as a sensation that arises from stimulation of the trigeminal nerve endings.

Taste begins on the tongue and involves the detection of stimuli dissolved in water, oil or saliva by the tongue, the major organ of taste. Figure 3.5 illustrates the taste system. Compared with olfaction, the contact between a solution and the taste epithelium located on the tongue and walls of the mouth is more consistent in that every receptor is immersed for at least a few seconds. There is no risk of the contact being too brief regarding time, but there is ample opportunity for oversaturation.

Taste buds are located in papillae, which are structures that are located primarily on the surface of the tongue as well as in the mucosa of the palate and areas of the throat (Fig. 3.6). Four types of papillae are found on the human tongue: filliform, fungiform, foliate and circumvallate papillae (Fig. 3.7). Filliform papillae, the most numerous, are evenly distributed on the anterior two-thirds of the tongue. These papillae lack taste buds and have a purely mechanical function of holding certain food constituents (Plattig, 1984). The fungiform papillae are large and mushroom-like in appearance and are highest in number at the tip and sides of the tongue (Amerine et al., 1965). They

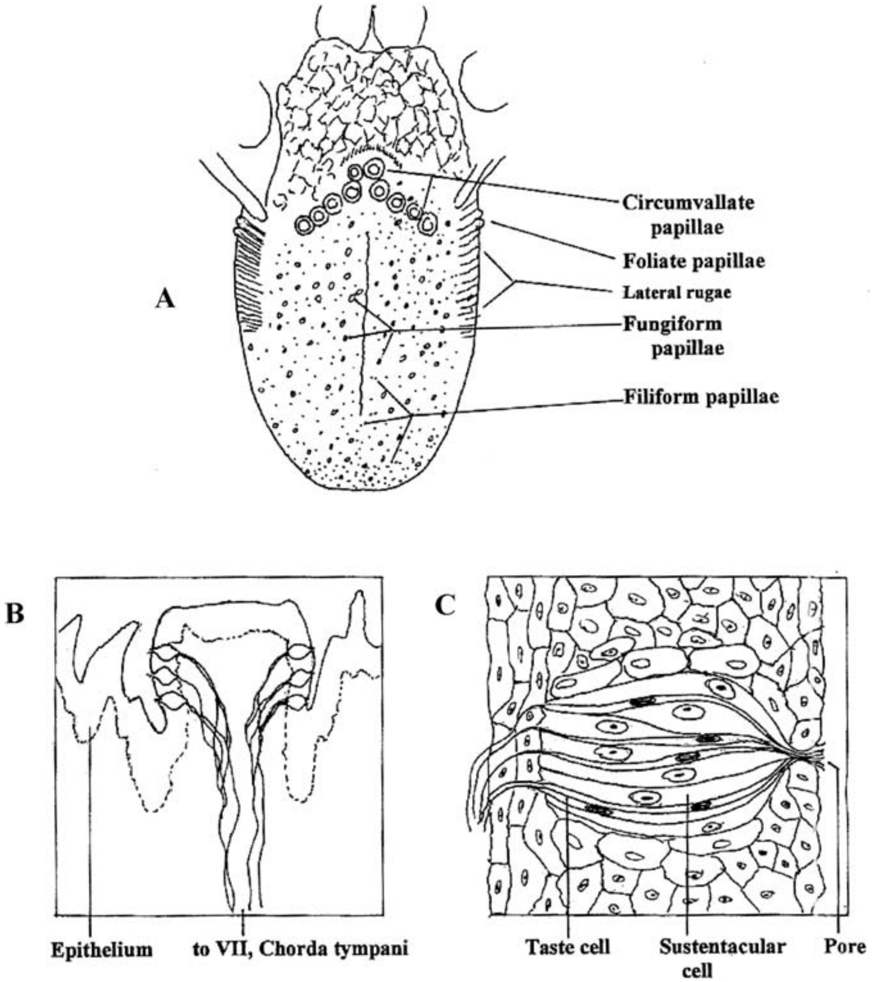

Fig. 3.5 The human tongue (**A**), a cross-section of a fungiform papilla (**B**) and a section of papillae showing a taste bud with receptor cells (**C**)
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are estimated to number between 150 and 400 on the tongue and contain 2–4 taste buds each (Miller and Bartoshuk, 1991). The foliate papillae, on the posterior third of the tongue, are not well developed and serve little function. The circumvallate papillae form a V-shape on the back of the tongue. There are usually 6–15 present on the tongue and are large and easily visible. Circumvallate papillae contain several hundred taste buds in the outer grooves that surround them.

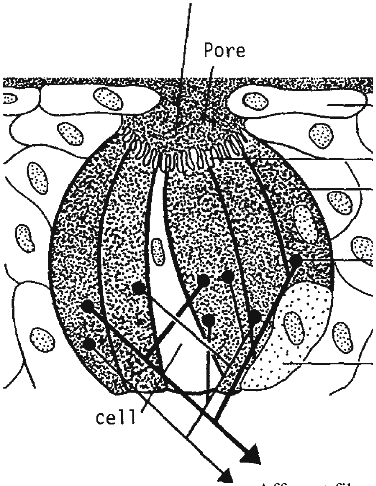

Fig. 3.6 The structure and innervation of a typical human taste bud
From: Altner, H., *Fundamentals of Sensory Physiology* (1981a). Courtesy of Springer-Verlag, Heidelberg, FRG and Bodyfelt, F.W., Tobias, J. and Trout, G.M. *The Sensory Evaluation of Dairy Products*. 1988 Van Nostrand Reinhold, New York

The distribution of taste buds is generally associated with certain papillae. Consequently, response to specific tastes may be felt more acutely in some areas compared to other areas of the tongue. The sour taste may be noted chiefly along the sides of the tongue, saltiness along the sides and tip and sweetness generally at the tip. Umami is generally noted along the sides and toward the base of the tongue, and the bitter taste is noted at the base of the tongue.

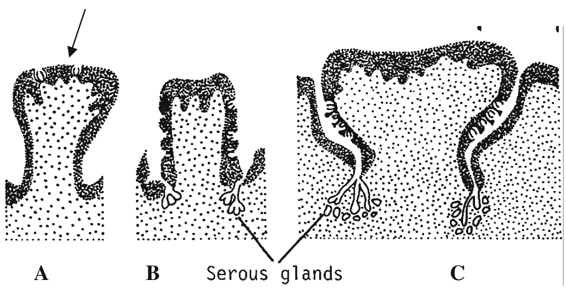

Fig. 3.7 The position of taste buds on the three different types of gustatory papillae: **A** – fungiform, cover the anterior *2/3* of tongue surface; **B**– foliate, cover the posterior *1/3* of lingual surface of the tongue, along with; **C** – vallate papilla
From: Altner, H., *Fundamentals of Sensory Physiology*.(1981a) Courtesy of Springer-Verlag, Heidelberg, FRG and Bodyfelt, F.W., Tobias, J. and Trout, G.M. *The Sensory Evaluation of Dairy Products*. 1988 Van Nostrand Reinhold, New York

Because of these differences, it is important that any sample to be evaluated should be manipulated in the mouth to allow direct contact between the taste buds and the taste compound. However, it is important to stress that the different tastes are perceived all over the tongue and not only in these specific areas.

In flavor perception, both volatile and non-volatile flavor compounds are released from the food. The release of compounds from the food matrix is influenced by the matrix structure, chemical and physical properties. Following their release, the volatile flavor compounds are transported from the saliva phase to the air phase in the mouth. These compounds travel via the throat to the olfactory receptors located in the nose, where they are sensed. The non-volatile flavor compounds released from the food enter into the saliva phase. Saliva is a complex solution of water, amino acids, proteins, sugars, organic acids and salts that bathe the gustatory sensors. In order for compounds to be carried to the taste buds and perceived, they must be in aqueous solution (saliva). 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. Taste receptor cells are groups of sensory epithelial cells stimulated by sensory nerve endings. They are in the cell membranes of groups of about 30–50 cells clustered in a taste bud and are renewed on average every 6–8 days. The taste molecules are thought to bind to the hair-like cilia near the opening of the pore. In the pore, the taste 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 onto the brain.

The composition of saliva serves to modulate taste response. 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 and Taylor, 1943). 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 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 amount during mastication. 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.

Decades of research have shown that salty and sour perception are mediated by ion channels, while sweet, bitter and umami tastes are mediated by G-protein-coupled receptors (GPCR). All of these receptors are within taste cells within the taste buds on the tongue (Smith and Margolskee, 2001). For bitter, sweet and umami transduction, the GPCR couple to specific intracellular G-proteins (Huang et al., 1999). Research has reported 25 functional TAS2R genes in humans, whose products are responsible for bitter perception (Bufe et al., 2002, Kim et al., 2003). For sweet and umami perception, the human

TAS1R family, which contains three genes that form heterodimers, serves as the appropriate receptor. For sweet receptors, the genes involved are TAR1R 2 + 3, and for umami, the genes involved are TAS1R 1 + 3 (Li et al., 2002; Zhao et al., 2003). The receptors for salty and sour tastes are less well understood. Salt perception is thought to be mediated by one or several ion channels (Ossebaard and Smith, 1995). Sour taste is mediated by an acid that is still of uncertain molecular composition (Kim et al., 2004). The reaction time to taste perception or the interval between initial stimulation of the receptors and reaction has been estimated to be 0.307 s (salty), 0.446 s (sweet), 0.536 s (sour) and 1.082 s (bitter) (Hollingworth and Poffenberger, 1917).

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 semi-dry 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. For flavor perception, the food must be masticated, solubilized and diluted in order for a taste reaction to occur. Manipulation of the sample in the mouth suffices to stimulate the flow of saliva; hence it is important to maneuver the sample around in 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).

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. Understanding how saliva is affected by different conditions and how this may impact sensory evaluation and dairy judging are important aspects to consider.

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 (non-tasters). Many studies have explored the genetic differences among individuals who are tasters versus non-tasters (Kaprio et al., 1987; Drayna et al., 2003).

The ability to taste the bitter compound 6-*n*-propylthiouracil (PROP) is also genetically determined. PROP tasters have been divided into tasters, non-tasters and super-tasters, 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 super-tasters having the highest density followed by tasters and then non-tasters (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, 1993a). PROP sensitivity has been linked with a greater frequency of food aversions (Drewnowski et al., 1998).

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 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 (non-taster, taster and super-taster) 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 super-tasters.

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 and Drewnowski, 1996). More recently, detection thresholds of NaCl, KCl, sucrose, aspartame, acetic acid, citric acid, caffeine, quinine-HCl and monosodium glutamate were determined of 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, sodium and potassium chloride.

3.4.5 Touch

In general, the skin senses are able to code three types of stimulus: mechanical, thermal and pain. Deep pressure sense (called kinesthesis) 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 a given foods' texture is judged partially through the perception of the forces that are needed to physically break down the structure of the food.

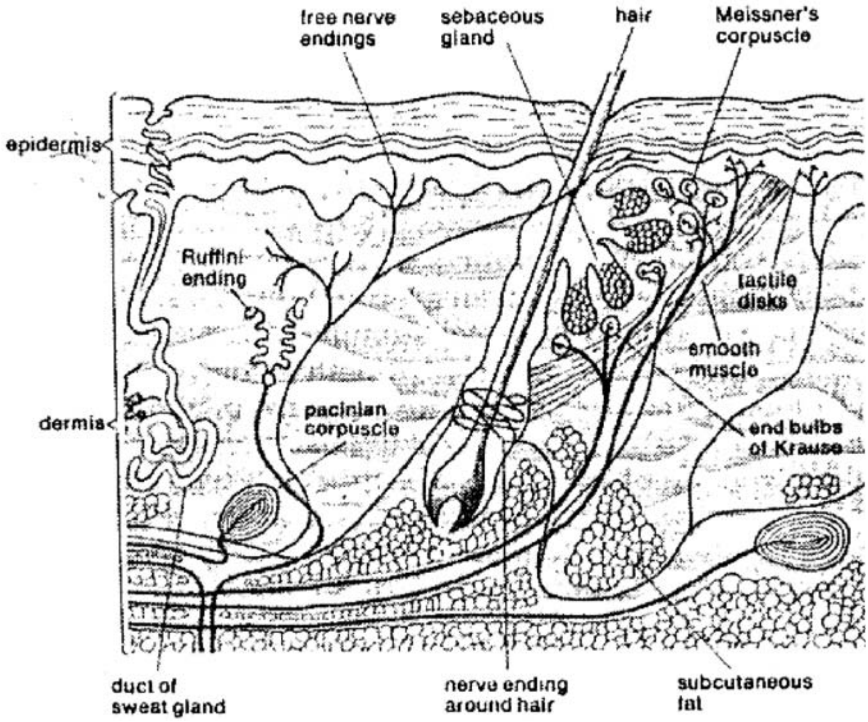

Fig. 3.8 Cross-section of human skin
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Somesthesis is the tactile sense or skin-feel caused by displacement of hairs or deformation of the skin without injury. Tactile sensations may be transmitted from a variety of sites as shown in Fig. 3.8. The epidermis, dermis and subcutaneous tissues are responsible for somesthetic sensations of touch, pressure, heat, cold, itching and tickling.

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. In other foods, the texture, while important, is not the primary sensory characteristic. 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 (1) the superficial structure of the mouth; (2) around the roots of the teeth; and (3) in the muscles and tendons of the mouth and jaw.

Texture judgment can also be undertaken by looking at the surface of a food product. Characteristics including shine (or sheen) and lumpiness provide visual texture cues. When a sample of solid food is manipulated in the hand by squeezing, bending or cutting with a knife, information of the product's firmness, toughness, crispness or fibrousness may be gained. The behavior of a liquid or semi-solid food when shaken, stirred or poured may yield information about 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).

So-called oral tactile texture attributes are those texture attributes perceived within the mouth. One scheme used for texture classification was first developed by Szczesniak (1963), and it is still used today. In this classification scheme, three categories of textural characteristics were proposed:

1. Mechanical characteristics – relate to the reaction of food to stress
2. Geometrical characteristics – relate to the size, shape and orientation of the particles in the food
3. Other characteristics – relate to the perception of moisture and fat content of the food

Szczesniak (1963) proceeded to perform extensive research in the texture area, including the development of a specific vocabulary for texture attributes.

A key characteristic of oral perceived texture is the geometrical characteristics of the various particles, specifically the size and shape of the particles in the mouth. Soft, rounded or hard, flat particles above 80 μm in size exhibit gritty properties or characteristics. By contrast, when particles are hard, angular and within the size range of 11–22 μm, then grittiness is noted (Tyle, 1993). For fat globules, panelists were able to distinguish between average fat-globule size and distance distributions in a range of 0.5–3 μm (Richardson and Booth, 1993). Of particular importance to dairy sensory judging, the effect of sample size was found to impact various texture attributes of cream cheese, American cheese and other products (Cardello and Segars, 1989). 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.

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), 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 afterfeel related (clean, lingering); physiological (filling, refreshing, thirst quenching); temperature (hot, cold); and extent of wetness (wet, dry).

The texture attribute that does change over time 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 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.

3.4.6 Chemesthesis

The burn of hot peppers, 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 (Fig. 3.9). In the nose and mouth, this general chemical responsiveness is mediated by the trigeminal nerves. 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). It is worth noting that chemical sensitivity is a property of all cutaneous nerves and sensory irritation is not exclusively mediated by the trigeminal nerve system (Green, 1996).

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

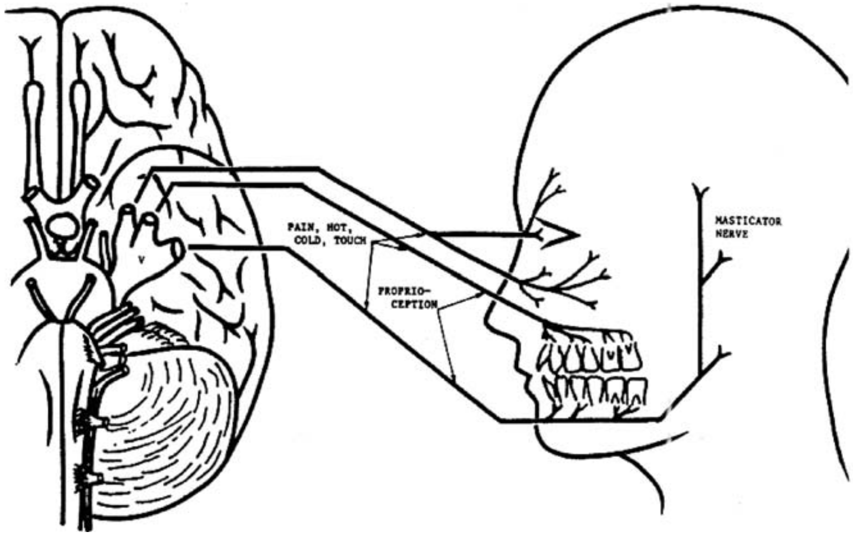

Fig. 3.9 The pathway of the trigeminus nerve
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stimulate taste receptors and heat-sensitive pain receptors in the mouth. Peppermint evokes coolness and sting due to menthol simulation of cold fibers and pain fibers, while pepper evokes burning through capsaicin stimulation of heat-sensitive pain fibers. As the trigeminal nerves also signal tactile, thermal and pain sensations, panelists often have difficulty separating chemical sensations from tactile sensations.

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.

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, in that most mucosal pain receptors lay within or beneath the epithelium rather that 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 and 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 contribute to product acceptance (Green, 1996).

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 and Stevenson, 1995). Consumers of hot spices frequently rate the extent of burn sensation from capsaicin lower than non-consumers do (Prescott and Stevenson, 1995).

3.5 Dairy Products Judging

All of the various human senses described in this chapter are applied in the sensory evaluation of dairy products. Dairy product appearance can indicate either (1) the presence of good qualities or (2) quality defects within the products (Bodyfelt et al., 1988). In general, factors that may be evaluated by sight include: product color, the style of the product, condition of the package, attractiveness of product finish and workmanship, and overall appearance characteristics. Using the aforementioned cues, a judge 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).

For practical example, a product may be presented for judging that is carelessly packaged and/or discolored in appearance. While these cues provide valuable information to the judge, caution must be exercised not to let the product appearance cues unduly influence the evaluator's taste and smell assessments of the given product (Bodyfelt et al., 1988).

Olfaction, or smelling, plays a critical role in the evaluation of dairy products. Using olfaction, important details about product quality can be determined. 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).

The sense of touch, including product texture and mouthfeel, is also an important aspect of dairy judging for quality assessment. The feeling of rubberiness or stringiness of cheese, the creamy or gritty mouthfeel of ice cream and the "briny" defect in butter are all indications of product quality. A judge's fingers are also used on the external surface of some product samples to provide information on the relative springiness or hardness of a product. Attributes of noise (sound) can also be used during dairy judging. For example, in Swiss cheese, quality can be evaluated by gently tapping the outside of the cheese with the fingers or a sampling device (cheese trier), which projects the relative size and/or distribution of "eyes" within the block of cheese. The relative amount of free moisture in butter 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).

For liquid product samples the prudent taster should take small sips (i.e., 8–12 ml) and 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).

In 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 product quality. 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 product 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 and Michael Costello

4.1 Introduction

Scorecard judging is a useful and practical tool for conducting the sensory evaluation of dairy products. Scorecards may serve as records for a processing plant or for routine and official use in the grading of dairy products (state or federal) and serve as the recording instrument for various county, state, regional, and national dairy product evaluation competitions. 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 at the document top, followed by an alphabetized list of body and texture attributes, with the appearance and color attributes listed at the bottom.

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

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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.” 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. 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

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 acidity (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 U.S. Department of Agriculture Scorecard for Milk and Cream 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 and Trout, 1951).

There are two main types of dairy products 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. This chapter is devoted to describing various U.S. Cheese Competitions, the National Collegiate Dairy Products Evaluation Contest and the Midwest Regional Dairy Products Evaluation Contest. This chapter is not an exhaustive summary of all the various dairy products contests and sensory evaluations that take place in the U.S. and Canada 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 (Fig. 4.1).

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 central if producers 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 U.S. 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*, essentially eliminates the need for scorecard evaluation of bacteria, sediment, temperature, and acidity. Milk quality evaluation focuses on flavor attributes. Contemporary official ADSA scorecards that are used to evaluate dairy products and the attributes associated with those products are included in Chapters 5–10.

The beginning of the twentieth century marked the establishment of brands and trade names for dairy products, particularly butter and cheese. This development necessitated recognition of set standards of quality by manufacturers and the subsequent need for 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.

Although label, price, package condition, and product appearance all influence a consumer's purchase decision, the acceptability of a product is not limited to these characteristics. Basic and applied research continue to play an important role in development of the dairy industry, and much attention has focused on the use of novel ingredients and technologies to improve flavor, appearance, as well as body and texture attributes of products, which will ultimately determine their eating quality and value to the consumer. Consumer evaluation, and decision to purchase a given product repeatedly (which is essential to a product's success in the market), involves a complex interplay among all of these characteristics as well as perceived "eating quality."

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 co-partners with dairy products 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 and 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: They are designed 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 90 years. Although designed for six different dairy products (which are detailed in Chapters 5–10), 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 plastic 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. With the passage of time, a majority of U.S. consumers have thus become accustomed to this particular milk flavor and they do not generally consider this as a flavor defect as such. 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 U.S. consumers drink packaged milk from semi-transparent plastic containers (that presumably have some degree of light oxidation) than any other packaged form of milk in the marketplace. Furthermore, research has reported that light contributes to partial loss of vitamins A, riboflavin (B_2), C, D, and some amino acids. The best protection of milk comes with paper board printed with large areas of dark ink or foil in the laminate (Bradley, 1980; Bradley et al., 2006).

Surprisingly and unfortunately, some cheese judges, upon the mere detection of a sulfide note in a medium-aged Cheddar cheese, will typically 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 (Fig. 4.2).

Fig. 4.2 Students independently judge products in the Collegiate Dairy Products Evaluation Contest

The American Cheese Society Annual Competition and other dairy product competitions 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 numbered scores, the evaluation forms used in other dairy product competitions contain spaces for feedback in addition to numbered scores. The American Cheese Society Annual Competition and other dairy product competitions are designed to recognize excellence and encourage producers 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 (not the Collegiate Dairy Products Evaluation Contest) 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 have had a strict proscription against 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) have, across the period of 1911–2008, forbidden the use of “awards received” information in any form of brand or company advertising/promotion).

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 (Fig. 4.3). 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.

Fig. 4.3 Butter evaluation being conducted by judges and coach judges in the Collegiate Dairy Products Evaluation Contest

Since 1916, over 85 Collegiate Dairy Products Evaluation Contests have been held throughout the U.S. and Canada (contests were not held in 1918 or during WWII, 1942–1946). 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 3,000 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 90 national contests conducted, over 65 different schools have participated (Table 4.1), with an average of 18 schools per contest. In 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 Midwestern Regional Contest survives.

The annual National Collegiate Dairy Products Evaluation Contest traditionally takes place in the fall. College students judge the quality of dairy products in six product categories: butter; Cheddar cheese; cottage cheese; vanilla ice cream; milk; and strawberry-flavored Swiss-style yogurt with natural and/or alternative sweeteners. Originally raw whole milk was evaluated, then pasteurized whole milk, and now 2% fat pasteurized milk is evaluated. For milk, 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.

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

Table 4.1 Teams that have participated in the Collegiate Dairy Products Evaluation Contest, between 1916 and 2007

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

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). Finally, 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.

The first butter judging contest was sponsored by the National Dairy Association. Now, this 6-Product contest is sponsored by the American Dairy Science Association (ADSA), the Food Processing Suppliers Association (FPSA) Foundation, and the International Dairy Foods Association (IDFA), and is under the direct supervision of the USDA. Between 1930 and 2005, the major sponsor of the Collegiate Dairy Products Evaluation 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. In 2006, IAFIS merged with the Food Processing Machinery Association (FPMA) to form the Food Processing Suppliers Association (FPSA). In addition to the IAFIS Foundation (now FPSA Foundation), other organizations and associations, including the Dairy Recognition and Education Foundation and Avonmore Cheese, Inc., donate team and individual plaques and monetary awards to the three top-performing individuals and teams across the six products evaluated (Tables 4.2 and 4.3).

The ADSA, through its Dairy Products Evaluation Committee (i.e., "The Coaches Committee"), is responsible for the contest rules and overall policy for conducting the contest. The ADSA Coaches Committee develops and revises the official scorecards, which are scored electronically. Scorecards of the individual contest products are included and described in Chapters 5–10. Along with the ADSA, the committee is also responsible for any modifications to the scoring guides, which are employed throughout the U.S. and Canadian dairy industries.

Since the early days of the contest, the USDA, Agricultural Marketing Service 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

Table 4.2 Team awards[1,2] in the Collegiate Dairy Products Evaluation Contest

Award	Trophy	Donor
1st place all products	$2000 Shirley Seas Memorial Scholarship	FPSA Foundation[3]
1st place all products	Cup and plaque	FPSA Foundation
2nd and 3rd place all products	Plaques	FPSA Foundation
1st place butter	Cup and plaque	FPSA Foundation
2nd and 3rd butter	Plaques	FPSAFoundation
1st place Cheddar cheese	Cup and plaque	FPSA Foundation
2nd and 3rd place Cheddar cheese	Plaques	FPSA Foundation
1st place cottage cheese	Cup and plaque	FPSA Foundation
2nd and 3rd place cottage cheese	Plaques	FPSA Foundation
1st place ice cream	Cup and plaque	FPSA Foundation
2nd and 3rd place ice cream	Plaques	FPSA Foundation
1st place milk	Cup and plaque	FPSA Foundation
2nd and 3rd place milk	Plaques	FPSA Foundation
1st place yogurt	Cup and plaque	FPSA Foundation
2nd and 3rd place yogurt	Plaques	FPSA Foundation

[1] A team winning first place three times retires the cup.
[2] All plaques are permanent awards.
[3] The foundation of the Food Processing Suppliers Association.

Table 4.3 Individual Awards in the Collegiate Dairy Products Evaluation Contest

Undergraduate honor	Award	Donor
1st place all products	$400 R. Rosenbaum Award & pewter bowl	DREF[1], and FPSA Foundation[2]
2nd place all products	$300 E. Byers Award & pewter bowl	DREF and FPSA Foundation
3rd place all products	$200 H. Roberts Award & pewter bowl	DREF and FPSA Foundation
1st to 5th place students all products	Induction into Dairy Shrine	FPSA Foundation
Coach of the Year	$500 Weigold Award & plaque	DREF
1st place Butter	$500 Bert Aldrich Award & plaque	Avonmore Cheese, Inc.
1st place butter	$100 Award	DREF
1st, 2nd, 3rd place butter	Pewter Bowl	FPSA Foundation
1st place Cheddar	$100 Award	DREF
1st, 2nd, 3rd place Cheddar	Pewter Bowl	FPSA Foundation
1st place cottage cheese	$100 Award	DREF
1st, 2nd, 3rd place cottage cheese	Pewter Bowl	FPSA Foundation
1st place ice cream	$100 Award	DREF
1st, 2nd, 3rd place ice cream	Pewter Bowl	FPSA Foundation
1st place milk	$100 Award	DREF
1st, 2nd, 3rd place milk	Pewter Bowl	FPSA Foundation
1st place yogurt	$100 Award	DREF
1st, 2nd, 3rd place yogurt	Pewter Bowl	FPSA Foundation
Joe Larson Merit Award for leadership potential	$500 Award and plaque	FPSA Foundation
Graduate honor	**Award**	**Donor**
1st place all products	$400 Genevieve Christen Award & plaque	FPSA Foundation
1st place, each of the six products	$100 Award	FPSA Foundation

[1] Dairy Recognition and Education Foundation.
[2] The Foundation of the Food Processing Suppliers Association.

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 one generally involves travel to the contest site by teams and The Coaches Committee meeting. Day two is the day of the contest, while day three typically includes an awards ceremony and 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 U.S., to Montreal (1975 and 1989), and Toronto (1998) in Canada. The most common contest site has been Chicago, IL, where the contest has been held in conjunction with the World Wide Food Expo (1979–2005) or the Pack/Process Expo (2006).

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).

Closer to the contest, students must be informed of the rules. For instance, contestants are only allowed to take a cheese/butter trier and sheath, 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 fanny packs, purses, or bottled water 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 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 include FPSA representatives, FPSA foundation members, Contest Superintendent, assistant superintendent, and proctors. Official and associate judges are selected by the Contest Superintendent from one or more commercial dairy enterprises or other impartial (i.e., government) entities. Official judges for the national contest may not participate as an official judge for the same product in a regional contest.

Products are provided for the contest by the Foundation of FPSA or are donated by any commercial dairy enterprise. The producers 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 do share 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 typically stored under appropriate refrigeration or frozen conditions at one or more dairy processing facilities local to the contest site.

Coach judge and coach observer assignments and arrival times for judging on the following day are announced at the Coaches Committee meeting. Coach judge and coach observer assignments are determined by preference listing by respective coaches (part of the set of contest entry forms). All coach judges and coach observers are university team coaches. Coach judges and official judges consult with one another to guarantee product attribute and score consensus on all eight product samples entered into a given product category. After official industry judges ($\geq$3 persons for each of the 6 contest products) evaluate a set of eight products submitted and designated for this student competition (described below), coach judges (typically $\sim$3 for each contest product) and coach observers (typically 1 for each contest product) are invited to evaluate each set of products. 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.

The Collegiate Dairy Products Evaluation Contest is a very carefully coordinated event. Usually on the day before the contest (or alternatively early in the morning of the contest day) official judges gather to conduct the so-called official sensory evaluations of the six sets of products. Official judges initially rate each product set without input from coach judges and/or coach observers. Next, at about 7 a.m. on the contest date, the assigned coach judges and coach observers join each official evaluation committee for each product. The evaluation committee for each product consists of (a) an official lead judge and no fewer than two official associate judges and (b) the set of coach judges assigned to each product (Fig. 4.4). 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

Fig. 4.4 Official judges, coach judges, and coach observers evaluate the quality attributes of Cheddar cheese

Fig. 4.5 An official judge marks an official scorecard while a coach judge looks on for accuracy

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 reasonably and well judged (Fig. 4.5).

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 informed of any pertinent or limiting venue, location, or site circumstances. Contestant numbers are written in the "CONTESTANT NO." box on each and every scorecard to insure that the respective contestant identities can be recorded. 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.

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. During the interval before starting each product category, contestants should ensure that their assigned contestant number is written in the "CONTESTANT NO." box on the scorecard for each given product.

For contestants, there is no pre-set 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. 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 scorecards for stray marks or 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°C to –15°C [0°F–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 is provided in 64-pound cubes, while Cheddar cheese samples are generally provided as 40-pound blocks. 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 1/6th 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 fresh or "undisturbed" 1/6th 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. 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 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 8 oz. commercial containers. Replicates #2 and #3 are covered with foil or a blank carton. Replicate #1 is inverted onto a plate for observation. 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 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 (Fig. 4.6).

Fig. 4.6 Student contestants are allowed 10 min to evaluate the appearance and color of strawberry Swiss-style yogurt prior to removal of the plates from the display table

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 (i.e., ice cream) and "re-calibrate" 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, explaining definitions used within the industry and providing suggestions for training students to detect and identify particular attributes. Lively discussion and ideas interchange are generally generated because all coaches have unique insights into training and degrees of standardization on descriptors, intensity, and scoring strategies.

Upon completion of each session of the contest, contestant scorecards are turned over to the Contest Superintendent, who works with industry volunteers to enter the scorecard results into the official electronic reader. Specially printed, "scanner-ready" scorecards are used, in which contestants fill 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 is scanned, and a computer using software written specifically for the contest captures each contestant entry. This software 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 each scorecard to be sure that it was scanned correctly and also checks for potential tie scores and ascertains that the scoring software has broken the possible ties according to the official rules. Individual scorecards, along with team scores, are returned to each competing team at the conclusion of the awards ceremony. Contest scorecards are graded by at least two computer tabulation officials, selected by the Contest Superintendent.

A contestant's score for each sample (represented on the scorecard) 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 shall be

1) Perfect, 0, when the contestant
   a. Marks only those defects recognized by the official judges, or alternatively
   b. Recognizes, like the official judges, that the item is "above criticism," under which conditions a mark is not necessary.
2) The maximum, 2.0 points, when the contestant
   a. Fails to mark the defect(s) noted by the official judges;
   b. Marks a defect(s) when the sample was judged by the official judges as being above criticism;
   c. Fails to check a criticism(s) when the official judge scores the sample within the criticizable range (although the contestant may have scored the sample above criticism); or
   d. Fails to mark any defect(s) when his/her score indicates he/she should have (although the official judges scored the sample above criticism).
3) Less than 2: 0.50, 0.67, 1.00, 1.33, 1.50, or 1.60, etc., of a point according to the percentage (%) of the defects marked correctly.
   Examples:
   a. The official judges marked three defects and the contestant marks only one, which is identical with one of the official defects. The grade is 1.33.
   b. The official judges marked one defect and the contestant marks three, one of which coincides with that of the official judge. The grade is 1.33.
   c. The official judges marked three defects and the contestant marks three, one of which is identical with one of the official defects. The grade is 1.60. (A total of five different criticisms has been involved by the official judges and contestant. The contestant and official agree on one of them. Thus, the contestant is 1/5 correct or 4/5 incorrect, earning a grade of 1.60.)

In this contest a "grade" means "points lost"; the contestant with the lowest grade is declared the winner of the product evaluation, and the team with the lowest "grade" is declared the winning team for 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. A team grade for each product is thus the sum of the grades of its three respective members.

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. 4.7). 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

Fig. 4.7 At the conclusion of the contest, official scores and explanations are placed near corresponding entries

judging team per each product category and to help convey how to better recognize and score attributes.

Generally on the morning after the competition, the contestants, coaches, officials, and judges attend a special awards breakfast, sponsored by FPSA, 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 10th place through 1st 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 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 U.S.; however, international teams are not permitted in this regional event. The number of participating teams fluctuates from 8 to 12 each year and averages approximately 10.

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 Midwestern contest is hosted annually by the Kraft Research Center in Glenview, IL. Along with the physical facilities, Kraft Foods provides products, judges, a free continental breakfast for all workers, as well as a free lunch for all contestants and work volunteers. Kraft Foods also contributes departure gifts and a collection of Kraft products to all participants. A post-competition tour of Kraft research facilities is also offered as a part of the Midwestern contest experience.

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 a trophy, with a special trophy awarded to the top All Products team. Awards are also made to top performing graduate students, but graduate student competitors are only allowed to compete as individuals. All prizes are sponsored/provided by the Chicago Dairy Technology Society and are financially covered with funds raised by this society from industry sponsors.

4.5 American Cheese Society Annual Competition

The American Cheese Society (ACS) Annual Competition recognizes the craftsmanship of artisanal and specialty cheese making (Table 4.4). This competition is conducted in conjunction with the American Cheese Society's Annual Conference. 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.

Table 4.4 Cheese categories for the 2006 American Cheese Society Judging Competition

A. Fresh unripened cheeses
Mascarpone, Cream Cheese, Neufchatel, Ricotta, Impastata, Quark
Exempt: Fresh Goat Cheese, Queso Blanco types, and Cottage cheeses
AC: Cheeses made from cow's milk
AG: Cheeses made from goat's milk
AS: Cheeses made from sheep's milk and/or mixed milks
AM: Mascarpone – made from cow's milk
AR: Ricotta – made from cow's milk
B. Soft ripened cheeses
White surface mold ripened cheeses – Brie, Camembert, Coulommiers, etc.
BA: Open class for all cheeses made from cow's milk
BB: Brie cheese made from cow's milk
BC: Camembert cheese made from cow's milk
BG: Cheeses made from goat's milk
BS: Cheeses made from sheep's and/or mixed milks
BF: Flavor added – spices, herbs, seasoning, fruits, etc.
BT : Triple crème soft ripened (cream added/blue cheeses exempt) all milks
C. American originals
Cheeses recognized by the ACS Competition Committee as uniquely American in their original forms.
Monterey Jack, Brick Muenster, Colby,
Brick Cheese, Teleme, Liederkranz, Oka, etc.
Exempt: Brick Mozzarella,
CC: Open category made from cow's milk
CG: Open category made from goat's milk
CS: Open category made from sheep's milk and/or mixed milks.
CJ: Monterey Jack – cow's milk
CP: Monterey Jack with Flavors – cow's milk
CY: Colby – made from cow's milk

Table 4.4 (continued)

D. American made/international style

Exempt: All Cheddar's, all Italian Type cheeses

DD: Dutch style, all milks (Gouda, Edam, etc.)
DC: Open category made from cow's milk
DG: Open category made from goat's milk
DS: Open category made from sheep's or mixed milks

E. Cheddars

All Cheddars, all milks sources
EA: Aged Cheddars, all milks (aged between 12 and 24 months)
EF: Flavor added – spices, herbs, seasonings. fruits, etc.– any age
EC: Cheddar from cow's milk, aged less than 12 months
EG: Cheddar from goat's milk, aged less than 12 months
EM: Mature Cheddars: aged between 25 and 35 months
EX: Mature Cheddars: aged between 36 and 48 months
EE: Mature Cheddars: aged longer than 49 months

F. Blue mold cheeses

All cheeses ripened with *Penicillium roqueforti or glaucum*

Exempt: Colorless Mycelia

FC: Blue-veined made from cow's milk
FG Blue-veined made from goat's milk
FS: Blue-veined made from sheep's or mixed milks
FE: External Blue molded cheeses – all milks

G. Hispanic and Portuguese style cheeses

GA: Ripened category: Cotija, Flamingo Bolla, St. Jorge types, etc. – all milks
GC: Fresh Unripened category: Queso Blanco, Queso Fresco, etc. – all milks
GF: Flavor added – spices, herbs, seasonings, fruits, – all milks

H. Italian type cheeses

HP: Pasta Filata types – Provolone, Caciocavallo, and all milks
HA: Grating types – Reggianito, Sardo, Domestic Parmesan, all milks – Romano made only from cow or goat milks and *not* from sheep milk
HM: Mozzarella types – Brick, Scarmorza, String Cheese – all milks
HY: Fresh Mozzarella types – Ovalini, Bocconcini, Celligini sizes – all milks

I. Feta cheeses

IC: Feta made from cow's milk
IG: Feta made from goat's milk
IS: Feta made from sheep's milk
IF: Flavor added – spices, herbs seasoning, fruits – all milks

J. Lowfat/low salt cheeses

JC: Open to goat, sheep and water buffalo milk cheeses
JL: Fat-free and low-fat cheeses –

Limited to cheeses with 3 g or less total fat per serving size

JR: Light/lite and reduced-fat cheeses – *Limited to cheeses with 25–50% reduction of fat per serving size when 50% of calories in the serving size come from fat.*
JF: Flavor added – spices, herbs, seasonings, fruits – all milks

**Nutritional information qualifying cheese as a dietary-type cheese must accompany each cheese entry! Each cheese entry must be labeled one of the following terms:*

Definition of Terms:

Fat-free**:** Less than 0.5 g fat per labeled serving size and no added fat or oil

Table 4.4 (continued)

Lowfat: Maximum 3 g total fat per serving for serving size if serving size is > 30 g or 2 tablespoons; and 3 g of fat or less per 50 g of product if serving size is < 30 g < 2 tablespoons.

Light or lite: If less than 50% of calories come from fat, the cheese label must show a 33.3% reduction of calories than referenced amount or 50% reduction in fat. If more than 50% of calories come from fat, the cheese labels must show a minimum of 50% reduction of fat per referenced amount

Reduced fat: Minimum 25% reduction in total fat per referenced amount.

Source: U.S. Nutrition Labeling & Education Act -Nov., 1990

K. Flavored cheeses

Entries are limited to cheeses NOT listed in categories B-C-E-G-I-J-N-O-P-R-S.

Cheeses in this category include but are not limited to Cream Cheese, Cottage Cheese, Cheeses with edible flowers, cultured cheese products.

KC: Cheeses flavored with all peppers (Chipolte, Jalapeno, Chilies, etc.) – all milks

KF: Cheeses flavored with herbs, fruits, vegetables, flowers, syrups

KP: Cheeses flavored with crushed or whole peppercorns or savory spices

KG: Open category made from goat's milk

KS: Open category made from sheep's milk

L. Smoked cheeses

**Information about the smoke source (i.e., natural, chemical, liquid) must accompany each cheese entry.*

LC: Open category made from cow's milk

LG: Open category made from goat's milk

LS: Open category made from sheep's milk

LM: Smoked Italian Styles (i.e., Mozzarella, Scarmorza, Bocconcini, Ovalini, etc.)

LD: Smoked Cheddars

M. Farmstead cheeses

**Limited to cheeses and fermented milk products produced with:*

1. Milk from herds on the farm where the cheeses is produced

2. Care and attention given to the purity, quality, and flavor of the milk

3. Production primarily accomplished by hand

4. Natural ripening with emphasis on development of characteristic flavor and texture, without the use of shortcuts and techniques to increase yield and shelf life at the expense of quality.

5. Respect for the traditions and history of cheese making regardless of the size of the production.

MA: Open category for cheeses aged longer than 90 days – all milks

MC: Open category made from cow's milk

MG: Open category made from goat's milk

MS: Open category made from sheep's milk

MF: Open to all cheeses with flavored added – all milks

N. Fresh goats milk cheeses

Open to all shapes and styles of ***rindless, unaged, fresh*** goat cheeses.

NO: Open category

NF: Flavor added – spices, herbs, seasonings, fruits.

O. Fresh sheep's milk cheeses

Open to all shapes and styles of ***rindless, unaged, fresh*** sheep milk cheeses

OO: Open category

OF: Flavor added – spices, herbs, seasonings, fruits.

Table 4.4 (continued)

P. Marinated cheeses
**Entries must identify the type of marinade (i.e., olive oil, safflower oil, vinegar, wine, etc.)*
PC: Open category made from cow's milk
PG: Open category made from goat's milk
PS: Open category made from sheep's milk
PF: Flavor added – spices, herbs, seasonings, fruits – all milks
Q. Cultured cheese products
Limited to Plain Yogurt, Crème Fraiche, Fromage Blanc, Kefir, Labne, etc. All cultured products with flavorings belong in Category "K". Cultured products made with added oil belong in Category "P"
QC: Cultured products made from cow's milk
QG: Cultured products made from goat's milk
QS: Cultured products made from sheep's milk
QF: Limited to Crème Fraiche products made from cow's milk
QQ: Limited to Fromage Blanc and Quark Cheese made from cow's milk
QY: Yogurts made from all milk sources
R. BUTTERS
Whey Butter, Salted Butter, Sweet Butter, Cultured Butter, etc.
RC: Salted butter made from cow's milk with or without cultures
RO: Unsalted butter made from cow's milk with or without cultures
RG: Butter made from goat's milk
RS: Butter made from sheep's milk
RF: Flavor added – spices, herbs, seasonings, fruits – all milks
S. Cheese spreads
Cold pack, Cheddar based, Cream Cheese, and Yogurt-based spreads
SC: Open category made from cow's milk
SG: Open category made from goat's milk
SS: Open category made from sheep's milk
SF: Flavor added – sspices, herbs, seasonings, fruits – all milks
T. Aged sheep's milk cheeses
Caciotta, Romano, Manchego, Table Cheeses, etc.
TO: Open category
U. Aged goat's milk cheeses
Taupineres, rinded Logs, and pyramid types, etc.
UG: Open category
V. Washed rind cheeses
Liederkranz, Limberger, Brick Types and Styles, etc. Cheeses with a rind or crust washed in salted brine, whey, beer, wine, or other alcohol, grape lees that exhibit an obvious smeared or sticky rind and/or crust. Exempt: All washed curd cheeses
VC: Open category, cow's milk
VG: Open category, goat's milk
VS: Open category, sheep's milk

Blind-coded entries are judged by pairs of one technical and one aesthetic judge, with each pair scoring each individual entry, based on a cumulative point system (Figs. 4.8 and 4.9). The judges are selected from the academic, dairy industry, dairy science, cultures manufacturing, food retailing, food distributing,

Fig. 4.8 Entries in the ACS competition are blind-coded based on category and sub-category

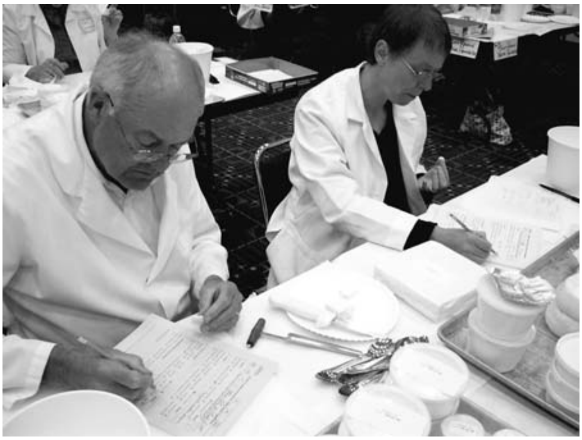

Fig. 4.9 Pairs of technical and aesthetic judges evaluate entire categories, or flights, of cultured dairy products

and food press communities, as well as the ACS membership. While the technical judge subtracts a single point from a perfect score of 50 for each technical defect, the aesthetic judge adds single points, up to 50 points, for aesthetic qualities and values. For instance, an aesthetic fresh goat cheese may lose points for “musty” and “unbalanced” off-flavors, but may gain points for the appearance of “fresh flowers” on the surface of the cheese. Technical judges may assign a maximum of 3 points for aroma, 25 points for flavor, 15 points for body and texture, and 7 points for appearance. The technical judge scorecard (Fig. 4.11) is organized with boxes for noting defects in products, with space left for additional comments. Comments should be constructive, as they are meant to help processors improve product quality.

Aesthetic judges, on the other hand, may assign a maximum of 3 points for aroma, 30 points for flavor, 7 points for body and texture, and 10 points for appearance. The aesthetic judge scorecard (Fig. 4.12) is organized with boxes for noting attributes in products, with space left for additional comments. As with the technical judge’s form, comments must be constructive, as they are meant to help processors improve product quality.

4.6 World Championship Cheese Contest

Since its inception in 1957, the World Championship Cheese Contest (conducted on odd-number years) has grown rapidly and is now the largest international cheese and butter competition in the world. Hosted by the non-profit Wisconsin Cheese Makers Association, the World Championship Cheese Contest is a technical evaluation of cheese and butter, by class (Fig. 4.10).

Fig. 4.10 Emblem of the World Championship Cheese Contest

The American Cheese Society

T		A		TOTAL SCORE	

Technical Judge Scoresheet for 2006 Cheese Competition

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

TECHNICAL JUDGES WILL DEDUCT POINTS FOR DEFECTS IN CHEESE QUALITY.

1. AROMA **3** points maximum **Score** ☐

ammoniated/rancid ❑ moldy or stale ❑ animal or barnyard ❑ chemical aroma ❑
unclean ❑ unpleasantly earthy aroma ❑ other: ______

2. FLAVOR **25** points maximum **Score** ☐

ammoniated/rancid ❑ too acidic ❑ chemical/soapy ❑ too sour ❑ cooked/burned ❑
bitter/metallic ❑ feedy/fruity ❑ too salty ❑ lacking flavor/weak ❑ moldy/too earthy ❑
blue mold flavor too harsh ❑ too much smoke or oil flavor (categories K or L) ❑
other: ______

3. TEXTURE AND BODY **15** points maximum **Score** ☐

cracked ❑ crumbly ❑ curdy ❑ gassy ❑ mealy ❑ waxy ❑ weak ❑
hard or corky ❑ slits ❑ chalky ❑ too open ❑ too soft ❑
poor eye formation ❑ incorrect hole formation (mechanical,pin,gas) ❑
other: ______

4. APPEARANCE/RIND DEVELOPMENT **7** points maximum **Score** ☐

whey taint ❑ cracked or disturbed rind ❑ too moist or wet ❑ uneven ❑ puffy ❑
crooked or lopsided ❑ surface mold ❑ blistered ❑ uneven color ❑ flaking ❑
other:

ADDITIONAL COMMENTS

Technical Judge's Score ☐

Fig. 4.11 Technical Judge Scoresheet for 2006 ACS Cheese Competition

The judges, trained experts in cheese evaluation, examine entries and deduct points for defects. Seven cheese experts from the U.S. and seven international experts evaluate products. Judges work in teams of two to evaluate entries with in a designated class. 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

Aesthetic Judge Scoresheet for 2006 Cheese Competition

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

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

1. AROMA **3** points maximum **Score** ☐

fresh cream ❑ pleasantly fruity ❑ nutty ❑ sweet ❑ woody ❑ fresh herbs ❑

floral/fresh flowers ❑ buttery ❑ buttermilk ❑ other values: ______

2. FLAVOR **30** points maximum **Score** ☐

new or noteworthy flavor profile (explain) ______

butter/cream/milk flavors are in balance with acidity ❑ sharp - not harsh ❑

herb and/or spice flavors in balance with cheese flavors ❑ tangy finish ❑ desirable aftertaste ❑

other flavor comments: ______

3. TEXTURE AND BODY **7** points maximum **Score** ☐

smooth/rich texture ❑ piquant (pleasant edge or bite in finish) ❑balanced mouthfeel ❑

evenly moist ❑evenly firm ❑ evenly smooth/spreadable ❑

other texture values/comments: ______

4. APPEARANCE/RIND DEVELOPMENT **10** points maximum **Score** ☐

rind appeal - visually noteworthy (explain) ______

double rinded ❑ desirable shape or design ❑ desirable use of color ❑

desirable use of flavorings ❑ other values/comments:

ADDITIONAL COMMENTS

Aesthetic Judge's Score ☐

Fig. 4.12 Aesthetic Judge Scoresheet for 2006 ACS Cheese Competition 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 U.S. 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 U.S. $1,000. All winners are honored at a gala Awards Banquet during the International Cheese Technology Exposition. On alternate years, (even number) the U.S. Championship Cheese Contest is conducted by the Wisconsin Cheese Makers Association (since 1980).

4.7 World Dairy Expo Championship Dairy Product Contest

Sponsored by the Wisconsin Dairy Products Association, the World Dairy Expo Championship Dairy Product Contest is in its fourth year (as of 2006). The most unique thing about the World Dairy Expo Championship Dairy Product Contest is that it involves all dairy product categories, including the special separate, creative and innovative technologies category. The category is a totally open category for highlighting creative uses of dairy products. Any dairy product not listed under any other appropriate category can be submitted under this category. The given product can be for retail or non-commercial use. *Some entry examples include: smoothies, probiotic products, dairy-based beverages and desserts, novelty cheese products, sports drinks, frappuccinos, calcium-fortified products, cheesecakes, etc.* The submitted product must contain a minimum of 25% dairy ingredients.

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 promote a focus on high quality dairy products quality. 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 and 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 and Cream Products

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Courtesy of Quality Chekd Dairies, Inc.

5.1 Introduction

Milk has almost a 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 3.5% milkfat, lowfat milk 1–2%, 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 U.S. is about

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S. Clark et al. (eds.), *The Sensory Evaluation of Dairy Products*,
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79.61 L (IDFA, 2006). 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 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 (Dunkley, 1982).

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). 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 (Polyanskii et al., 2005; Hutchinson et al., 2005). Psychrophilic bacteria (i.e., the genus *Pseudomonas* sp.) are primarily responsible for spoilage or deterioration of milk prior to pasteurization. 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 300000 CFU/mL before pasteurization and usually ranged between 12000 and 60000 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 indicated that some plants had greater bacterial count differences among test days than others (Fromm and Boor, 2004). The findings suggested that the processing plant as well as processing conditions, production, volume, and sanitation practices significantly influenced the final microbial numbers.

Microbial spoilage of fluid milk after pasteurization has been attributed to either Gram-negative bacteria that contaminate milk postpasteurization or some Gram-positive microorganisms that are able to survive pasteurization (Ternström et al., 1993). 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 and Boor, 2004). A similar study found that fillers were the main source of microbial contamination during processing and the common postpasteurization contaminants were psychrotrophic Gram-negative bacteria (Gruetzmacher and 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 and Kasper, 1993; Tetra Pak, 2003).

5.3 Market Milk

5.3.1 Classes of Milk

Milk in the U.S., 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 institution, 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 U.S., market milk is currently "Grade A pasteurized" for all practical purposes. The 2005 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 2005 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 lowfat milk

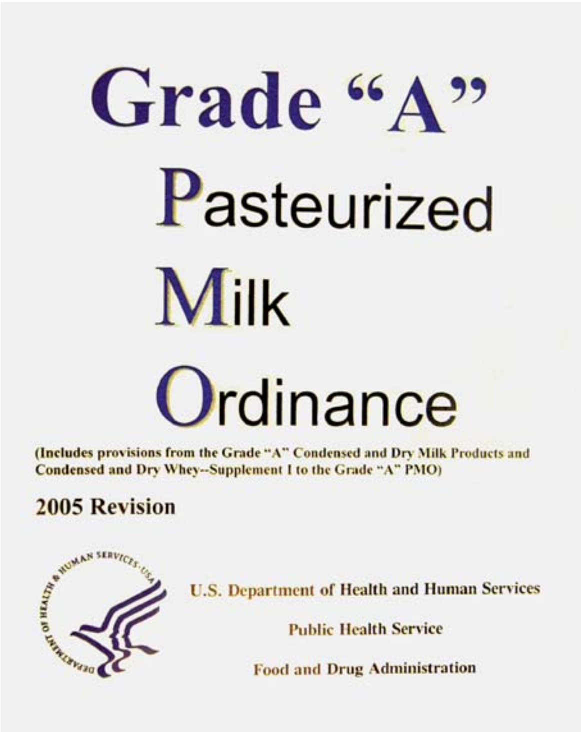


Fig. 5.1 The USPHS/FDA Grade A Pasteurized Milk Ordinance (PMO) 2005 recommendations (with appropriate revisions) serve as an important model code for most states and fluid milk and cream products in interstate commerce

(1 or 2% milkfat), skim milk, light cream, whipping cream, and/or half-and-half. 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 facilities' standards established for producing Grade A raw milk. Recommended requirements for manufacturing grade milk have been issued by the U.S. Department of Agriculture, Consumer and Marketing Service, under the title "Milk for Manufacturing Purposes and Its Production and Processing," 2005. Currently, the vast majority of raw milk produced in North America meets Grade A requirements.

Classes of utilization. The U.S. 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 assure consumers of adequate supplies of pure and wholesome milk at all times.

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 lowfat 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 is particularly true for market milk. The 2005 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 U.S. Public Health Service, Pasteurized Milk Ordinance 2005. 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 U.S. 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 2005 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
72	161	15 s
89	191	1 s
90	201	0.5 s
94	204	0.05 s
100	212	0.01s

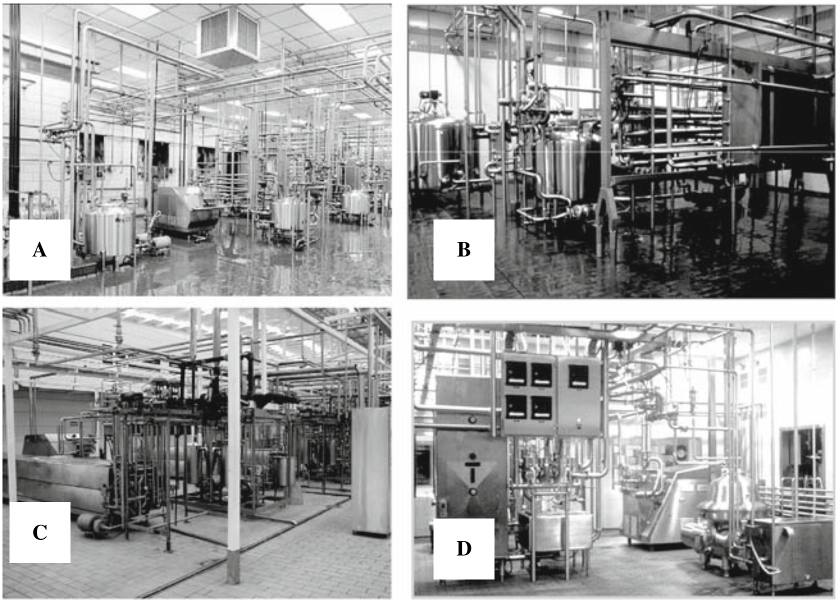
* If the milkfat content is 10% or more, or if it contains added sweeteners, the specified temperature shall be increased by 3°C (5°F), provided that eggnog shall be heated to at least the following temperature and time combinations:

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 (Herreid and Tobias, 1959; Hall and Trout, 1967; Henderson, 1971; Jones and Harper, 1976; Tetra Pak, 2003) 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 Pak, 2003). 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 Pak, 2003).

Pasteurized milk 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 (Gould and Sommer, 1939; Gould, 1940; Patton et al., 1956; Swaisgood, 1980; Sliwkowski and Swaisgood, 1980; Badings et al., 1981; Boelrijk et al., 2003). The initial flavor intensity depends on the temperature and holding time employed, as well as the method of heating.



Courtesy of Seiberling Associates, Inc.

Fig. 5.2 A, B, C. Examples of typical pasteurization systems for fluid milk products. **A**: A modern U.S. HTST centralized pasteurization room. **B**: A meter-based HTST pasteurization system. **C**: Ultra-high temperature (UHT) system. **D**: Cream separator and clarifier

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.

Practically all milk marketed in the U.S. is both pasteurized and homogenized. "Homogenized" is defined in the 2005 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." Except for being homogenized, homogenized milk does not differ in composition or any other provision of the definition from unhomogenized milk. However, there are some differences between the two products in their susceptibility to development of certain off-flavors (Dorner and Widmer, 1932; Doan, 1933; Halloran and

Trout, 1932; Tracy et al., 1933; Hood and White, 1934; Trout, 1940, 1941, 1950); 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 nonhomogenized 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). Later studies reported that oxidation of milkfat leads to development of undesirable flavors in nonhomogenized milk. The decrease in milkfat oxidation, after homogenization, is due to antioxidant properties of sulfhydryl compounds formed during heat treatment of milk (Smith and Dunkley, 1962; Shipe et al., 1978).

Research by Dunkley (1968) supported the tendency of milk flavor changes for nonhomogenized 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; Dunkley et al., 1962b; Wishner, 1964; Parks, 1965). The "re-distribution" 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 (Tracy et al., 1933; Shipe, 1964; Parks, 1965).

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 and Hill, 1992). 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 changes 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 (Strobel et al., 1953; Nursten, 1997). Oxidation (auto-oxidative) and hydrolytic rancidity (lipolytic) reactions are common in milk flavor development. Oxidation of milkfat produces the development of undesirable flavors in nonhomogenized 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 (Min and Boff, 2002). Singlet oxygen is the electron-rich reactive specie 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 a 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 (Min and Boff, 2002). 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 (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 postpasteurization 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 (Shipe et al., 1978; Fromm and Boor, 2004). Additionally, psychrotrophic Gram-negative microorganisms are responsible for postpasteurization 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). This 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 (Fitz-Gerald, 1974; Deeth, 1986). 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. Doan (1933) found that the critical temperature for inhibiting rancidity development in homogenized milk by flash heating was ~63.9°C (~147°F). Recent studies report 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 and Shahani, 1964; Tetra Pak, 2003). Furthermore, it must be emphasized that raw milk must never be mixed with homogenized milk in the course of 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 nonhomogenized milk. This was first noted in studies by Tracy et al. (1933), and later substantiated by other researchers (Cervato et al., 1999; 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 nonhomogenized, 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 (Shipe et al., 1978; Min and Boff, 2002). 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 and the flavor associated with it has been described as cabbagey, burnt, burnt protein, burnt feathers, and medicinal (Ogden, 1993).

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. The ESL technologies may include ultra-high-temperature pasteurization (UHT), or ultra-pasteurization (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 (Hansen, 1987). 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 U.S. 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 could also be found, such as in the case of Asian markets importing milk from Australia and New Zealand (Sepulveda et al., 2005).

Organic milk. This category of milk is processed following the guidelines for Grade A Pasteurized Milk. However, the U.S. 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 2005, organic milk represented less than 1% of the total 6.2 billion gallon milk market. Although organic milk can sell for up to double the cost of other milk, the demand for this milk continues to increase (Schultz, 2006). The demand for organic milk has been linked to perceived health benefits, or environmental and animal rights’ issues.

Sedimentation. Although sedimentation is not a prevalent issue in pasteurized fluid milk, the following discussion may be helpful as 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 (Hood and White, 1934; Trout, 1940, 1941; 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.

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 2005 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 lowfat 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 (Weckel and Chicoye, 1954; 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 U.S. milk processors.

Lowfat milk. The legal definition of milk is given in the U.S. Code of Federal Regulations, 21 CFR 131.110. However, 21CFR 101.62 deals with the labeling of lowfat products. Lowfat 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%. Lowfat 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 lowfat 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 lowfat 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 lowfat milk; preferences will vary with the individual.

Optional ingredients in lowfat milk include concentrated skim milk, nonfat dry milk, or other milk-derived ingredients to increase the nonfat solids 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, the lowfat 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 on 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 U.S. Code of Federal Regulations, 21 CFR 131.110. However, 21CFR 101.62 deals with the legal requirements for labeling milk as "skim." Skim differs from lowfat 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 lowfat 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 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, and sulfur compounds (Forss, 1979). 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). 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).

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. Despite the fact that 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 are due to lipid oxidation (Hall et al., 1985; Hall and Anderson, 1985; Hough et al., 1992). 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 (Scott et al., 2003).

Commercially sterile and UHT milk. The 2005 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 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. 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. During storage, the intensity of the cooked flavor gradually diminishes, so that under the most favorable circumstances, a sterilized product may taste similar to 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 and Swaisgood, 1980). 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 (1989) and Sederstrom and Peterson (2005). None of the preceding methods of reducing cooked flavor in UHT milk have been commercialized.

5.5 Precautions for Evaluating Raw Milk

Raw milk has been, and continues to be, discussed for nutritional and safety reasons in the epidemiological literature. Therefore, there are no common rules regarding the sale and consumption of raw milk in the U.S.. 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. Twenty-nine states have recorded foodborne outbreaks traceable to raw milk consumption (NASDA, 2004). Furthermore, 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). Outbreaks associated with the consumption of raw milk occur every year. In 1995, the Center for Food Safety and Applied Nutrition and the U.S. Food and Drug Administration published guidelines that established a list of pathogen organisms transmitted through raw milk and milk products, such as *Salmonella* spp., *Staphyloccocus aureus, Campylobacter jejuni, Yersina 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 2005 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 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. Hence, appropriate techniques need to be employed to insure 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 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).

Miscellaneous products. The 2005 PMO describes low-sodium milk, whole milk, lowfat milk, skim milk, and lactose-reduced milk. Other dietary products may also be encountered where permitted by local ordinances, in the form of mineral- and/or vitamin-fortified milk. The flavor properties of such products should be evaluated in a manner similar to milk. These "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. Hence, some effect on flavor (taste) would be expected, but these products should be relatively free of other flavor defects common to milk.

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 USDA/ADSA (2005) scorecard is evaluated on a 10-point scale according to the scoring guide (Table 5.1). A 100-point scorecard similar to the original U.S. 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

Table 5.1 A suggested scoring guide for sediment in processed milk

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

* Stirred sample. Disks with so little sediment do not reproduce clearly enough to be illustrated. (See 7 CFR 58.134).

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

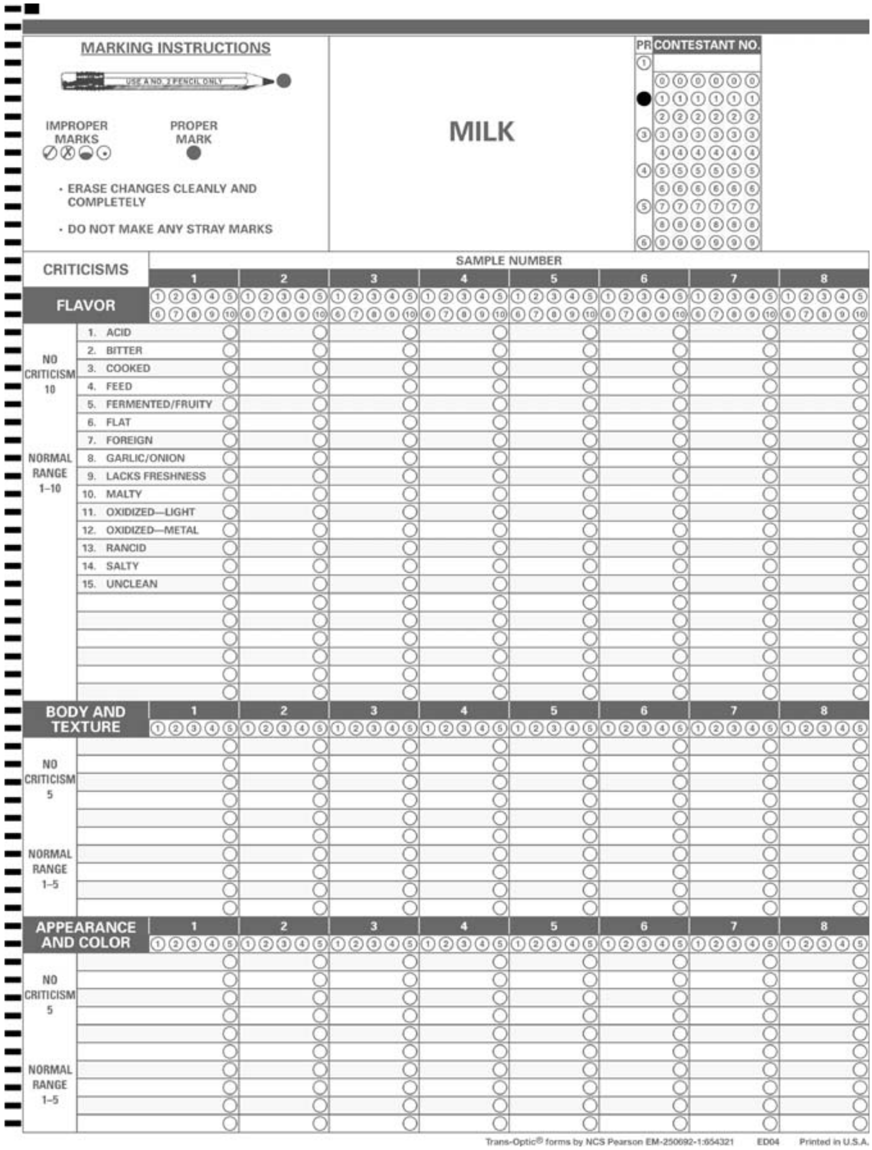
		1	2	3	4	5	6	7	8	9	10	Total Score
8 points	*Student Score*											
	Official Score											
	Grade Difference											______

Problem Solving

		Total Score
		______
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

sensory observations may be in use by individual companies or have been developed for specific purposes (Fig. 5.3). The ADSA Committee on Evaluation of Dairy Products 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 was slightly modified in 2005 (Fig. 5.4).


MARKING INSTRUCTIONS

USE A NO. 2 PENCIL ONLY

IMPROPER MARKS

PROPER MARK

• ERASE CHANGES CLEANLY AND COMPLETELY

• DO NOT MAKE ANY STRAY MARKS

MILK

PR CONTESTANT NO.

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

FLAVOR

NO CRITICISM 10

NORMAL RANGE 1–10

1. ACID
2. BITTER
3. COOKED
4. FEED
5. FERMENTED/FRUITY
6. FLAT
7. FOREIGN
8. GARLIC/ONION
9. LACKS FRESHNESS
10. MALTY
11. OXIDIZED—LIGHT
12. OXIDIZED—METAL
13. RANCID
14. SALTY
15. UNCLEAN

BODY AND TEXTURE — 1 2 3 4 5 6 7 8

NO CRITICISM 5

NORMAL RANGE 1–5

APPEARANCE AND COLOR — 1 2 3 4 5 6 7 8

NO CRITICISM 5

NORMAL RANGE 1–5

Trans-Optic® forms by NCS Pearson EM-250692-1:654321 ED04 Printed in U.S.A.

Fig. 5.4 Scorecard of the National Collegiate Dairy Products Evaluation Contest of the American Dairy Science Association (ADSA)

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. The specific methods for sample preparation are found in 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.

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, Dairy Standardization Branch.

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 2005 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 paper containers. An examination of the heat seal of the carton is appropriate. 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 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 2005 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. As soon as 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. 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.

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.

5.8 Requirements of High-Quality Fluid Milk

Evaluating sediment in milk. 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 (U.S. 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

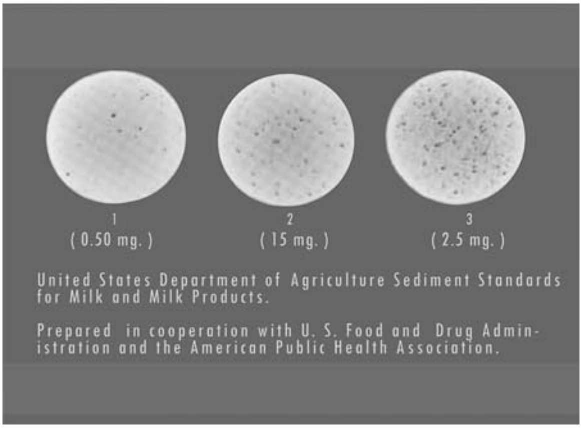


Fig. 5.5 Standard discs that represent known weights of sediment for a given volume of tempered milk sample (one pint)

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 nonhomogenized 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.

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.

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: 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 examination of milk for bacterial content is a laboratory procedure that can be performed by a qualified technician who

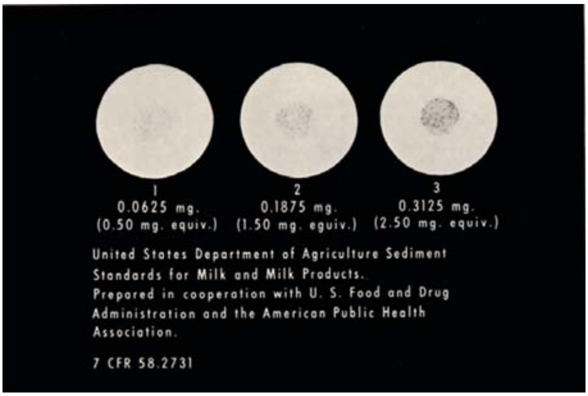


Fig. 5.6 A small grouping of sediment discs that demonstrate various weights of extraneous material per pint of milk

may have no experience in milk judging. The maximum permissible bacterial counts for raw Grade A and pasteurized market milk are specified in the 2005 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 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

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
>8,000–12,000	4–6	3
>3,000–8,000	1–3	4
≤3,000	0	5

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

1 coliform/ml would receive a score of “2” on the basis of the 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 and 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 solids-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; 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 U.S. 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.

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.

The term "unsealed" is used to mean "not tamperproof." Closures that meet the requirements of the 2005 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

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

assigned a score of “5.0.” At the other extreme, any milk container that does not meet the 2005 PMO recommendations should be disqualified and assigned a score of “0.” Containers that are dirty inside, 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.

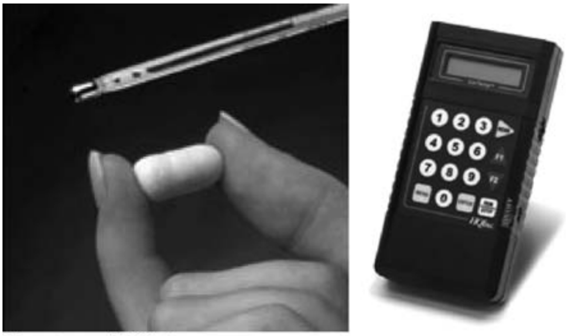
Evaluating temperature. The temperature at which pasteurized market milk and other fluid products are held is very important in determining the keeping quality, and for retention of good flavor characteristics. Even commercially sterile milk, which is microbiologically stable at room temperature, may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

The 2005 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 and Davidson, 1975, 1976).

A number of packaging materials have been developed recently that will change color if a food product has undergone temperature abuse. Also, small-scale and relatively inexpensive devices such as that shown in Fig. 5.7 are available for continuously monitoring the temperature of the storage environment of milk and other perishable products.

Balasubramaniam and Sastry (1996) have developed a “temperature pill,” a device designed to transmit temperature data from within a food container

Fig. 5.7 A continuous monitoring device for measuring and recording temperatures of a food storage environment



Courtesy of HQ, Inc.

Fig. 5.8 A wireless "temperature pill" and data recorder for continuous measurement of the internal temperature of a milk container

to a remote antenna. With this approach, it is possible to get an actual time–temperature history of a carton of milk over the entire shelf life of the product immediately after postpasteurization packaging. Commercial temperature pill devices (Fig. 5.8) are the approximate size of a large medicine capsule, and include an inert polymer outer coating, battery, temperature sensor, and temperature data transmitter. Transmitted data from the temperature pill may be received and recorded by an external data logger (Fig. 5.7).

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 2-point scale may be employed. A sample that 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 and 7.2°C (40 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 2005 PMO are as follows: "Cooled to 7°C (45°F) or less within two hours 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 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). 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.

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 which suggest scores for milk that possess varied intensities of specific defects. Two scoring guides for milk, one developed by the 2005 Committee on Evaluation of Dairy Products of the American Dairy Science Association, and the other by Bodyfelt et al. (1988), are illustrated in Tables 5.6 and 5.7, respectively. 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 (Bodyfelt et al., 1988). 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 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.

Table 5.5 The 2005 ADSA scoring guide for off-flavors of milk and cream

	Intensity of defect		
Flavor defect	Slight	Definite	Pronounced
Acid	3	1	*
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	*
Salty	8	6	4
Unclean	3	1	*

* Unsalable

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

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: **A**bsorbed (barny, cowy, feed, garlic/onion), **B**acterial (acid, bitter, fruity/fermented, malty, rancid, unclean [i.e., psychrotrophic]), **C**hemical (astringent,

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)

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).

cooked, lacks freshness, light oxidized, metal oxidized, rancid) and **D**elinquency (flat, foreign, salty, unclean). When considering the values associated with the various off-flavors on the ADSA 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, cowy* have been removed from the ADSA milk scorecard, due to general improvements in the quality of the U.S. milk supply. However, since these defects may occur in other countries or in rare instances in the U.S., 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 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 are tasting 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, -lactones, phytol and acetone derivates, and volatile carbonyl products present in fresh milk. Methyl sulfide contributes significantly to the characteristic flavor of milk (Patton et al., 1956; Bendall, 2001). 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, benxothiazole, *cis*-3-methyl--nonalactone, indole, -12:2, and -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 (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 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 (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 the elapse of 24 h 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 (Fink and Kessler, 1986; Calvo and De La Hoz, 1992; Anderson and Oste, 1992). This 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 caramel-like note frequently intensifies and becomes increasingly more objectionable with increased storage.

Gould and Sommer (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). This distinguishes it from the more aromatic sensation suggestive of sulfides, which is more typical of the cooked flavor (Patton et al., 1956; Boelrijk et al., 2003).

In the report of the 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 of 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. Of particular note, when a heated flavor occurs in milk or cream products, an accompanying oxidized off-flavor is seldom, if ever, present (Calvo and De La Hoz, 1992). This 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 (Hedrick, 1955; Mounchilli et al., 2005). This 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 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 U.S. 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.

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 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" (Morgan, 1976; Crow et al., 2002; Hayes et al., 2002). 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 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).

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 Collegiate Dairy Products Evaluation Contest, 2% lowfat milk is evaluated, which contains approximately 1.2–2% 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.

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 (Mostafa, 1999). The character and intensity of weed off-flavors depends 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 an obnoxious 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. 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 [$\sim$ 18.2°C ($\sim$ 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 simultaneously perceive the malty aroma and the acid taste (or odor). 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 (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 (Smith and Dunkley, 1962; Bassette et al., 1986; Havemose et al., 2006; Hedegaard et al., 2006). 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 auto-oxidation by way of free radical formation, which yield aldehydes, ketones, and other offensive end products within the milk.

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 and Min, 2006).

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) 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." 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 and 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 (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 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 light-induced and the generic oxidized off-flavor.

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 (Shipe et al., 1978; Fromm and Boor, 2004). Short-chain fatty acids (butyric, caproic, caprylic, lauric, and capric 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) native milk lipase is not inactivated by heating, or (2) 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 (Caric, 1993), or (3) raw milk is agitated excessively (or frozen), thus rupturing the milkfat globule membrane that exposes the milkfat to native lipase (becomes susceptible to lipases secreted by spoilage bacteria).

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 high-temperature-short-time (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 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 most 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 ($\sim$ 7.2°C or $\sim$ 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, 1980b; Bradley, 1983; Hankin and Anderson, 1969; Hankin and Stephans, 1972; Hankin et al., 1977; Mikolajcik and Simon, 1978; Polyanskii et al., 2005; Hutchinson 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. This 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 milk flavor quality ideal 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 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 (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.

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.

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* a. Rancidity—In raw milk; bitter, soapy off-flavor; defect more intense in cream than in milk, and more intense in butter than in cream b. Oxidized—Occurs most often in raw and unhomogenized pasteurized milk; cardboardy; metallic; tallowy; odor similar to wet cardboard c. 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)

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 postpasteurization contaminants that can easily produce objectionable spoilage off-flavors such as the fruity, unclean, rancid, and bitter off-flavors. With

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

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)?

the increased usage of transparent or translucent plastic milk containers, the light-activated off-flavor has become more prevalent (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; Kim et al., 1980; Kilic and Lindsay, 2005). Also, dry lot feeding (with either none or minimal pasture or green feeds) has become quite prevalent with U.S. 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 the year-round in order 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, I, and Se 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 Pb and Cd were 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 omega 3 fatty acids were found in organic and conventional milk. Organic milkfat contained >0.56% C18:3 omega 3 whereas conventional milk contained 0.53% (Molkentin and Giesemann, 2007).

A recent study identified greater percentages of unsaturated fatty acids, including two common isomers of conjugated linoleic acid in milk from cows fed with pasture-based forage (Croissant et al., 2007). The above analytical results showed that there are 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 lowfat milk and skim milk), chocolate milk is by far the most popular one in the U.S. (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 viscosity so thick 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 nonchocolate 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 toward 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; 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 Other Uncultured Fluid Dairy Products

Included in this category are skim milk, lowfat milk, half-and-half, light cream, light whipping cream, and heavy cream. 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, lowfat 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 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 lowfat milk fortified with vitamin A. Fluid milk processors continue to occasionally experience puzzling off-flavors in vitamin-fortified milk, apparently caused by the auto-oxidation 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. Lowfat 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.

Lowfat milk. The CFR definition for lowfat milk was provided earlier in this chapter. Since the milkfat content may vary from 0.5 to 2%, the sensory properties of lowfat 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). 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 and Duncan, 1996). However, if the milkfat content is high, 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 improves 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. 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 and Kessler, 1989). The most practical protocol is to homogenize the cream base at the lowest possible range of homogenization pressures in order to achieve noncream-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 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: (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 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 re-form 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 U.S.. However, demand for the various types of whipping creams peaks dramatically during the U.S. seasons of Thanksgiving and Christmas through the New Years holiday. Interestingly, many U.S. 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 U.S. 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 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 solids 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 Chapter 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.

5.13 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. 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

Butter, as defined by Webster's dictionary, is a solid light yellow emulsion of fat, air, and water made by churning milk or cream and used as a food. 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.

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The Standards for U.S. grades of butter are addressed in Title 7 of the Code of Federal Regulations (2002), Part 58, and Subpart P.

6.2 Butter Defined (CFR 58.305)

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 according to its quality grade in the U.S. These butter grades are based on sensory quality and are assigned by competent “official” graders who conduct prescribed sensory examinations of the product. 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 U.S.

In addition, to milkfat, butter contains moisture, curd (milk proteins, milk ash, lactose, and other minor constituents), and common salt (usually). Thus, the 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 U.S. butter supply, but for all practical purposes this form is nearly extinct. Currently, all commercial butter in the U.S. is creamery or factory made butter (Wilster 1968). 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).

6.3 Ingredients for Buttermaking

A typical butter manufacturing facility starts with either fresh milk or cream 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 cream to cream-buying stations, which in turn supplied the butter manufacturing plants. At the creamery receiving platform, the cream had to be carefully graded, since most of it came from small producers who produced the 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, containers, or to the storage temperature of the raw cream.

The vastly improved quality of current U.S. butter supplies is primarily due to the "fresh milk system" of the creamery operation. As the overall quality of the U.S. milk supply continues to improve, low-grade butter either has or soon will be expected to practically disappear (Hunziker 1940, Wilster 1968).

6.4 Kinds of Butter

Sweet cream butter.The majority of the butter in the U.S. market is of the "sweet cream" type. The "sweet cream" designation implies that the apparent titratable acidity of the churning cream did not exceed 0.10% (calculated as lactic acid). Currently most cream probably has no "developed acidity" whatsoever. Bulk forms of sweet cream butter that are free of off-flavors normally receive U.S. Grades AA, A, or B (when and if graded).

Cultured cream butter. "Cultured cream butter" is ideally made starting with high-quality sweet cream in which a pleasant delicate aroma was developed by the addition of lactic culture prior to churning. The cream (or a portion of the cream) is inoculated with a carefully selected lactic culture (starter) for the production of certain 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 working it directly into the butter.

Other butter types.The addition of salt to butter is optional as expressed in the standard. The salt intensity of butter can vary over a wide range (0.75–2.5%). Most of the butter on the U.S. market is salted, and the trend in recent years has been toward more slightly salted (<1.5%) butter. The various types of butter available to U.S. consumers (although not necessarily in all markets) include lightly salted and unsalted butters; cultured cream salted and unsalted butters; whipped butters; and flavored butters (e.g., spices, herbs, honey, fruit, or berries).

Whipped butter is available for both institutional and home use. The air or gas (preferably nitrogen) is incorporated by a whipping process that changes the body characteristics and generally improves product spreadability.

Whey cream butter. This butter is sometimes termed "blended cream butter" and usually is made from a mixture of sweet cream and whey cream. Whey cream is derived from the separation of milkfat from cheese whey. It is frequently an inferior product because of its flavor profile and lack of casein compared to sweet cream butter. For reasons of this lesser flavor character and its lack of frozen storage stability, 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. If "whey cream" flavor is detected by a USDA-Dairy grader, the butter will be marked "undergrade." 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.

Miscellaneous spreads. Other products which emulate butter are margarine, butter–margarine blends, and "lowfat spreads" made from either milkfat and/or vegetable oil. Vegetable oils with differing melting points are the principal constituents of margarine. 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; melting, spreading and non-burning when used for frying.

6.5 Grading Milk and Cream for Buttermaking

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

The cream used for buttermaking is generally graded in accordance with the grade of butter that can be made from it (if properly processed). A close review of flavor defects (and their respective intensities) associated with various butter grades reveals that most of the frequently encountered butter off-flavors are derived from the cream. Some off-flavors may result from faulty cream or milk; handling, processing, or churning; and certain other flavor defects may develop in the finished butter. Butter flavor defects that may be derived wholly or in part from cream include (some of which are summarized in Table 6.1): acid, barny, cheesy, coarse, feed, foreign, fruity, metallic/oxidized, old cream, onion/garlic, rancid (lipase), scorched, unclean, unnatural, and yeasty.

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. Appropriate segregation into quality groups may be simply and practically accomplished by the sense of smell at receiving. The same precautions that apply to the sensory evaluation of raw milk are applicable to raw cream. Due to the potential health hazard of tasting raw products, a laboratory pasteurization procedure should be designed and used for a small sample that insures adequate destruction of potential pathogens. Developed acidity in cream may require neutralization with approved alkaline chemicals, which is done prior to pasteurization.

Table 6.1 USDA classification of flavor characteristics

Identified flavors	Flavor classification AA	A	B
Feed	S	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

S – slight; D – definite; P – pronounced; – – not applicable.

Title 7, Code of Federal Regulations (2006), Part 58.334 addresses quality specifications for cream as follows:

58.334 Pasteurization. The cream for buttermaking shall be pasteurized at a temperature of not less than 165°F (74°C) and held continuously in a vat at such temperature for not less than 30 minutes; or pasteurized at a temperature of not less than 185°F (85°C) and held continuously for not less than 15 seconds; or it shall be pasteurized by any other equivalent temperature and holding time which will assure adequate pasteurization.

Sensory examination. Cream received at a receiving plant or substation shall be identified as to the producer, seller, or shipper from whom it was received. Each shipment shall be examined for physical characteristics, off-tastes, and off-odors. The condition of the cream shall be wholesome and characteristic of normal cream. The sensory examination and segregation of the cream which is used in the manufacturing or processing into butter shall be consistent with the applicable flavor classification of butter set forth in the U.S. Standards for Grades of Butter.

6.6 Grades of Butter

Since April 1977, the U.S. Department of Agriculture (USDA) has recognized only three consumer grades of butter, namely, U.S. Grade AA, U.S. Grade A, and U.S. Grade B (Code of Federal Regulations 2006). The U.S.

Grade C designation was deleted at that time in recognition of the substantial improvements that had been made in cream and butter quality. Handling and production practices for cream and whole milk improved so markedly by the mid-1970s that only insignificant quantities of butter of U.S. Grade C were assigned. U.S. Grade designations based on numerical values (previously used as an alternative to the letter grade) were also deleted in 1977. Thus, the highest quality butter was known as U.S. Grade AA or "U.S. 93-score" butter. Other equivalent designations were Grade A and "92-score," Grade B and "90-score," and Grade C and "89-score (United States Department of Agriculture Agricultural Marketing Service, Dairy Division 1989)." Numerous butter samples entered in competitions or contests were frequently scored higher than 93 points. Sometimes those particular "high" scores approached, though probably rarely achieved, the mythical "perfection of 100 points." Butter judges and contest officials still employ the 100-point scoring system for butter exhibits, trade association, and/or State fair competitions (Bodyfelt et al. 1988).

Since so much butter is evaluated by government graders prior to marketing, the USDA grading system for butter should be examined at this point. The following tables provide an overview of the USDA butter grading process. For example, to merit U.S. 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 (which pertains to butter body, and color and salt content and distribution), a concept known as a "disrating" is used see (Table 6.2). For

Table 6.2 Characteristics and disratings for body, color, and salt of butter

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

S – slight; D – definite; P – pronounced; – – not applicable.

Table 6.3 Flavor classification and total disratings in body, color, and salt characteristics permitted in each grade of butter

Flavor classifications	Total disratings	U.S. Grade
AA	1/2	AA
AA	1	A
AA	1 1/2	B
A	1	B
B	1/2	B

Grade AA butter, the total permissible disrating for a "workmanship fault" is only 0.5 points (Tables 6.3 and 6.4). Thus for a given butter, the flavor classification may actually be "AA," but the assigned U.S. 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.

Section 58.2628. Relation of U.S. Grade Butter to the flavor classification as affected by disratings for body, color, and salt characteristics.

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."

6.7 Techniques of Butter Grading

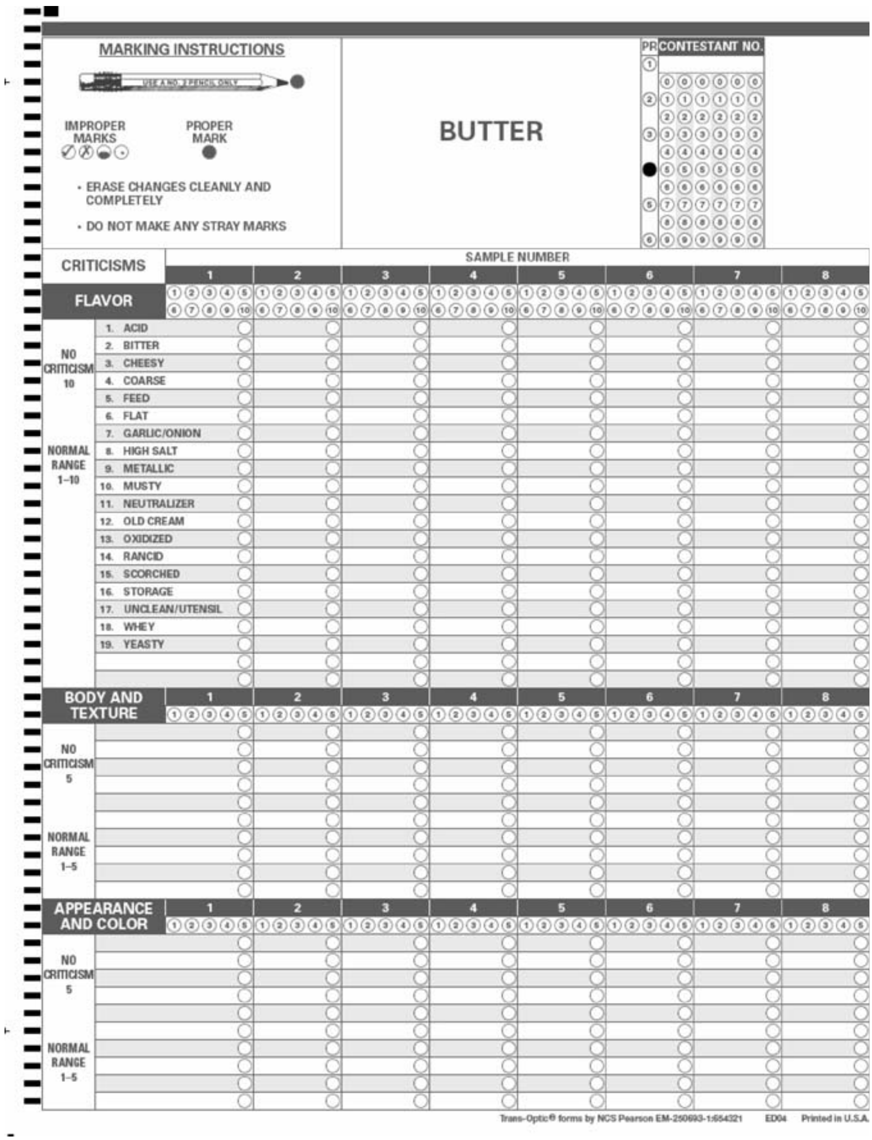
*The butter scorecard.*The USDA grading system for butter may be inappropriate for some quality assurance activities or for those situations wherein the quality of one product is compared with that of others. A group of products may include some samples for which a U.S. grade is not assignable, but which solicit 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. The butter scorecard and scoring guides were adopted from those proposed by the (American Dairy Science Association 2006). This scorecard is the same one used in the National Collegiate Dairy Products Evaluation Contest (Fig. 6.1) except that Body and Texture, and Appearance and Color are not evaluated in student competitions because product temperature cannot be sufficiently controlled over the duration of the competition and the surface of the butter samples is marred by numerous student samplings. Butter scoring in the Collegiate Contest is delineated in Fig. 6.2.

*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 6.4 Examples of the relation of U.S. butter grades to flavor classification and total disratings for body, color, and salt classifications

Example no.	Flavor classification	Disrating Body	Disrating Color	Disrating Salt	Total disrating	Permitted total disrating	Disratings in excess of total permitted	U.S.Grade
1	AA	1/2	0	0	1/2	1/2	0	AA
2	AA	1/2	1/2	0	1	1/2	1/2	A
3	AA	0	1	0	1	1/2	1/2	A
4	AA	1/2	1	0	1 1/2	1/2	1	B
5	A	1/2	0	0	1/2	1/2	0	A
6	A	0	1/2	1/2	1	1/2	1/2	B
7	A	0	1	0	1	1/2	1/2	B
8	B	1/2	0	0	1/2	1/2	0	B

Source: Code of Federal Regulations (2002)


MARKING INSTRUCTIONS

USE A NO. 2 PENCIL ONLY

IMPROPER MARKS | PROPER MARK

• ERASE CHANGES CLEANLY AND COMPLETELY

• DO NOT MAKE ANY STRAY MARKS

BUTTER

PR | CONTESTANT NO.

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

FLAVOR

NO CRITICISM 10

NORMAL RANGE 1–10

1. ACID
2. BITTER
3. CHEESY
4. COARSE
5. FEED
6. FLAT
7. GARLIC/ONION
8. HIGH SALT
9. METALLIC
10. MUSTY
11. NEUTRALIZER
12. OLD CREAM
13. OXIDIZED
14. RANCID
15. SCORCHED
16. STORAGE
17. UNCLEAN/UTENSIL
18. WHEY
19. YEASTY

BODY AND TEXTURE | 1 2 3 4 5 6 7 8

NO CRITICISM 5

NORMAL RANGE 1–5

APPEARANCE AND COLOR | 1 2 3 4 5 6 7 8

NO CRITICISM 5

NORMAL RANGE 1–5

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Fig. 6.1 Collegiate Dairy Products Evaluation Contest Scorecard

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 for sensory evaluation. Butter stored at temperatures colder than 50°F (10°C) should be moved into the grading or sensory evaluation room in advance of judging to allow tempering to 50°F (10°C). Adjusting the temperature of butter samples is commonly

Fig. 6.2 Scores designated for flavor evaluation of butter in the Collegiate Dairy Products Evaluation Competition

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

referred to as "tempering." Guidelines for Federal (USDA) Graders state that the temperature of butter at the time of grading is quite important when determining the true characteristics of body and texture; products should be between 45 and 55°F (7–13°C). The lower the temperature at which butter is stored, the longer will be the time required for tempering in the judging room. 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, possibly overnight under some conditions, 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 of assessment.

Use of the butter trier.Samples are taken by a two-edged, curved bladed tool known as a "trier" as seen in Fig. 6.3. Means for cleaning the trier and disposal

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

of waste butter should be provided. The trier should not be washed in warm water (prior to use) but should be wiped with a single-service towel or absorbent paper. 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 the hands will usually come in direct contact with the butter during the 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 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. 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.

*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. 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) and their relative degree of clarity. Furthermore, the amount of butter clinging to the back of the trier should be carefully noted.

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 break 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.

6.8 Other Considerations in Butter Quality Evaluation

6.8.1 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 (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 U.S. 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.

6.8.2 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.

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. 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. 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.

6.9 Color and Appearance

A uniform light, pale yellow color seems to most often meet the demand for expectations of U.S. 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. Such a yellow color is commonly associated with milkfat, 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 imparted to milkfat). 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
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

Faulty 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 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. 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.

6.10 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.

The evaluator should determine whether the physical features of the plug seem to disappear. High-quality butter should melt evenly and disappear slowly. 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 iron-like 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 U.S., 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 salts 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; and (5) the manufacturing equipment and churning methods used.

6.10.1 Body and Texture Defects of Butter and Their General Causes

Briefly, 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 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:

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. 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 (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 gum-like 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, 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" as seen in Fig. 6.4. 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.

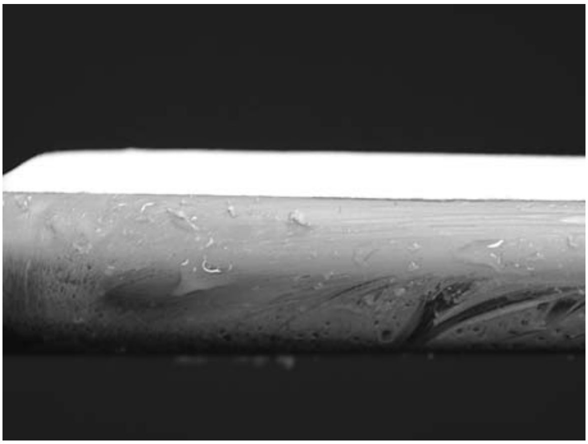

Fig. 6.4 An example of "leaky" butter; note moisture droplets on the trier

Leaky butter as a defect has disappeared with advent of the use of continuous churns. Fortunately, all of the above problems associated with leaky butter have nearly disappeared with advent of the use of continuous churns. However, traces of free moisture can occasionally be found, in 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, or adding too much oiled-off rework.

Improper melting of frozen cream, allowing milkfat in cream to separate or "oil-off" in the pasteurizer balance tank or remelting butter re-work in a vat 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 churning techniques, 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 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, the holding temperature of cream 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 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. 6.5. 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,

Fig. 6.5 An example of "short"-bodied butter

smooth-surfaced plug from such butter. The butter plug will appear "ragged" or "rough." This is particularly the case when the trier is cold. Since the market generally demands butter that spreads relatively easily, a sticky body is quite undesirable. As stated earlier, when crumbly or brittle-textured butter is overworked, the entire mass tends to become sticky. In fact, a sticky body and crumbly texture are often present concurrently in butter. A sticky body (as is crumbly- or brittle-textured butter) is observed most frequently in late fall and winter when there is a greater predominance of high-melting triglycerides in churning cream. Hence, 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, seem to markedly affect the occurrence of the sticky defect.

Weak. A "weak" body is typically indicated by a quick meltdown or 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; there is a tendency for the trier to "cut in" on the plug. When the ball of the thumb is pressed against a plug of "weak" butter, difficulty is often encountered in defining a distinct "breaking point" for the plug. Supposedly, a weak body is due to a state of incomplete milkfat crystallization, which results in an excess of milkfat in the liquid form within such butter. Incomplete crystallization of the milkfat may be caused by inadequate tempering of pasteurized cream, or due to a relatively high proportion of low-melting point triglycerides in the cream. 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' and milkfat producing regions of the country, it would seem appropriate that 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.

6.10.2 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 pertinent, 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 (i.e., demonstrated beyond any doubt), for the dual defects to be recorded.

6.11 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 as seen in Fig. 6.6. If obtained properly, this portion of butter represents 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 should continue manipulating 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

Fig. 6.6 Individual students evaluate butter in a recent Collegiate Dairy Products Evaluation Contest

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 is advised to prevent carry over 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 and studied. 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. Having done this, 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.

6.11.1 Characteristics of the Various Flavor Defects

High-quality butter should have a mild, 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 can be fermented. When buttermilk is retained (frequently indicated by a milky brine), it is often 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 U.S. grades; however, only the "storage" criticism appears on the grading sheet recognized by the Committee on Evaluation of Dairy Products of the American Dairy Science Association (2006). However, the "old cream" term (detailed later) is a part only of the Collegiate Contest scorecard. In the case of the ADSA grading sheet, both of these butter flavor defects are considered to be various stages or intensities of the same process of product deterioration.

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 tends to prevail to an extent beyond a "range of ordinary acceptability." Usually, the cause is simply the addition of too much salt, though uneven distribution of salt and water 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 comments 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."

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 at a relatively high temperature. 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). U.S. 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 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 actually allowed in U.S. 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 the first few months 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 (esp. 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, they 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.

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 to develop a cooked flavor in cream 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, 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, which are objectionable, are occasionally found in butter. They are easily detected from the distinctive odors suggestive of their names. Both of these off-flavors can be feed contaminants and are most pronounced when samples are warmed to body temperature. Interestingly, 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 extends throughout the entire tasting period and generally persists after the sample has been expectorated. The malty off-flavor results from the outgrowth of *Lactoccoccus 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-flavor is 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. 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 rates. 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 butter scorecard currently approved by the Committee on Evaluation of Dairy Products of the American Dairy Science

Association (2006) contains two entries for oxidized off-flavor: metallic and oxidized. The term "oxidized" best describes the metal-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 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 and Lindsay, 1984), but a vacuum pasteurization treatment will significantly decrease the level. A characteristic of the rancid off-flavor (which is 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. 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 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.

Unclean/utensil. As the term implies, the "unclean/utensil" 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 actually 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.

Weedy. "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. Some weeds are more common in early spring, when cows are in weed-infested pastures, while other weeds seem more prevalent in late summer or fall. Specific weeds cause characteristic off-flavors in butter, which are readily detected when encountered. Weed off-flavors are more pronounced after samples are warmed to body 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 present practice is to allow the assigned sample score to reflect 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.

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 dough-like). 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.

6.12 Frequency of Sensory Defects in Butter

Apparently, no known statistics are 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 U.S. 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 semi-automation 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.

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

Table 6.5 The 100-point contest butter grading sheet

Quality attribute	Perfect score
Flavor	45
Body and texture	30
Color	10
Package and appearance	5
Salt	10
Total score	100

consumers. Hence, applicable quality assurance precautions must be taken during the production of milk, cream separation, and the subsequent stages of butter manufacturing.

While the delicate flavor of butter can be markedly influenced by the feed of the bovine, flavor is amazingly consistent around the country. The student evaluator quickly finds out that 1.0 to 1.5% salt added to butter adds a whole, new dimension to perceived flavor. Both unsalted butter and salted butter have unique flavors that have never been duplicated and particularly the heated butter flavors.

Understanding scoring techniques is vital whether using the ADSA or USDA-Dairy methods. 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 while the other are additive. Flavor takes the score of the most serious defect if more than one is apparent.

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Chapter 7
Creamed Cottage Cheese

Floyd W. Bodyfelt and Dave Potter

7.1 Cottage Cheese Defined

Creamed cottage cheese is a soft, unripened cheese that is usually made by the acid 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), salted, and packaged.

Cottage cheese is consumed as a fresh product (within a maximum of 3–4 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 U.S. cottage cheese processors to incorporate a dried fermentate produced from *Propionibacterium shermanii* (Sandine 1984) and/or CO_2 into cream dressing (Chen and Hotchkiss 1991, Hotchkiss and Chen 1996) before addition to the curd. This process has shown to routinely extend the shelf life of commercial cottage cheese to up to 6 or 7 weeks. There remain a 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). Hence, the addition of carefully selected lactic microorganisms to the dressing can simultaneously serve to significantly enhance flavor and increase the shelf life of creamed cottage cheese.

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7.2 Cottage Cheese – An American Original

Creamed cottage cheese is an American (or U.S.-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 U.S. Several other cheese types considered to be U.S. 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 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, OR, said "lets build a factory" to manufacture and sell this new product we have mastered – creamed cottage cheese. Thus, *the* commercialization of creamed cottage cheese in the Pacific Northwest (Angevine 1964, Davies 1942, Olsen 1980) was the place and date (1915) of origin of this fresh cheese by this enterprising husband and wife team, and the springboard for would-be cottage cheesemakers in the upper midwestern U.S. This initial development of the U.S. cottage cheese industry and early technical expertise (the early pioneers and heroes) for the quality manufacture of this product are 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 non-existent. 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 (Nat. 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," 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.
4. The flavor profile for this new cheese product was "mild" and fresh tasting – thus providing flavor appeal to many prospective customers.

7.4 Types of Cottage Cheese

Creamed cottage cheese is the general term used to designate the fresh, soft, uncured, high-moisture (not over 80%) cheese made usually from pasteurized sweet 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. More recently, regional versions of cottage cheese have been labeled as New York, and California-style (Kosikowski and 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 (Kosikowski and Vistry 1997), and a unique Louisiana-style known as "Creole Cream Cheese" (an uncooked and congealed curd with half-and-half as a dressing (Potter 2007)).

Creamed cottage cheese marketed in U.S. 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 ("direct set" or "acidified").
2. ***Breaking or cutting the coagulum*** by
   a. Rigorous stirring (i.e., farmer-style, old fashioned, 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 (1.3–1.6 cm [3/8–5/8 in.])
      (3) Large curd (1.6–1.9 cm [5/8–3/4 in.])
3. ***Method of creaming*** (or not) by
   a. Traditional addition of cream dressing (~10% milkfat) at a typical ratio of 3 parts curd : 2 parts dressing; thus, resulting in ~4% milkfat in the final product.
   b. Addition of a lower milkfat "dressing mixture" (~3–6% milkfat content) to attain a 1 or 2% milkfat 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) No addition of a lactic culture to the creaming mixture.
      (2) Direct addition of an aroma-producing lactic culture (*S. lactis* subsp. *S. diacetylactis* and/or *Leuconostoc* ssp.) to the creaming mixture.
      (3) Addition of a dried cultured fermentate produced from *Propionibacterum shermanii* (primarily via the Microgard™ or Durafresh™ process) directly to the creaming mixture for a 2–3 fold increase in shelf life (Salih et al. 1990, Sandine 1984).
      (4) 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 (Chen and Hotchkiss 1991, Hotchkiss and 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. Dry unsalted curd is also sold in retail packages for use in cooking, baking, salads and for use in special “low salt,” “lowfat,” “low cholesterol,” and/or “reduced calorie” diets. Un-creamed 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 possess a highly appealing flavor. Most likely, a distinctive flat, 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. 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 odor. Initially, creamed cottage cheese tends to be 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. If facilities and time are available, the equivalent of a large tablespoonful of creamed cottage cheese can be “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 that may have escaped identification otherwise (i.e., by observing only unwashed cottage cheese).

7.5.2 Sensory Attribute Categories of Cottage Cheese

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

7.5.2.1 Color and Appearance

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 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. Figures 7.1 and 7.2 illustrate various appearance and color attributes of creamed cottage cheese. The ADSA scoring guide for various sensory defects of creamed cottage cheese (including flavor, body and texture, appearance and

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 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
	2. Too aggressive/abusive agitation during cooking	Use proper cutting techniques, train personnel in careful cutting, agitating, andcurd cooking methods

Table 7.1 (continued)

Color/Appearance defects	Probable causes	Remedial measures
Matted	1. Cutting pH of curd too high	Cut curd at pH of 4.65–4.70
	2. Insufficient/inadequate agitation especially during the first hour of cooking	Employ a "standardized" method of cooking and stirring out
	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 solids 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.

color) is presented as Table 7.1. This scoring guide serves as the standardized guideline by which the contestants in the National and Mid-West 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.

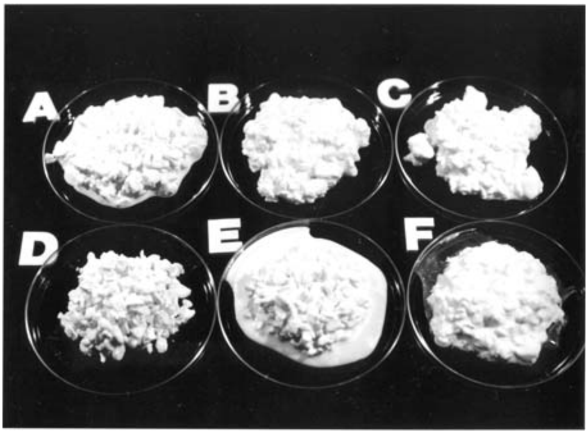


Fig. 7.1 Examples of some of the more common color and appearance defects of creamed cottage cheese: **A** a reference sample for the "ideal" appearance; **B** shattered curd; **C** matted curd; **D** lacks cream; **E** free cream; **F** free whey

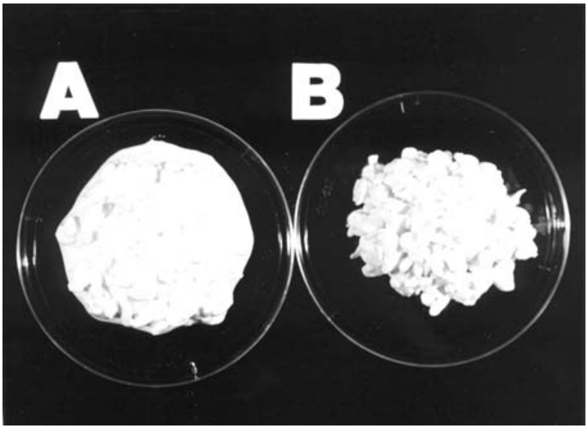


Fig. 7.2 A demonstration of the uniformity of curd size and curd shape by two different approaches: **A** careful visual examination of creamed curd; **B** visual examination of "washed" curd

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, 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 and 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.

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.

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). The curd particles are expected to be relatively uniform in both size and configuration for the given type of curd being considered. Understandably, the size of curd particles and the relative degree of firmness of cottage cheese curd in the U.S. has not been fully and objectively standardized (Kosikowski and Brown, 1973; Rosenberg et al. 1994a, 1994b).

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 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 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 (Fig. 7.1). By tearing apart curd particles, the evaluator can more 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.

Body and Texture Defects of Creamed Cottage Cheese

The more common body and texture defects of cottage cheese are

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

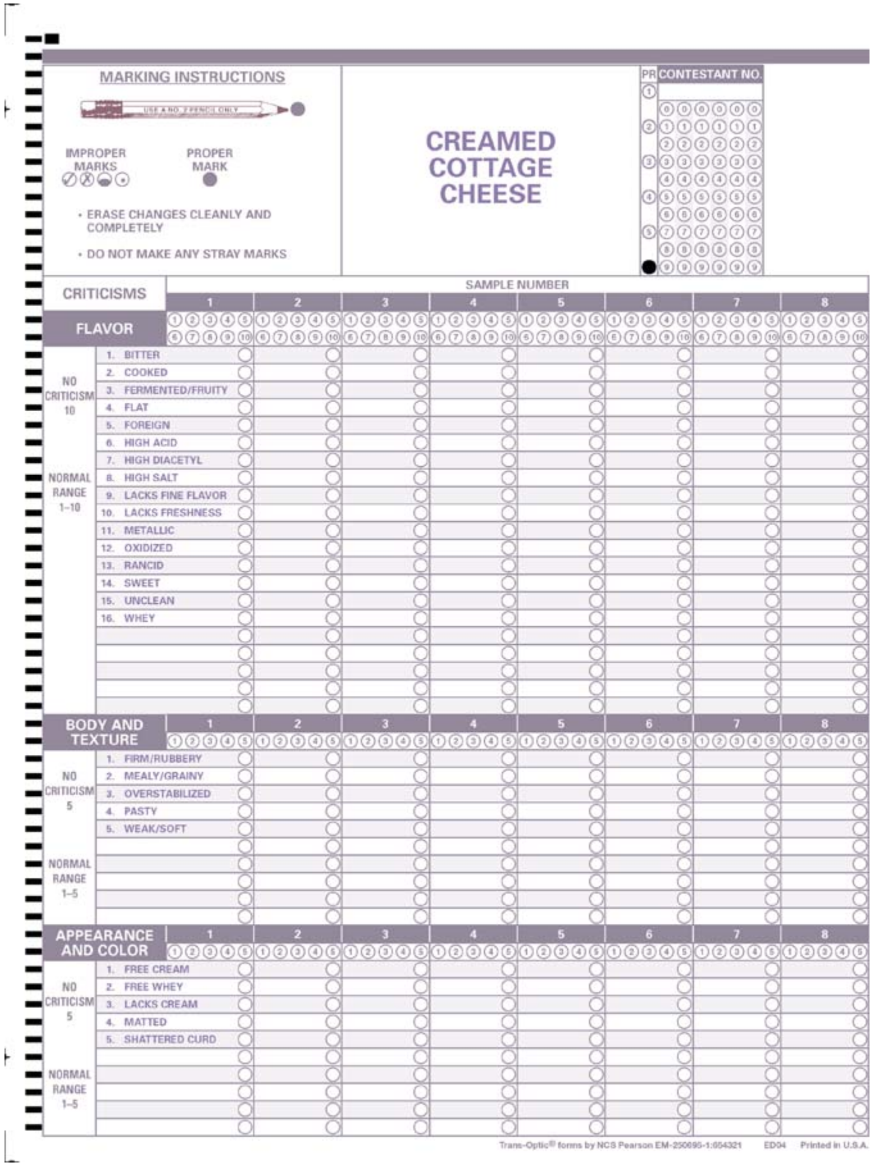
Brief descriptions of the characteristics that are indicative of the above-listed body and texture defects of creamed cottage cheese are detailed in the following paragraphs. The intensities of various body and texture defects are usually scored according to the guide for scoring creamed cottage cheese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

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 ADSA 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 U.S. cottage cheese. The "mealy/gritty" (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). Another way of detecting curd graininess is to "wash" away the cream dressing, carefully knead the 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 un-creamed 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


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. 7.3 ADSA scorecard for sensory evaluation of creamed cottage cheese (American Dairy Science Ass'n. 1987)

incorporated by cooking the curd more gradually and by use of 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) non-uniform cutting of the curd; (2) uneven heating (cooking) of portions of the curd; (3) too-rapid cooking of the curd/whey

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.

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. 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 high(er) 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.

Table 7.3 The ADSA 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

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

1. Excessive heat treatment of cheese milk.
2. Excessive acidity (low pH) at time of cutting coagulum and during cooking.
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. 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. 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 and 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 U.S., wherein variations of the intensity of the acidity taste and the diacetyl flavor note are either more or less preferred (Mather and Babel 1959, Connolly et al. 1984, Bodyfelt et al. 1988, Rosenberg et al. 1994a, Kosikowski and Mistry 1997).

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 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. Cream dressing should be added in such quantities that the curd can readily absorb it within a reasonable time period before marketing (5–24 h). The evaluator should recognize the possibility of two types of cream dressing, often depending on the U.S. 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.

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

- Bitter
- Cooked
- Fermented/fruity
- Flat (lacks flavor)
- Foreign, chemical, medicinal
- High acid (sour)
- High diacetyl
- High salt
- Lacks fine flavor (acetaldehyde, plain yogurt-like)
- Lacks freshness (stale, storage)
- Malty (not on ADSA/Collegiate Contest scorecard)
- Metallic
- Musty (not on ADSA/Collegiate Contest scorecard)
- Oxidized
- Rancid
- Unclean (dirty aftertaste)
- Whey
- Yeasty (vinegar-like; not on ADSA/Collegiate Contest scorecard)

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).

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. Some observers have noted that certain types of stabilizers and/or emulsifiers, if used to excess, can also contribute to this off-taste.

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). 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, not 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.

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 may result in too much whey retention 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 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 flavor of high-quality cottage cheese. Addition of 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.

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 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 milkfat 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 ADSA 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 milkfat 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 milkfat, 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.

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. 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 (Bodyfelt 1981a, 1981b, Morgan 1970a, 1970b).

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 U.S. 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 non-existent, 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).

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 U.S. 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 U.S. 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 products 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 U.S. 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 U.S. 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, lowfat 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 became 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 U.S. 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

U.S. cottage cheese per capita consumption has remained relatively level throughout the past 7–10 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 has 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

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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 and 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 T. 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.

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

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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 1, 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 unfortunately 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 U.S. However, yogurt popularity commenced in the late 1930s and 1940s when Columbo and Danone (later renamed Dannon in the U.S.) began yogurt businesses on the east coast in the U.S. (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.

8.2 Yogurt Defined

The CFR 131.200 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; CFR, 2008a). 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 percent milkfat 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, dried maltose syrup; malt extract, dried malt extract; malt syrup, dried malt syrup; honey; and/or maple sugar may be used (U.S. Food and Drug Administration 2007).

8.2.1 Lowfat Yogurt Defined

The CFR 131.203 definition of lowfat yogurt includes "Lowfat yogurt is the food produced by culturing one or more of the optional dairy ingredients with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (CFR, 2008b). One or more optional ingredients may also be added, but must be done so prior to culturing".

Lowfat yogurt, before the addition of bulky flavors, contains not less than 0.5% nor more than 2% milkfat and not less than 8.25% milk solids not fat, and has a titratable acidity of not less than 0.9%, expressed as lactic acid. The food 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, lowfat yogurt may be heat treated after culturing is completed, to destroy viable microorganisms.

Optional dairy ingredients include cream, milk, partially skimmed milk, or skim milk, used alone or in combination with concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat solids content of the food provided that (1) the ratio of protein to total nonfat solids of the food and the protein efficiency ratio (P.E.F.) of all proteins present shall not be decreased as a result of adding such ingredients; (2) 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, dried maltose syrup; malt extract, dried malt extract; malt syrup, dried malt syrup; honey; and maple sugar may be also used (U.S. Food and Drug Administration, 2007).

8.2.2 Nonfat Yogurt Defined

The CFR description of nonfat yogurt states that it is the food produced by culturing one or more of the optional dairy ingredients with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (CFR, 2008c). One or more other optional ingredients may also be added. When one or more of the ingredients are used, they shall be included in the culturing process. All ingredients used are safe and suitable. Nonfat yogurt, before the addition of bulky flavors, contains less than 0.5% milkfat and not less than 8.25% milk solids not fat, and has a titratable acidity of not less than 0.9%, expressed as lactic acid. The food 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, nonfat yogurt may be heat treated after culturing is completed, to destroy viable microorganisms.

Optional dairy ingredients that may be used are; cream, milk, partially skimmed milk, or skim milk, used alone or in combination. Other optional ingredients are concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat solids content of the food provided that the ratio of protein to total nonfat solids of the food and the protein efficiency ratio 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, dried maltose syrup; malt extract, dried malt extract; malt syrup, dried malt syrup; honey; and maple sugar may be used. Color additives, fruit, flavors, and stabilizers are also allowed (U.S. Food and Drug Administration, 2007).

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 thermophilus* and *Lactobacillus 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 (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 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

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, VE 2005). 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 anti-microbial 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. acidolphilus* propagation are 35–38°C (95–100°F), with maximums of 45–48°C (113–118°F).
2. *Bifidobacteria infantis* and longum (*B. infantis and B. longum*) 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 immuno-competence, as measured by impact on mean corpuscular volume of red blood cells and macrophages (Gibson, 2001).
3. Several types of capsule formers, microorganisms that can be used to produce unique polysaccharides, increase the viscosity of yogurt. Certain strains of *S. thermophilus* and *L. bulgaricus* in regular cultures display little polysaccharide-capsule-forming ability. However, certain cultures produce polysaccharide levels that exhibit improved viscosity. Wise discrimination in the selection and use of capsule formers may relieve excessive reliance on stabilizers and a richer, creamier texture can be achieved even in lowfat or nonfat products. 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 U.S. now 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; however, for mild-flavored yogurt the cocci:rods ratio may be as high as 15:1.
2. *Fermentation*. A properly conducted product 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 typically outnumber the lactobacilli by three or four to one within the first hour to two hours. 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 "nutty" 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 lower pH 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 product 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 in regard to body and texture, depending upon the type of ingredients, processing, starter cultures, flavor, and packaging that is used.

The processing of yogurts can be broken down into the following steps: blending, pasteurization, homogenization, culturing and cooling, packaging and storage. Each is extremely important in the process, and strict attention to detail must be taken.

Blending. There are a number of different types of blending equipment that are available and used by yogurt manufacturers. 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; such as nonfat dry milk, whey or whey protein, sugars, and/or stabilizers.

Regardless of the blender used, the purpose of using the blender is to speed up the time it takes to add the dry ingredients, and to aid in the dispersion of the dry ingredients. 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 will remain in the tank after emptying.

Many yogurt production plants pre-heat the milk prior to adding the dry ingredients, and generally, this is helpful to completely hydrate the stabilizer and aid in mixing and suspension, but it is not absolutely necessary. The most important aspect of ingredients blending is to incorporate as little air as possible, and to completely and to add the dry ingredients to the base without forming lumps. After the blending process, adequate agitation is important in the holding tank to keep the ingredients suspended. After blending, it is common to hold and agitate the yogurt mix up to 4 h prior to pasteurization, which helps native starch and gelatin to hydrate.

8.5.1 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. In addition, it is very important to denature the proteins to attain the highest level of functionality from the milk proteins. 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. 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 length of holding tube), and (3) ultra-high 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 hold tubes for an additional 5–20 min at the pasteurization temperature in order to denature whey proteins and improve product viscosity.

8.5.2 Homogenization of Yogurt Mixes

Yogurt mix homogenization 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 1st stage and 3 MPa (500 psi) in the 2 nd stage, or alternatively, 7 MPa (1000 psi) 1st stage and 3 MPa (500 psi) 2 nd 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 pasteurizator, and some homogenize after the cooling section.

Composition of the yogurt stabilizer can affect the homogenization pressure and temperature that is used. Some gums and starches that 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, defects such as weak body, syneresis, or wheying-off. Processing recommendations from stabilizer supplier representatives are advised for material sources and utilization strategies.

8.5.3 Culturing the Yogurt Mix (Stirred Style)

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 dependant 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 equipments 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 Culturing the Yogurt (Set-in-the-Cup)

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 is pumped and filled prior to incubation. During the pumping and filling it is common for the mix to cool several degrees. Therefore, it is import 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 dependant 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 and 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 prior to packaging as well. Addition of the fruit–flavor system is commonly completed in line. Some possible concerns with the fruit are sinking or 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 discuss 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 pH 4.4–4.6. This usually takes between 5 and 6 hours depending upon regional differences and variations in solids levels, and heat treatments. 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 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 are both moving 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.

8.5.6 Packaging and Cooling

After the product smoothing and filling steps, the filled fruit yogurt cups may be placed into either a corrugated box or a tray, and then over-wrapped 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 hours. 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 non-homogenous 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 U.S. is packaged in three sizes: 170 g (6 oz), 230 g (8 oz), and 910 g (32 oz). 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 10 flavours for flavored yogurt (ranked from most to least popular; Euromonitor, 2007) are

Vanilla
Strawberry
Mixed berry
Blueberry
Peach
Raspberry
Strawberry/banana
Cherry
Lemon
Key lime

Many additional yogurt flavors have been developed, but are either a version of the top 10 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 5 flavors constitute approximately 80% of all flavored yogurt sales.

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.

Starch. Starch is the major carbohydrate reserve in plant tubers and seed endosperm, where it is found as granules, each typically containing several million amylo-pectin molecules accompanied by a much larger number of smaller amylose molecules. The largest source of starch in the U.S. 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 stabilizers. It is a protein that is derived from the partial hydrolysis of 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 isremoved and the 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 extracted from the seeds of the Carob tree (*Ceratonia siliqua*), is a galactomannan. 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 beat 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 an 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 dependant 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 iso-propylalcohol, followed by centrifugation, drying and milling. Xanthan gum is soluble in cold water and is both thixotrophic 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, VE 2005).

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 thixotrophic. 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 Yogurt Sensory Defects

8.8.1 Body and Texture

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 mis-handling 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 actions 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. 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.

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, as well as (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 S. 2004).

In determining a corrective action, it is a good idea to check all processing procedures to ensure correct make 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.

Gel like/too firm. This attribute has the appearance of formed gelatin in the cup (or on the plate), and a very firm set. 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. 8.1) should have little or moderate resistance, and should melt-away very smoothly. Gel like or too firm (Fig. 8.2) 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

Fig. 8.1 Ideal yogurt body

representative to confirm proper usage and incorporation of the best or correct stabilizer for the given yogurt mix formulation (Lyck S. 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 non-nutritive 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 structure that was created by the stabilizer, culture and proteins, or combinations thereof (Bodyfelt et al. 1988).

Fig. 8.2 Gel-like or too firm yogurt appearance

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 S. 2004).

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. 8.3). The causes of shrunken defect are many, but fortunately, the corrective action is relatively easy. Defect causes can include heat shock (temperature abuse), too high acid production, too high stabilizer usage or incorrect stabilizer used, or disruption of the yogurt mass – after container filling and while the yogurt is knitting together.

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 S. 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 un-appealing. 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 S. 2004).

Ropy. Ropy yogurt texture is detected by placing a spoon into a yogurt mass, lifting the spoon. If the observer readily views a trailing stream (or stringiness)

Fig. 8.3 Shrunken yogurt exhibiting free whey

of yogurt between the spoon edge and the product container, it is Ropy. This defect can be confirmed by placing the bottom of the spoon on top of the yogurt mass and slowly raising the spoon vertically for 5–13 cm (2–5 in.). If there is a tail or string of more than 2 in., the product is considered “ropy”. 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-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 equipments are being cleaned and sanitized properly (Lyck S. 2004).

8.8.2 Color and Appearance Defects

Atypical color. Atypical color (Figs. 8.4 and 8.5) 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. Atypical color is usually observed in those products that are

Fig. 8.4 Strawberry yogurt exhibiting atypical color (*light*) (*See* Color Plates)

Fig. 8.5 Atypical color (*dark*) (*See* Color Plates)

labeled "all-natural", or 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.

Problem corrections involve the utilization of only high-quality fruits and fruits-based materials that have acid-stable color, plus storage of yogurt and fruit flavorings under proper temperature conditions.

Color leaching. This defect reflects a difference in color between the yogurt mass and the added fruit. Color leaching (Fig. 8.6) commonly shows up as a ring or a halo effect around pieces of fruit or berry, which is caused by a difference in

Fig. 8.6 Color leaching (*See* Color Plates)

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 (Fig. 8.7) 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.

To best prevent or control the frequency of this defect, one needs to confirm that the proper amount of fruit has been added. 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, 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.

Lumpy. This unpleasant appearance defect causes the yogurt mass to appear rough, uneven, and non-homogenous. It somewhat resembles the surface of cauliflower. Lumpy yogurt (Fig. 8.8) is unattractive although it may not affect

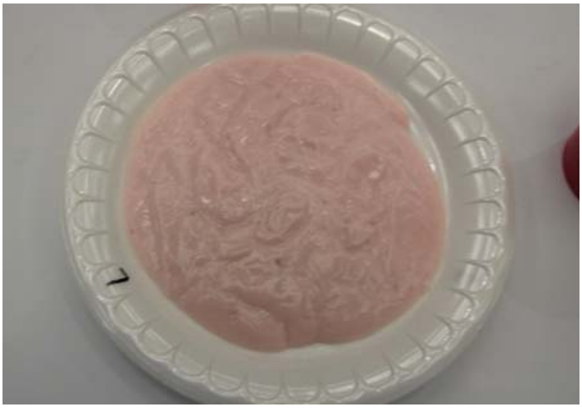


Fig. 8.7 Lacks fruit

Fig. 8.8 Lumpy

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 use of a smoothing-device helps eliminate this issue.

8.8.3 Flavor Defects

High acetaldehyde. Acetaldehyde is the chemical compound responsible for the traditional green-apple flavor produced by yogurt bacteria. This flavor note is common in practically all 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. As mentioned, it is a natural, always present flavor common to yogurts. 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 flavours, 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, D. 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, as well as 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 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, 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, D. 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. 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" has either a stale off-flavor, a storage off-flavor, or happens to be a product that is at or near the end of its shelf life. 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 very 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 is 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 out-dated 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 "card boardy" 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 un-pasteurized 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 easy to detect and to remedy. It 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.

8.9 Procedures for Sensory Evaluation

The preparation for evaluating yogurt samples may be as critical as evaluating the samples themselves. 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 effect the 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, as well as 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.

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.

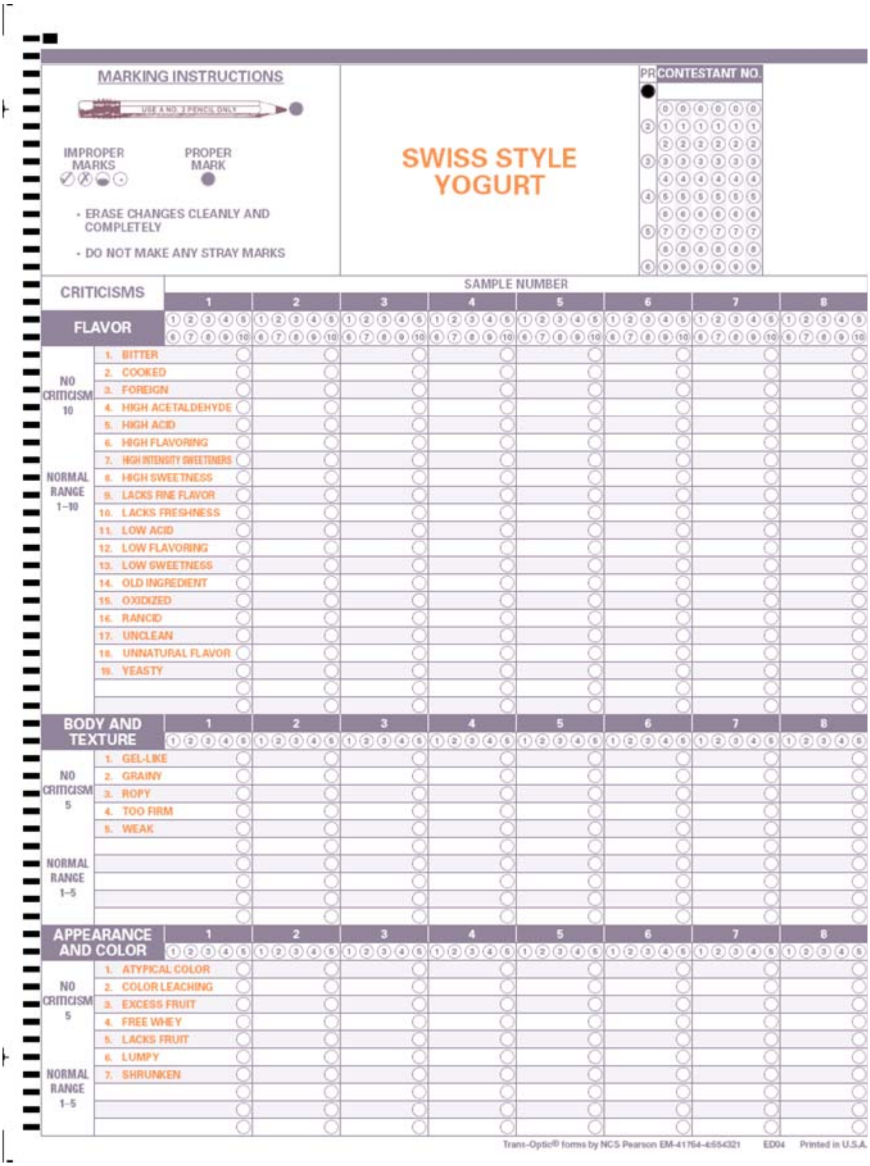
The precise time that the product is placed on the plate is noted. This is important, because yogurt will change in appearance as it warms up. Most visual changes occur after it is been left at room temperature for more than 15 min. After the yogurt has been placed on the plate, observers first notice the yogurt appear on the plate. For most yogurts, it should resemble a thick pudding with little to no running. Next notice if there are color streaksance associated with “color leaching”, and any unusual color. 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. 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 over-powering. 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.

The USDA scorecard system (Fig. 8.9) prescribes different penalties for different attributes and defects. These disparities are not arbitrary. Defects arising from egregious manufacturing errors, such as rancid, old ingredient, foreign, or oxidized, or spoilage issues, such as unclean or yeasty require greater penalties than less serious defects, such as low acid, high acetaldehyde, etc., which are less severely penalized (Table 8.1). The origin and remedies of the defects described in this chapter make it clear how to avoid these problems, and sensory evaluation is an invaluable tool that should be made a part of any quality assurance program.


MARKING INSTRUCTIONS

USE A NO. 2 PENCIL ONLY

IMPROPER MARKS

PROPER MARK

• ERASE CHANGES CLEANLY AND COMPLETELY

• DO NOT MAKE ANY STRAY MARKS

SWISS STYLE YOGURT

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. FOREIGN
4. HIGH ACETALDEHYDE
5. HIGH ACID
6. HIGH FLAVORING
7. HIGH INTENSITY SWEETENERS
8. HIGH SWEETNESS
9. LACKS FINE FLAVOR
10. LACKS FRESHNESS
11. LOW ACID
12. LOW FLAVORING
13. LOW SWEETNESS
14. OLD INGREDIENT
15. OXIDIZED
16. RANCID
17. UNCLEAN
18. UNNATURAL FLAVOR
19. YEASTY

BODY AND TEXTURE

NO CRITICISM 5

NORMAL RANGE 1–5

1. GEL-LIKE
2. GRAINY
3. ROPY
4. TOO FIRM
5. WEAK

APPEARANCE AND COLOR

NO CRITICISM 5

NORMAL RANGE 1–5

1. ATYPICAL COLOR
2. COLOR LEACHING
3. EXCESS FRUIT
4. FREE WHEY
5. LACKS FRUIT
6. LUMPY
7. SHRUNKEN

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Fig. 8.9 USDA Swiss Style Yogurt scorecard

A scorecard should suggest priorities for improving a product, tracking perceived attributes to likely origins, and indicating processing and product handling improvements. Perfect scores include 10 for flavor, 5 for body and texture and 5 for color and appearance sections.

Table 8.1 Suggested scoring guide (ADSA) for flavor and body and texture and appearance and color of strawberry Swiss style yogurt for designated defect intensities

Swiss style yogurt			
Flavor	Slight	Definite	Pronounced
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 sweetener	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/color			
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

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 Cheese

John A. Partridge

9.1 Introduction

A chapter on the evaluation of Cheddar cheese has been included in all of the previous editions of *Judging Dairy Products* (Nelson and Trout, 1964) and *Sensory Evaluation of Dairy Products* (Bodyfelt et al., 1988); the current author/editor would like to acknowledge the excellent work of the authors of

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the five previous editions. Much of the text in the current chapter is the result of the careful work of the previous authors with addition of new materials, deletion of redundancies, and a rearrangement of the chapter.

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 U.S. Commodity data from the U.S. Department of Agriculture show that Cheddar cheese increased from 5.8 pounds available per capita (papc) in 1970 to a high of 10.6 papc in 1987, and has subsequently fluctuated between 9.0 and 10.3 papc through 2005. 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 availability of Mozzarella has steadily risen from 1.2 papc in 1970 to 10.2 papc in 2005 (USDA, 2007). 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.

A cheese judge is often called upon to evaluate one or more varieties or types of cheese. To be proficient, the evaluator should be knowledgeable in the sensory characteristics and the desirable and undesirable qualities of each cheese variety under consideration. 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 sequence of procedures for grading will be followed by a section defining defects and attributes in detail. The use of the American Dairy Science Association (ADSA) 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 conversion of milk into finished Cheddar cheese can be divided into nine essential steps, which are the following:

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 consumption, 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 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 30–31.1°C (86–88°F).
2. *Ripening of milk*. The first addition to the tempered milk in the vat will be 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 accelerated ripening.

3. *Setting and cutting the curd*. Following 30–60 min of ripening, rennet or another coagulating enzyme will be added to induce the formation of the milk gel within 25–35 min. The milk gel (coagulum) will then be cut into individual curds using appropriate cheese knives (harps).
4. *Cooking the curds*. The curds will be allowed to heal for approximately 10–15 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 will be drained from the curds, which will be allowed to bind together, thus forming mats of curd. The mats will be cut into blocks 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 will be milled into approximately $^{3}/_{4}$″” × $^{3}/_{4}$″” × 3″” size curds. Modified make procedures that eliminate the Cheddaring step or add a wash after milling may be substituted for traditional practice for the manufacture of stirred or washed curd Cheddar, Colby, and Monterey Jack.
7. *Salting*. Salt is added to the properly acidified curd to help with moisture control as well as flavor and body and texture development of the finished cheese.
8. *Molding*. After mixing of the salt and curd, the curd is introduced to the molding step, 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. *Curing*. After extraction of the cheese from the mold, one of several types of coating or packaging materials is applied to the block as a barrier to oxygen and water. The barrier eliminates the growth of molds and prevents 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.

Numerous variations and sub-routines 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 (2006) (Table 9.1).

Table 9.1 Code of Federal Regulations for Cheddar-type cheeses

Cheese variety	CFR, Title 21, 2008 Paragraph:
Cheddar	133.113/114
Colby	133.118/119
Washed curd and soaked curd	133.136/137
Granular and stirred curd	133.144/145
Monterey and Monterey Jack	133.153

All of the varieties listed in Table 9.1 require a minimum milkfat content that will be at least 50% by weight of the solids. Given a constant milkfat-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-ten fold 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 and Lelievre, 1987).

Cheese curd retains the most important nutrients of milk. Most notable are the nutritionally complete protein, casein, as well as 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 milkfat content of the cheese milk to approximately 3.8%, thus maintaining a constant casein:milkfat 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 milkfat content of Cheddar cheese is about 31–35% of total weight (>50% of dry matter). Cheddar cheeses meeting the labeling requirements of reduced (25% reduction in fat), lowfat (3 g of fat or less in a reference serving of 30 g), or nonfat (0.5 g of fat or less in a reference serving of 30 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 milkfat and protein composition for each lactating species.

9.4 Federal (CFR) Definition and Standards

The U.S. government (Code of Federal Regulations [CFR], Title 21, Part 133.113 [2008]) 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, with or without the addition of coloring matter (usually annatto bean extract). Common salt (NaCl) is typically added.

9.5 Degree of Ripening

Much pasteurized milk Cheddar cheese is marketed shortly after manufacture (≤ 90 days), as a mild cheese or for use in producing processed cheese (Chapter 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 (sometimes years, for extra-sharp cheese flavor). Consequently, Cheddar may be found on the market in various stages of ripeness. For best results, cheese ripening requires carefully controlled temperature and humidity.

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 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 one and one-half to two years (Table 9.2).

The grading of cheese and assignment of extent of ripening designation for labeling is dependant 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 of curing have much to do with the nature and intensity of flavor in the cured product. However, development of typical Cheddar cheese flavor is so dependent on the age factor that it is not generally advisable to evaluate cheese of various age categories 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.

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

Table 9.2 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

Note: These are typical aging times for traditionally manufactured Cheddar and may vary slightly among cheese manufacturers. Modern accelerated ripening techniques significantly shorten this timetable.

displayed in Table 9.2, but should be judged by the same set of standards as any Cheddar cheese. The acceleration of ripening will also 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.

9.6 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. 9.1), 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 (Fig. 9.2) have evolved as the predominant forms and sizes in contemporary cheese manufacture for reasons of economy, ease of handling, and warehousing.

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"	15⁵⁄₁₆"
2	Favorite or ½ Young American....	5½	7" x 3½"	5⅜"
3	Young American..............	10	7" x 7"	9¹⁄₁₆"
5	Daisy....................	22	13½" x 4¼"	6⁵⁄₁₆"
27	Midget....................	11	9⅝" x 5"	6⅝"
28	Gem.....................	2½	5⅛" x 3¼"	5⅛"
14	20-pound Square Wilson-Style....	20	14³⁄₁₆" x 11³⁄₁₆" x 3¼"	2⅜"
44	40-pound Square Wilson-Style....	40	14³⁄₁₆" x 11³⁄₁₆" x 6½"	4¼"
46	60-pound Square Wilson-Style....	60	14³⁄₁₆" x 11³⁄₁₆" x 9¾"	6"

*First dimension listed for round hoops is diameter, second dimension is height.

Fig. 9.1 Examples of some of the hoops or molds used to form various shapes and sizes of Cheddar and related cheeses (Bodyfelt et al., 1988)

Fig. 9.2 The manufacture of 500-lb (227 kg) barrels or 640-lb (291 kg) blocks has become a common size for Cheddar and several other cheese varieties due to some advantages of handling, transporting, warehousing, and economics (Courtesy USDA Grading Branch)

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.

9.7 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 to compare either "cheese to cheese" as in the World Cheese Championships or "judge to judge" as in the Annual Collegiate Dairy Products Evaluation Contest (Chapter 4). 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.

To possess the desired characteristics, the so-called “ideal” 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 (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.

9.7.1 Federal Grading of Cheddar Cheese

U.S. 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) U.S. Grade AA; (2) U.S. Grade A; (3) U.S. Grade B; and (4) U.S. Grade C. A general description of Federal Cheddar cheese grades is summarized in Table 9.3. Cheeses within Grades are

Table 9.3 A summary of the U.S. grades of Cheddar cheese (USDA)

Grade	General description of medium-cured to aged Cheddar	Approximate score or score range[1]
AA	Flavor: Fine, highly pleasing, very slight feed flavor permitted. Body and Texture: Firm, solid, smooth, compact, close, translucent, few small mechanical or sweet holes permitted, no gas holes. Color: Uniform, tiny white specks if aged and very slight seaminess permitted. Finish: Sound rind well protected and smooth, even-shaped.	93 or above
A	Flavor: Pleasing, may possess limited feed, or acid or bitter flavor (if aged). Body and texture: Reasonably solid, compact, dose and translucent, few mechanical holes not large or connected, limited to two sweet holes per plug, no gas holes.	92

Table 9.3 (continued)

Grade	General description of medium-cured to aged Cheddar	Approximate score or score range[1]
	Color: Slight white lines or seams. May be very slightly wavy. Finish: Sound firm rind, well protected but may possess to a very slight degree a soiled surface or mold growth; may be slightly lopsided, have high edges or rough, irregular surface.	
B	Flavor: May possess certain limited undesirable flavors according to age. Body and texture: Texture may be loose and open and have numerous sweet holes, scattered yeast and other scattered gas holes, pinny gas holes not permitted. Color: May possess about the same defects as Grade A except to a greater degree. Finish: Rind sound, may be slightly weak, but free from soft spots, rind rot, cracks, or openings, bandage may be uneven, wrinkled but sound, surface may be rough, unattractive, but have good protective coating; paraffin may be scaly or blistered; no indication that mold has entered the cheese; may be huffed, lopsided, or have high edges	90–91
C	Flavor: May possess somewhat objectionable flavors and odors with a certain increase in tolerance according to age and degree of curing. Body and texture: May be loose with large connecting mechanical openings; have various gas holes and body defects with limitations varying with the degree of curing; must be sufficiently compact to permit drawing a full plug. Color: May possess various defects, but not to the extent that the color is unattractive. Finish: Rind may be weak, have soft spots, rind rot, cracks, and openings, with certain limitations varying with degree of curing. Bandage may be uneven, wrinkled, but not torn; may have rough unattractive appearance, paraffin scaly or blistered; mold permitted, but not evidence that mold has entered the cheese; may be huffed, lopsided, and have pronounced high edges	$\leq$89

[1] These are the approximate numerical scores of each U.S. grade if scored by the scorecard system. The U.S. grades are reported in letter grades only.
Source: U.S. Department of Agriculture (1956).

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 U.S. 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 (http://www.ams.usda.gov/standards/standair.htm).

9.8 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 will introduce the ADSA scorecard. The following section will describe the defects/attributes of Cheddar cheese in more detail.

9.8.1 Tempering Cheese

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 ($\leq$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.

9.8.2 Preparation for Evaluation

Appropriate facilities for cheese tempering, sampling, proper disposal of waste cheese, and cleaning of sampling equipment should be provided for evaluators. 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.

9.8.3 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) 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. However, in the instance of transparent film-encased cheese, the judge can easily note the presence or absence of mold growth.

9.8.4 Sampling

Cheese samples are usually obtained with a double-edged, curved-blade instrument known as a cheese (or butter) 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 is immediately broken off and replaced, flush with the surface of the original hole. 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

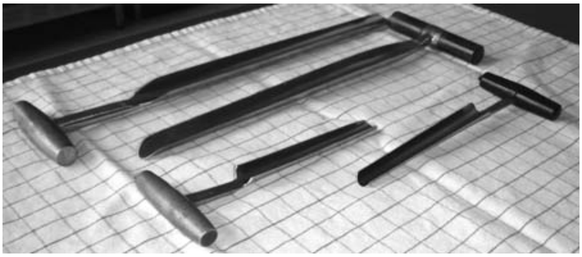


Fig. 9.3 Cheese triers of various sizes

Fig. 9.4 Removing a cheese plug from a 40-lb block with a 127 mm (5-in) trier

trier holes to restrict the access of oxygen to the center of the cheese. During the Collegiate contest, trier holes need not be plugged. The practice of smelling the plug of cheese immediately after sampling should automatically become a part of the evaluation technique.

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.

9.8.5 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; this depends on the milkfat and/or carotene content of the cheese milk. Other groups of consumers seem to prefer an intense deep-orange color for Cheddar cheese. Although not judged in the Collegiate contest, a good judge will note any defects in color that may be an indicator of defects in flavor or body and texture.

9.8.6 Body and Texture

The judge should observe the nature and extent of the mechanical or gassy openings in the cheese plug. In the Collegiate Contest, a single plug drawn by the lead judge, and appropriately displayed, will be evaluated by all contestants. 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 Collegiate Contest, 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. 9.5 for examples of gassy and open defects.

The evaluator should take the ends of the cheese plug by the forefingers and thumbs of both hands and bend the plug slowly into a semicircle, and carefully observe 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; and if the plug bends until the plug ends nearly touch (if it breaks apart at all), a "weak" defect is noted (see Fig. 9.11).

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

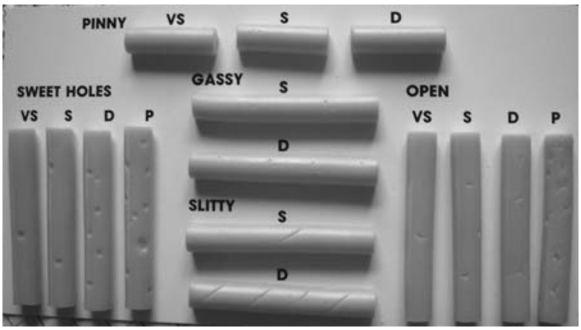


Fig. 9.5 USDA Visual aid for gassy and open defects in Cheddar cheese
Source: NASCO (2007)
(VS = very slight; S = slight; D = definite; P = pronounced)

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 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 a total of 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 (see Fig. 9.11).

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.

9.8.7 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 then 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 needs to 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.)

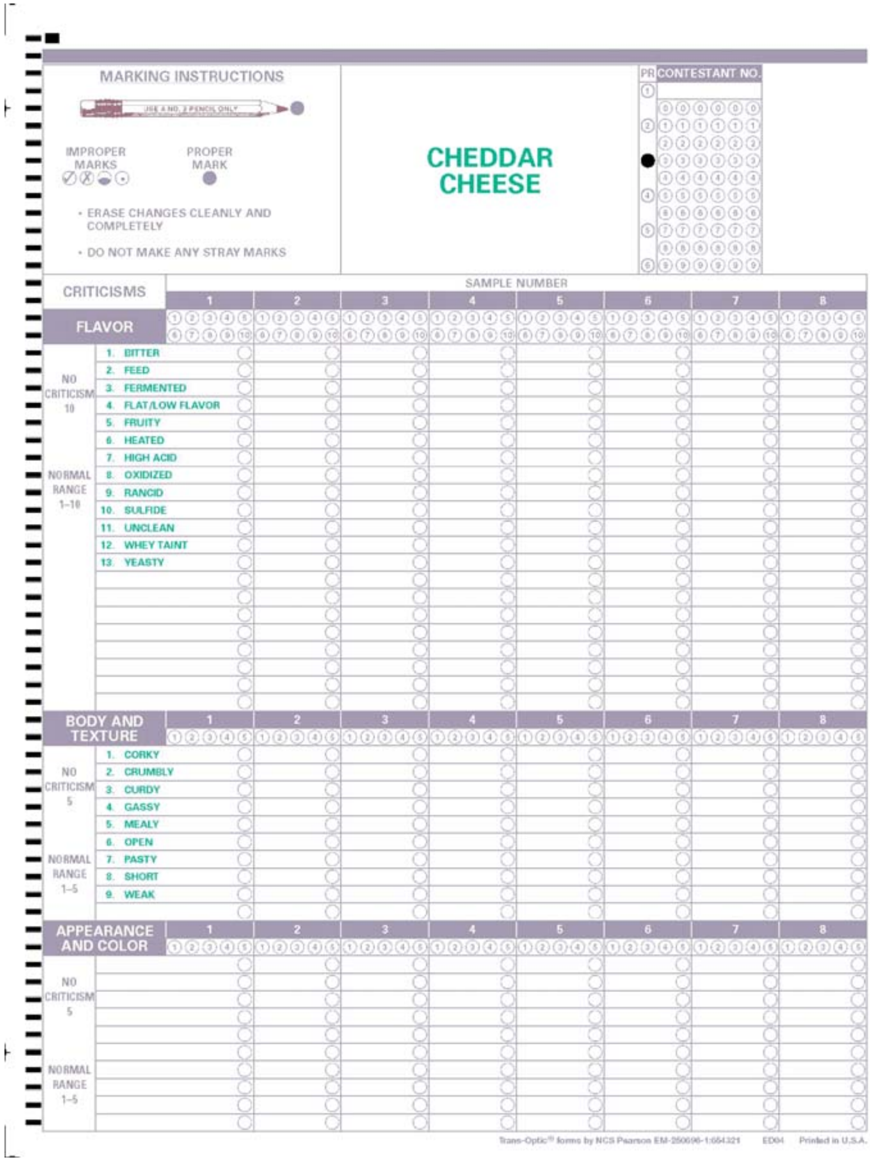
As a rule, since many types of cheese tend to dull the sense of taste and smell, ideally, no more than 15–20 samples should be tasted at one scoring, as they may eventually all tend to taste alike. For beginners, about 10 samples can be tasted successively with some assurance that the taste sensing nerves are functioning normally or are not overtaxed.

Rinsing the mouth occasionally with tepid water will allow appropriate reconditioning of the mouth for subsequent sampling and is the only reconditioning provided to contestants during a Collegiate Contest. 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. An experienced cheese judge can often grade cheese without actually tasting, on the basis of the color and appearance, amount and nature of openness, body and texture, and the perceived aroma of the worked sample mass. The experienced judge may taste an occasional sample simply to verify judgments ascertained by means of other sensory observations.

Smelling and tasting the cheese samples generally completes the evaluation process. All sensory observations should be recorded on a designated cheese scorecard or a form 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. 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.

9.9 The ADSA Scorecard

The American Dairy Science Association scorecard (Fig. 9.6) was developed for use in training students in sensory evaluation of Cheddar cheese, as well as serving for many years as the official card for the Collegiate Dairy Products Evaluation Contest. The standard of perfection is somewhat arbitrary in origin



MARKING INSTRUCTIONS

USE A NO. 2 PENCIL ONLY

IMPROPER MARKS

PROPER MARK

• ERASE CHANGES CLEANLY AND COMPLETELY

• DO NOT MAKE ANY STRAY MARKS

CHEDDAR 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. FEED
3. FERMENTED
4. FLAT/LOW FLAVOR
5. FRUITY
6. HEATED
7. HIGH ACID
8. OXIDIZED
9. RANCID
10. SULFIDE
11. UNCLEAN
12. WHEY TAINT
13. YEASTY

BODY AND TEXTURE

NO CRITICISM 5

NORMAL RANGE 1–5

1. CORKY
2. CRUMBLY
3. CURDY
4. GASSY
5. MEALY
6. OPEN
7. PASTY
8. SHORT
9. WEAK

APPEARANCE AND COLOR

NO CRITICISM 5

NORMAL RANGE 1–5

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Fig. 9.6 The ADSA contest Cheddar cheese scorecard for sensory defects

and the judge in training should realize that some characteristics listed as defects on the ADSA 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, use of the cheese lexicon and descriptive analytical techniques or appropriate consumer acceptance testing needs to be used in place of the ADSA scorecard. A discussion of proper sensory methods for research use is given in Chapter 17.

The scorecard lists essential factors or items by which a cheese is evaluated; these items are 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. 9.6) and associated scoring guide (Table 9.4) can be essential evaluation tools; as such, they should be studied in detail. The evaluator should keep in mind the relative values of the various scorecard items that are considered in the quality grading process. The ADSA 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.

Table 9.4 Suggested scoring guide (ADSA) for flavor and body and texture of Cheddar cheese for designated defect intensities

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
Oxidized	8	6	3
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
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 using the ADSA 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*.

9.10 Defects/Attributes of Cheddar Cheese

9.10.1 Color Evaluation

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 9.5.)

Table 9.5 Common color and appearance, body and texture, and flavor defects of Cheddar cheese, their probable causes, and remedial measures

Color and appearance 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. Non-uniform moisture distribution in the cheese.	1. Monitor acid development carefully. 2. Take precautions to insure consistent and uniform moisture retention in curd.
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."

Table 9.5 (continued)

Color and appearance defects	Probable causes	Remedial measures
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).
White specks: granules or small hard mineral or protein deposits	If young cheese, results from calcium lactate complex formation (not desired). 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.
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.
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.

Table 9.5 (continued)

Color and appearance defects	Probable causes	Remedial measures
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 defect	**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.
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.

Table 9.5 (continued)

Color and appearance defects	Probable causes	Remedial measures
Rancid	1. Milk lipase activity. 2. Microbial lipases from contaminants. 3. Accidental 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.

Source: Compiled from Blake et al. (2005), Chandan (1980a,b), Comotto (2006), Johnson (2004), Van Slyke and Price (1979), Wilson and Reinbold (1965), Wilster (1980), and Wendorf (2007).

Acid-cut (bleached, faded). These several color defects are quite similar, but differ primarily in their intensities. 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. 9.7). 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 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

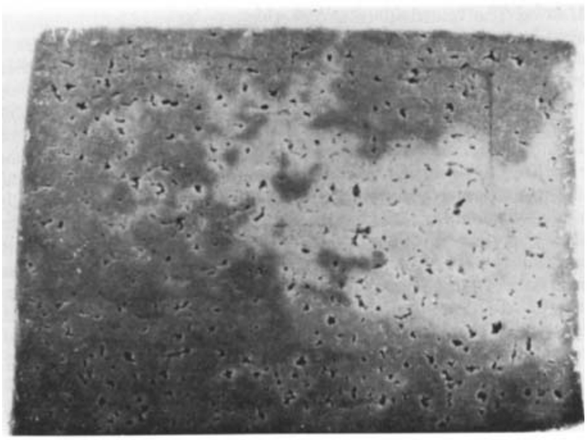

Fig. 9.7 The acid-cut color defects of Cheddar cheese (excessive mechanical openings are also evident) (Bodyfelt et al., 1988)

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 dusty 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 color intensity, often by an orange-yellow hue, 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 non-uniform 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.

Pinking. A "pink" discoloration of the cheese occurs when the water-based colorant annatto is exposed to intense lighting. This defect is most often found

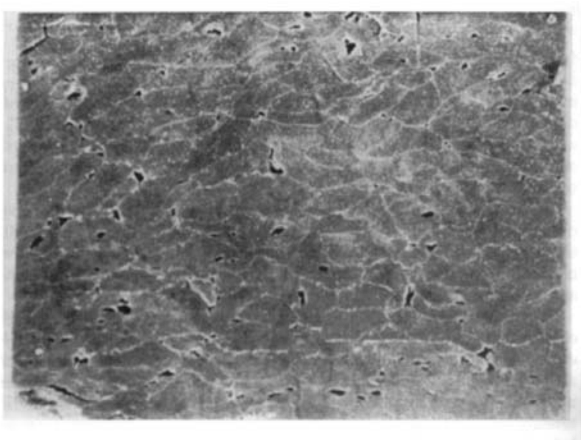

Fig. 9.8 The appearance defect "seamy" is interlaced with light-colored lines (definite mechanical openness is also apparent) (Bodyfelt et al., 1988)

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 light-colored lines around each original piece of curd (Fig. 9.8). This is particularly noticeable when one directly examines the surface appearance of freshly cut cheese possessing the seamy defect. The seamy appearance defect usually results from physically altered curd surfaces caused by exuded or crystallized milkfat, uneven 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. The slight degree of seaminess that is occasionally noted in fresh or young Cheddar cheese is not particularly objectionable, since this form of seaminess generally disappears with additional aging. 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.

White specks. Cheddar cheese that has small "white specks" interspersed throughout its 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. 9.9) 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.

Curing of cheese that contains nonstarter lactic acid bacteria at elevated temperature, then followed by lower storage temperature, tends to favor

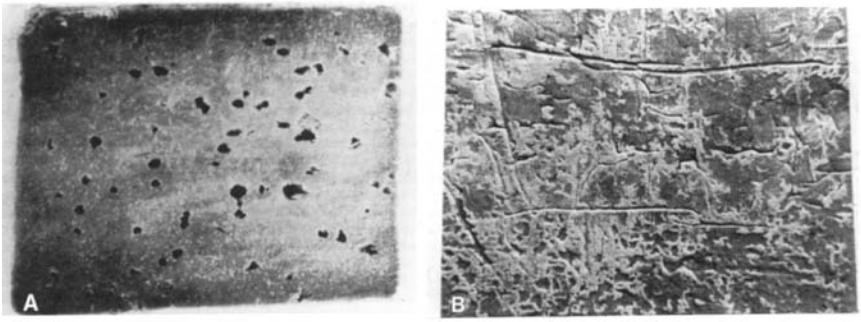

Fig. 9.9 The color/appearance defect of "white specks" or "surface precipitate" **A** calcium lactate crystals evident along loose edges of a package of mild Cheddar cheese; **B** tyrosine crystals evident on surfaces of aged Cheddar cheese (Bodyfelt et al., 1988)

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 white specks (and the possible associated mouthfeel) with an aged cheese; the cheese sample will most likely also have a fully developed intense flavor. White specks 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.

9.10.2 Finish and Appearance Evaluation

Cheese with a desired finish should generally exhibit symmetrical, parallel ends; square, even edges; an evenly folded, neat, close-fitting plastic film or the 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, 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 9.5.)

9.10.2.1 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, 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, if at all possible. 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.

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.

9.10.2.2 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.

9.10.2.3 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 Section 9.10.2.6); 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.

9.10.2.4 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.

9.10.2.5 Surface

Bruised. Slightly depressed areas over which the paraffin is broken suffice to 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 U.S. 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.

9.10.2.6 Miscellaneous Factors

Huffed, bloated. So-called "huffed" or "bloated" cheese results from gassy fermentation. A cheese suffering from this defect usually becomes rounded on 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.

Rust spots. "Rust spots" on the surface of cheese are uncommon, since they are usually caused by corrosion of nails in wooden boxes, which are infrequently used for cheese storage. This defect may be caused by careless placement of oversized nails when closing wooden boxes. A rust spot is most objectionable because it represents a waste area and the puncture furnishes a focal point for possible mold contamination or cheese pest infestation.

Cheese mites and "skippers. "A 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). "Skippers," the larvae of the cheese fly, may be infrequently noted; they only occur as the result of poor sanitation practices.

9.10.3 Body and Texture Evaluation

Cheddar cheese with the most desirable body and texture displays a full, solid, close-knit plug (see Fig. 9.10) that possesses smoothness, meatiness, waxiness, and silkiness, and is entirely free from gas holes or mechanical openings. Cheddar cheese with the above-described quality attributes lends itself to uniform slicing into thin, intact pieces.

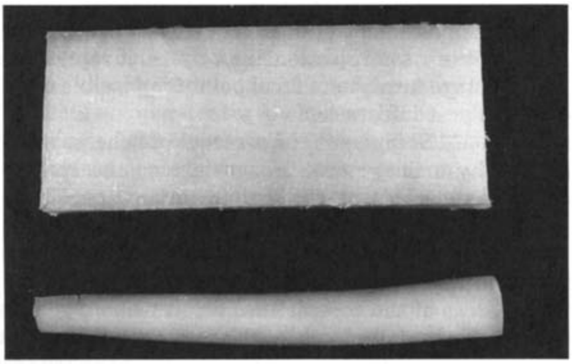

Fig. 9.10 A Cheddar cheese that exhibits the preferred attributes of pliable body and close texture (no or few openings) (Bodyfelt et al., 1988)

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. As a general rule, a "close" (few or no openings in the cheese mass) or medium-close 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 cheese.

A close-textured cheese should yield a solid plug with practically no visible openings (Fig. 9.10). The plug, however, may gradually break apart along a curd seamline, especially in a young cheese. A plug withdrawn from a moderate close-textured cheese displays a few mechanical openings that may have been caused by 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 holes." Cheddar cheese may also exhibit "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 close-textured cheese, but in this instance, the plug will exhibit a split appearance. Worked plugs exhibiting various cheese body and texture characteristics are shown in Fig. 9.12.

9.10.3.1 Desirable Body and Texture Characteristics

Firm body. Cheese with a 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 (Fig. 9.11A). The preferred texture is close; 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 the thoroughly cooked breast meat of a chicken. 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 (Fig. 9.11 A and B), little resistance is offered other than the normal force required to mold the cheese into a cohesive "cheese ball." 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.

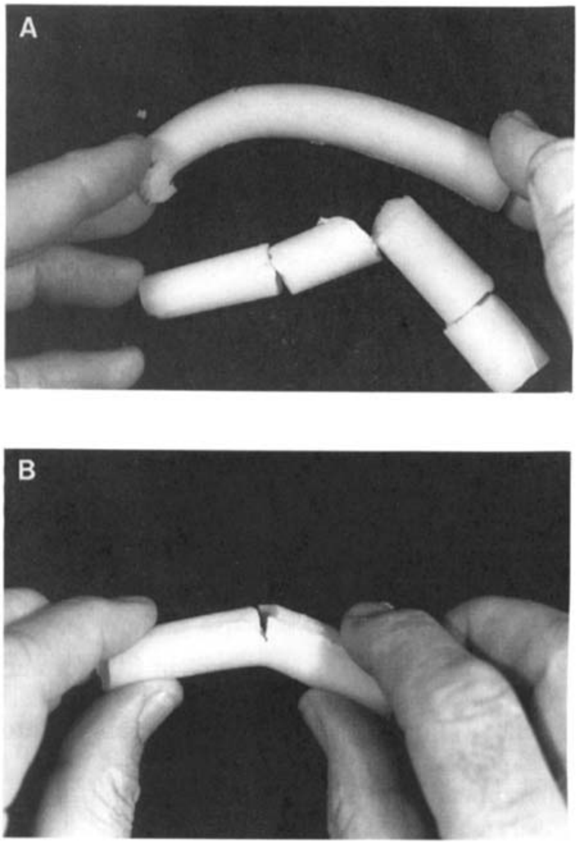

Fig. 9.11 A comparison of a "perfect"-bodied (**A**) and a "short"-bodied (**B**) Cheddar cheese (Bodyfelt et al., 1988)

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-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.

9.10.3.2 Body Defects

Many duplicate terms are used in an effort to characterize undesirable body and texture defects of Cheddar cheese. The more common descriptors of cheese body defects are listed below and are described in the following paragraphs: (Common body defects, probable causes and remedies may be found in Table 9.5.)

ADSA Descriptors:

Corky (dry, hard, tough)
Crumbly (friable)
Curdy (rubbery)
Pasty (smeary, sticky, wet)
Short (flaky)
Weak (soft)

Non-ADSA descriptors:

Greasy
Spongy

Corky (dry, hard, tough). This defect is generally associated with a low moisture, lowfat, and/or young 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. 9.12B). 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. 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 sliced and/or worked (Fig. 9.12C). 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 ($\sim$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. 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 to make a smooth ball. 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

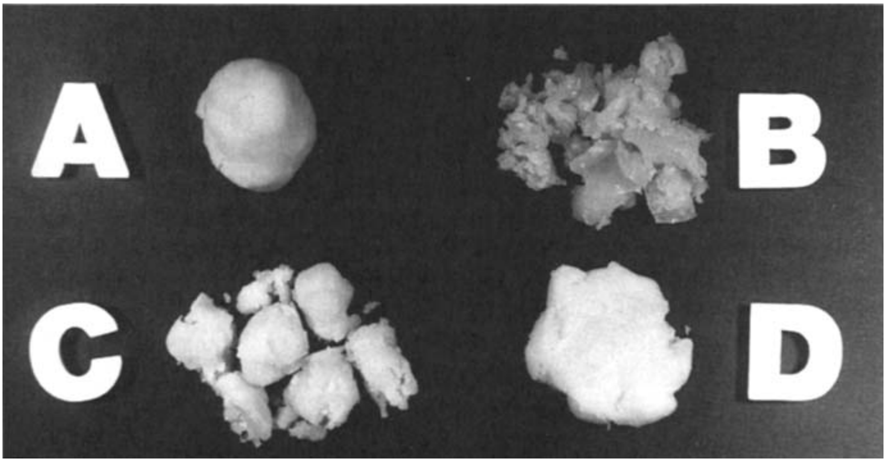

Fig. 9.12 "Worked" Cheddar cheese samples showing various body defects: **A** Example of an "ideal" body; **B** "Corky"-bodied curd; **C** "Crumbly"-bodied cheese; **D** "Pasty"-bodied cheese (Bodyfelt et al., 1988)

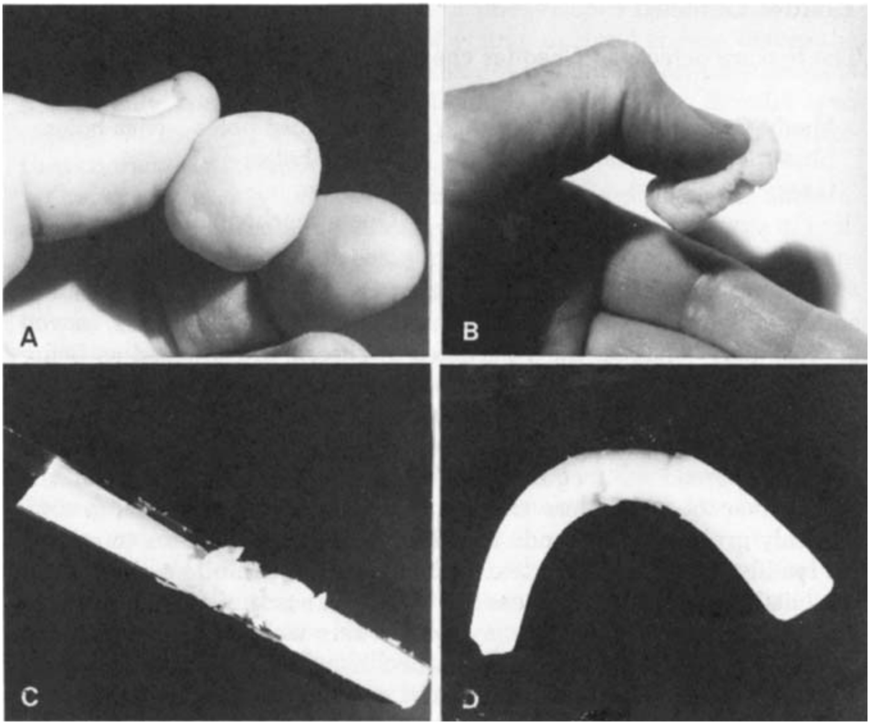

Fig. 9.13 Examples of some common body characteristics (defects) of Cheddar cheese: **A** An "ideal" waxy body (practically forms a marble); **B–A** distinctly "pasty" or "sticky" body; **C–A** "crumbly" plug; **D–A** "weak" body (Bodyfelt et al., 1988)

aging. A curdy cheese that breaks along a seam between curds should not be confused with a short-bodied cheese (see below).

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. The cheese breaks down easily into a pasty, sticky mass that tends to adhere to the fingertips as the product is manipulated (Fig. 9.12D and 9.13B). This defect is often associated with a weak body and/or high acid, fruity, and/or fermented off-flavors.

Short (flaky). A "short" or "flaky" body is characterized by a lack of meatiness, waxiness, or overall homogeneity; the consistency of the cheese may appear loose-knit. The plug will break easily on bending a short distance rather than tearing apart and will show a distinct lack of elasticity (Fig. 9.11B). 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 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).

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 break 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. 9.13D).

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-like cheese often exhibits marked seaminess or may eventually develop it upon additional aging.

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.

9.10.3.3 Texture Defects

The texture defects of Cheddar cheese are described in the following paragraphs. (Common texture defects, probable causes and remedies may be found in Table 9.5.)

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; white specks may be obvious as well. The cheese judge should also be able to detect a corn meal-like mouthfeel when the cheese sample is masticated and pushed against the roof of the mouth.

Gassy (pin holes, sweet-curd holes, Swiss holes, shot holes, slits, fish eyes, yeast holes). Gas holes in cheese vary in size and are 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 ADSA scorecard. Examples of the various defects can be seen in Fig. 9.4.

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 *actococcus diacetylactis* or *Leuconostoc* sp. 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. 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, pleasant 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.

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. 9.4). 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.

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.

9.10.4 Flavor Evaluation

Once the physical properties of the cheese have been assessed, the flavor characteristics should be determined. 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. Experienced judges may not even taste the cheese, but evaluate and grade samples on the basis of the noted odor characteristics and their association with certain observed physical attributes. 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 could 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 actual 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 (Davies and Law, 1984; Kosikowski and Mocquot, 1958; Van Slyke and Price, 1979; Wilson and 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, Drake, and Cadwallander (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) milkfat and milkfat 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 flavor correlations that may be associated with them.

9.10.5 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 9.5 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 Chapter 17, but are not included here due to lack of common use by graders and judges (Drake et al., 2001).

ADSA Descriptors:

Bitter
Feed
Fermented
Flat/low flavor
Fruity
Heated
High acid
Oxidized
Rancid
Sulfide
Unclean
Whey taint
Yeasty

Non-ADSA Descriptors:

Garlic/onion (weedy)
Malty ("Grape Nuts®")
Moldy (musty).

Bitter. If volatile, other cheese off-flavors will be detectable by the sense of smell, but bitterness is noted only by the sense of taste. 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 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.

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 (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 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 U.S. 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.

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 is an important production management task if cheese milk of *good* flavor quality is to be produced.

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 may 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. This flavor defect is occasionally 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).

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. Frequently, a bitter aftertaste may be associated with high acid in aged cheeses. Numerous other off-flavors may occur in conjunction with a high-acid note.

Oxidized. Occurrence of a metallic (oxidized) off-flavor in Cheddar cheese is quite rare, due to the reduction–oxidation potential of the cheese interior. This off-flavor (should it occur in cheese) is characterized by a flat, metal-like taste and a lingering puckery (mouthfeel) sensation. The sense of smell is of little or no value in detecting its presence. Oxidized (or metallic) cheese milk is the probable source for this cheese off-flavor when it infrequently occurs.

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. Sometimes an offensive sulphurous (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. 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. Numerous sulfur-containing compounds can be formed during the aging process. 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.

Unclean (dirty aftertaste). An "unclean" off-flavor is difficult to describe, since it often varies in intensity and lacks a definitive sensory description. 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. 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.

Other off-flavors. The off-flavors discussed above should be considered as the more common or frequently encountered ones in Cheddar cheese and are thus found on the ADSA scorecard. 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.

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.

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 and 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.

9.11 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 U.S. 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.

9.12 Colby, Monterey 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, gas and/or 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 that are essentially 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 a strong, evenly distributed flavor of the Jalapeños. Other varieties found in the market may include sun-dried tomato, caraway seed, sage, horseradish, and dill.

9.13 Conclusion

Cheddar and related cheeses present a daunting task to the cheese grader/judge, but also provide a great opportunity to fine-tune a wide array of sensory skills. Visual, tacti1e (feel), gustatory (taste), and olfactory (smell) senses are used together to make judgments regarding the value of the subject cheeses. Students dedicating time to training in the use of the ADSA scorecard for Cheddar cheese will find themselves well prepared to continue training as full-fledged judges/graders of Cheddar and Cheddar-type cheeses. Learning to observe the fine balance of flavor components will also prepare the same individuals for training to make similar judgments on other varieties of cheese and food.

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Chapter 10
Ice Cream and Related Products

Valente B. Alvarez

Courtesy of Quality Chekd Dairies, Inc

10.1 Introduction

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 U.S. standards, ice cream must contain at least 10% milkfat, 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

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yolk is called French ice cream or frozen custard. Super-premium 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 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 U.S., with approximately 5.83 billion liters (1.54 billion gal) produced in 2005 (IDFA, 2006). Most of the ice cream produced in the U.S. is the hard-frozen type, but the production of soft serve has increased over the past decade. U.S. per capita consumption of ice cream, sherbet, and other commercially produced frozen dairy products was 21.95 L (20.33 quarts) in 2005. It is estimated that 98% of all U.S. households purchase ice cream (IDFA, 2006).

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 milkfat replaced in whole or part with vegetable or animal fat. FDA Standard of Identity (21 CFR 135.130) 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 (Marshall et al., 2003).

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.

Water ices are similar to sherbets, but contain no dairy ingredients.

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 2006 CFR, 21CFR135 (Table 10.1), ice cream is basically defined as that food produced as a result of freezing, while stirring, a pasteurized mix that consists

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 (%)	Milkfat (%)	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.

[a] Increases in milkfat 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 lowfat 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] Milkfat 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 milkfat 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 List of optional dairy ingredients approved for use in ice cream and frozen custard [a]

Cream:	Fresh, dried, plastic (concentrated milkfat)
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.

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.

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; though, 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 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 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. 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 ADSA 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.

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). 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, malto-triose, malto-tetraose, 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). 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).

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). 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 and Hartel, 1997). Low storage temperature and 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). 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, excepting 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 non-enzymatic 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). A degree of destabilization of fat globules is essential to produce ice cream with desirable body (Goff and Jordan, 1989). 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 and Goff, 2002); 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 and Walstra, 1981). The partially coalesced fat globules stabilize air cells, forming three-dimensional network structures with the air cells (Berger, 1997; Zhang and Goff, 2004). 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 whey 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 mono-oleate), 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 and Sahagian, 1996; Vega et al., 2004). 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 recrystalization, i.e., when storage temperatures fluctuate or become too high (referred to as "heat shock") (Donhowe and Hartel, 1996; Hagiwara and Hartel, 1996; Sutton and Wilcox, 1998; Flores and 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 and Wilcox, 1998). 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., 2000a; Chavez-Montes et al., 2004). 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 solids 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 and 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 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). 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 U.S. is vanilla, which accounts for nearly one half of all ice cream sales (IDFA, 2006). 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. 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 and Marshall, 1998).

Off-flavors in the mix are more difficult to detect in the presence of stronger flavorings, such as chocolate. 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 scorecard. The scorecard in Fig. 10.1 is the one developed

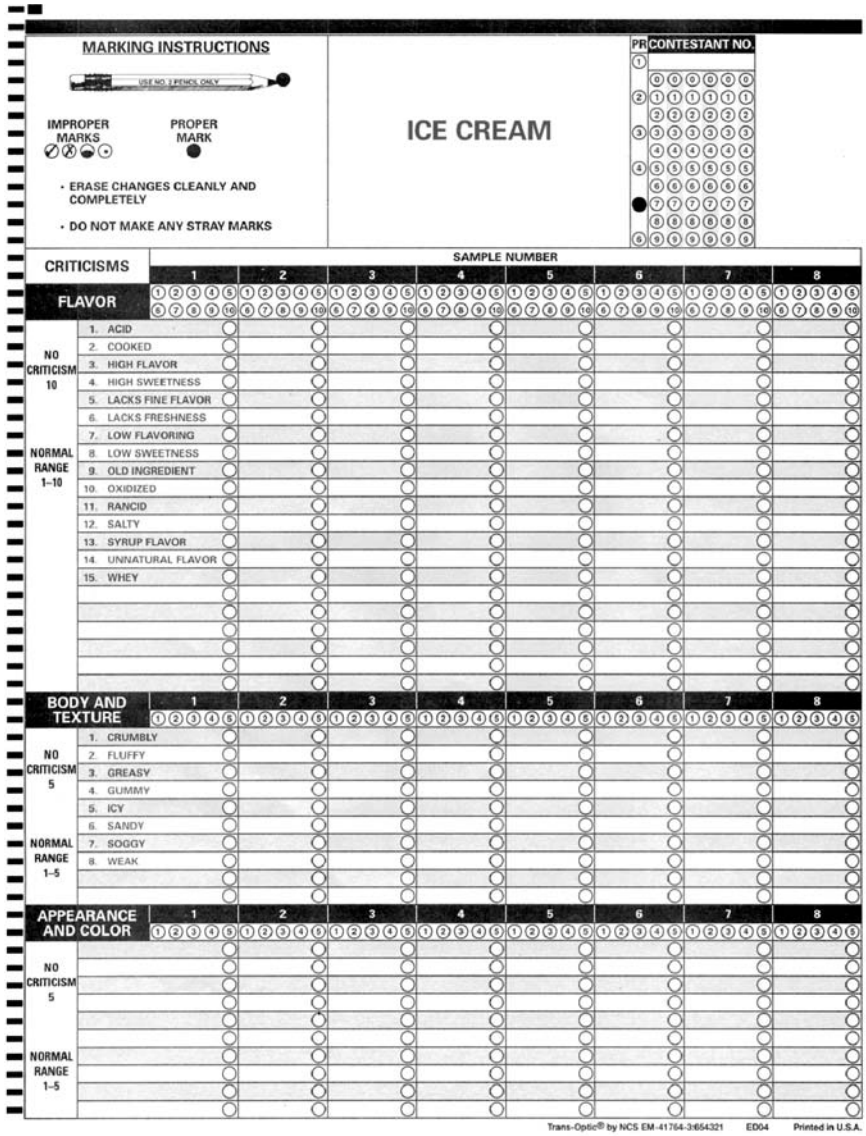


Fig. 10.1 ADSA Annual Collegiate Dairy Products Evaluation ice cream scorecard

Table 10.3 ADSA scoring guide for flavor defects of vanilla ice cream

	Intensity of defect		
Flavor criticisms	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 use of such products in contest.

and approved by the American Dairy Science Association and is used throughout the U.S. 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 standardization of judgments among different evaluators. Further modifications of the scorecard will be suggested later in this chapter when other frozen products are discussed. The so-called official scorecard (as of 2005) for ice cream (which is approved, revised as deemed appropriate, and published through the ADSA Committee on Evaluation of Dairy Products) is shown in Fig. 10.1; the associated "official" scoring guide is duplicated in Table 10.3.

The 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.

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 collegiate dairy evaluation contest sponsored by the ADSA 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 ADSA collegiate dairy evaluation contest, 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 anyone 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. 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 insures 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 to 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 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

Fig. 10.2 Several types of scoops and spades used for dipping ice cream samples

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 l0-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.

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. 10.4).

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 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 6-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 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 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 of body and texture of 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) 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 to 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, 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 U.S., 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 29 more popular flavors of ice cream in the U.S., vanilla accounts for 26% and chocolate 12.9% of recorded ice cream sales (IDFA, 2006).

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 any more, a gray, dull color is easily recognized by its "dead," soiled white, and unattractive appearance. Such

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.

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 U.S.

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 can be caused by varying overruns attained from multi-barrel freezers or may derive from different freezers that have a common discharge. 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 milkfat). An unnatural color may be any shade of yellow, orange, or tan – colors that do not correspond to the true color characteristics of milkfat. 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 et al., 1979), of product rerun, re-melted ice cream, or 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 possible 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 U.S. 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 seems 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 toward melting when a dish is exposed to room temperature for at least 10–15 min (Bodyfelt et al., 1988).

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).

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) recently 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, namely

1. Select a uniformly heated, well-lit area for placing and observing the samples (>20°C (70°F) as 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

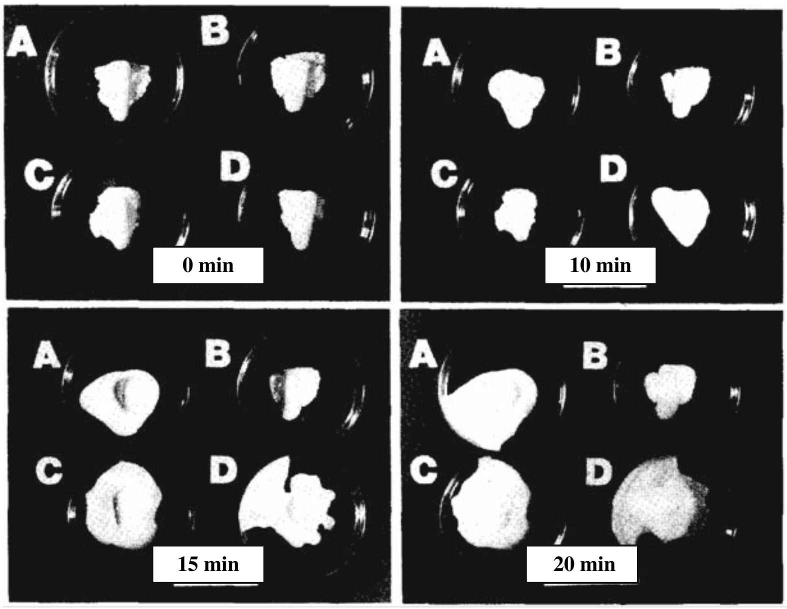


Fig. 10.3 Examples of various meltdown defects of ice cream as observed after elapse of 0, 10, 15, and 20 min: **A** the "ideal" melting characteristics; **B** does not melt; **C** curdy meltdown (non-homogenous); **D** wheyed off (watery separation) (Bodyfelt et al., 1988)

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

Table 10.5 Scoring guide for the melting quality of ice cream

Defect[a]	Slight[b]	Intensity of defect 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.

large air bubbles or excessive foam occur. The consumer may associate the presence of foam with excessive overrun, even though this defect may not be associated with high overrun, but more often (or 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 layman, 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 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 and Goff, 2004). 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. 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 decreases melting rate and enhanced shape retention during the melting process (Bolliger et al., 2000b). 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). This 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 agglomeraion. Substantial fat agglomeration is responsible for the "slow melt," and/or an unattractive dry, "flaky" surface of the melted product. Protein destabilization will result in melting throughout and hence "curdy" ice cream. Occurrence of these undesirable conditions may further be prevented by minimizing the temperature abuse (Stanley et al., 1996).

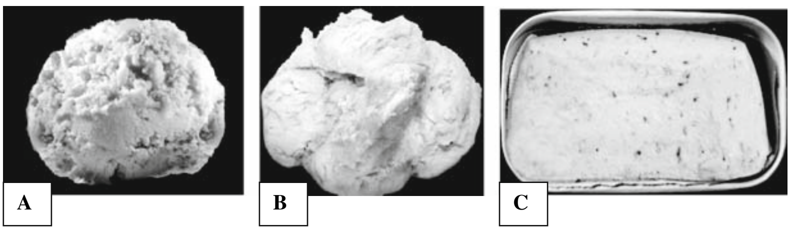
Wheying-off (syneresis). Wheying-off may usually be noted by the appearance of a bluish fluid leaking from the melting ice cream at the initiation of the meltdown test. If the sample is disturbed during melting or the observation is delayed, it may be difficult to see this condition. Whey separation may be noted in some ice cream and reduced fat ice cream mixes even before they are frozen. This 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, (4) and 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*-carageenan 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, 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 the 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), 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., 2000b). 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 (Goff et al., 1989). A proposed mechanism for protein effects on body and texture is the formation of networks of phase-



Courtesy of Bruce Tharp and Elizabeth C. Alvarez.

Fig. 10.4 Examples of vanilla ice cream defects: **A** brittle, crumbly, friable; **B** elastic, gummy, pasty, sticky; **C** shrunken separated milk proteins and polysaccharides (Syrbe et al., 1998). 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). 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).

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 and Arents, 1994). The following are the evaluation and scoring guidelines for body and texture used in the Collegiate Dairy Products Evaluation Contest.

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 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. This 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:

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 some what sticky like gum between tongue and roof of 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.
Weak: lacking body and resistance, low solids, watery, more like ice milk

Table 10.6 ADSA 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.

10.7 Description of Body Defects

Body defects showing in ***Italic/bold*** are evaluated in the Collegiate Dairy Evaluation Contest.

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). Lower fat ice creams (7%) tend to develop crumbly texture more readily than an ice cream mix with higher fat content (10%) (Rolland and Phillips, 1999). A similar defect is identified as *flaky, 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). 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 Collegiate Dairy Products Evaluation Contest. This defect may be associated with high overrun, low mix solids, fluctuations in air pressure, or substantial changes in altitude during product distribution (Dubey and 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). 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 (Collegiate Dairy Products Evaluation Contest 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 and White, 1997). 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).

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).

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 milkfat content and over-emulsification of the product. In soft-serve frozen dairy desserts, churning may be due to de-emulsification of milkfat 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). 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; 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 and Hartel, 2007). 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 and Muck, 1981; Tobias, 1982; Bodyfelt, 1983a, b). Stable storage conditions at –20°C for 60 (−4°F) 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 and Goff, 1999). 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 of 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, and 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). 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).

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). 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 and 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 be (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 milkfat. Some of the taste bud sites may be partially coated or blocked by milkfat, and hence lessen the ease of taste perception (Stampanoni-Koeferli et al., 1996; Guinard et al., 1997).

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 matter 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 ice milk 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 trouble-shooting, pinpointing, and correcting difficulties with sensory quality. While

Table 10.7 Classification of ice cream flavor defects according to their cause of origin

1. 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	
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)	3. Non-milk food solids
2. Stabilizer/emulsifier	
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)

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 which 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. Table 10.7 classifies some of the possible flavor defects of ice cream according to their cause or origin.

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 Collegiate Dairy Evaluation Contest.

*10.9.1 Off-Flavors from the Ingredients Used**

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 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

* *The following materials are directly from the previous edition (Bodyfelt et al., 1988) unless otherwise noted by the update reference.*

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 Gassenmeir (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.

Lacks flavoring (deficient). 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 (or hide) the vanilla flavor, thus invoking the "lacks flavor" criticism, even though the added quantity of flavoring seemed adequate to the manufacture.

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 (Gassenmeir, 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 flavoring (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. In fact, this is probably the most common cause of this type of unnatural (or atypical)

Table 10.8 Labeling requirements for various categories of vanilla ice cream according to the flavor source

Flavor declaration			Flavor requirements	
Ice cream type orcategory	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.

off-flavor in U.S. 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).

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). 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), 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 or 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 for adversely affecting 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 lowfat 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 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 and 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 Gassenmeir (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). 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 and Marshall, 1998).

Rancid. Fortunately, a rancid off-flavor is infrequently observed in ice cream (Tobias, 1983). 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 milkfat 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")*. Federal Standards of Identity limit 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 et al., 1979; Bodyfelt et al., 1988), 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 as 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 lowfat 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 Chapter 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. Lowfat 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 lowfat 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 lowfat 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

Lowfat ice cream. As noted in Table 10.1, this product (formerly called ice milk) differs from ice cream principally in the quantity of milkfat content. Although lowfat ice cream is offered in a variety of flavors, vanilla is the most popular. For evaluating the sensory properties of lowfat 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 milkfat content, lowfat 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 lowfat ice cream. However, in spite of these inherent problems, many manufacturers have mastered the required technology and art for producing lowfat ice cream of excellent flavor, body and texture. In fact, the sensory properties of many samples of lowfat 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 lowfat 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, ice milk, 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 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 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 “blind fold 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 1 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). 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 is by no means an all inclusive list.

10.10.2 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).

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 (1 part of sugar to 4 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 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, and/or
atypical color of fruit particles.

10.10.3 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 U.S. 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).

10.10.4 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 U.S. 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.

10.10.5 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).

10.10.6 Direct-Draw Shakes

This product, similar in composition to lowfat 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°F–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.

10.10.7 Frozen Yogurt

In some respects, frozen yogurt resembles ice cream, lowfat ice cream, and sherbet. This product is available in packaged, novelty, or soft-serve form and in a variety of flavors, most commonly fruit flavors (Bodyfelt, 1978). The general criteria used in the sensory evaluation of frozen yogurts are comparable to those used for sherbets or lowfat 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

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

system, culture system characteristics, sweetener aspects, process-related considerations, and the potential for dairy ingredient off-flavors.

10.10.8 Soft-Serve Frozen Desserts

These products (usually lowfat 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 (lowfat 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) 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 lowfat 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.

10.10.9 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 takes into account 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 ($\leq$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

Defective pattern
Too little added material
Poor distribution of added material
Poor appearance of added material.

10.10.10 Sorbets and Water Ices

U.S. federal standards describe water ices as a food that is prepared from the same ingredients as sherbets, except that no milkfat, 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 U.S. 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; though, packaged and hardened sorbet is also available from the freezer cabinets of retail food stores.

10.10.11 Frozen Novelties

A group of products referred to as frozen novelties may be made of ice cream, lowfat 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

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 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 ADSA Annual Collegiate Product 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

The common characteristic of various types of concentrated milk products is the reduced water content. Generally, the 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]). 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) utilized. 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, U.S. consumers tend to resist purchasing milk products manufactured from rehydrated dairy ingredients. In countries where high-quality milk is not available, 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 ingredients with regard to functional and flavor deficiencies. Additionally, a growing amount of scientific evidence suggesting that specific milk components or fractions have great nutritional value has further strengthened the market for such ingredients (Miller et al., 1999).

This chapter is entirely based on the works published by Bodyfelt et al. (1988). Much of the language and organization of the text is retained in this revision in keeping with the theme and intentions of the revision of the entire book.

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11.1 Concentrated Milk Products

Included here, verbatim and in order of relevance, are several definitions from the U.S. Grade "A" Pasteurized Milk Ordinance (U.S. Department of Health and Human Services, 2005), 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 lowfat milk, frozen milk concentrate, eggnog, buttermilk, buttermilk products, whey, whey products, cultured milk, cultured reduced fat or lowfat milk, cultured nonfat (nonfat) milk, yogurt, lowfat yogurt, nonfat yogurt, acidified milk, acidified reduced fat or lowfat milk, acidified nonfat (nonfat) milk, low-sodium milk, low-sodium reduced fat or lowfat milk, low-sodium nonfat (nonfat) milk, lactose-reduced milk, lactose-reduced reduced fat or lowfat milk, lactose-reduced nonfat (nonfat) milk, aseptically processed and packaged milk and milk products as defined in this Section, milk, reduced fat, lowfat 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 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 Section 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 lowfat 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 means 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 means concentrated (condensed) or dry whey and whey products, which complies 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 (2006) contains specific standards of identity and compositionally based definitions for the following products of immediate significance to this chapter, including

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 U.S. Government Printing Office. 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.

11.1.1 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 percent by weight of moisture, and not more than 1 and 1/2 percent 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 referenced methods of analysis are from "Official Methods of Analysis of the Association of Official Analytical Chemists," 18th Ed. (2006), which is incorporated by reference. Copies may be obtained from the AOAC INTERNATIONAL, 481 North Frederick Ave., suite 500, Gaithersburg, MD 20877, or may be examined at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to: http://www.archives.gov/federal-register/cfr/.

(1) Milkfat content – "Fat in Dried Milk – Official Final Action," Sections 16.199–16.200.
(2) Moisture content – "Moisture – Official Final Action," Section 16.192.

(d) Nomenclature. The name of the food is "Nonfat dry milk." If the fat content is over 1 and 1/2 percent 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 percent 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.

11.2 Sensory Considerations

Concentrated milk intended for use as a reconstituted beverage milk or as an ingredient in other applications is generally evaluated for sensory properties in a manner similar to the original unconcentrated milk product by first reconstituting it with good-quality potable water or distilled water. Many concentrated dairy products may also be evaluated without reconstitution, with the caveat that some tastes and aromas are more readily noticed after reconstitution or rehydration. This phenomenon may relate to the entrainment or binding of flavor 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 general ideal that the reconstituted product should emulate its counterpart in flavor, mouthfeel or consistency and appearance. In addition to flavor defects, any visible evidence of immediate discoloration, thinning or thickening and other abnormalities should be noted as defects (Hammer, 1919; Hunziker, 1949; Sommer and Hart, 1926). A generally accepted practice for preparing powders for sensory evaluation suggests that an approximately 10% solution in distilled water is adequate (Drake et al., 2003; Carunchia Whetstine and 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 problems of sensory quality involved shortcomings of both taste and mouthfeel. The off-flavors that regularly developed in these products during storage were difficult to describe. Judges commonly labeled these off-flavors of sterile milk concentrates as stale, caramel-like or a combination of stale/caramel defect. This particular off-flavor could be associated with the browning reaction of heated milk (Arnold et al., 1966; Muck et al., 1963). Any possible future success of sterile milk concentrates will depend on processors' ability to prevent flavor 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 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. Furthermore, the container should present an attractive appearance and exhibit a neat, well-applied label; the ends of the can should appear polished and show no evidence of bulges or dents. The overall examination of the product includes flavor, body and texture/viscosity and appearance (color, fat separation and serum separation). A comprehensive examination of evaporated milk should 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 standard 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."

11.3 Examination Procedures for Evaporated Milk

Establishment of a definite routine for examining cans of evaporated milk can facilitate the evaluation of numerous samples. 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 under-surface 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 cut-away 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 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 U.S. 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 or spoilage 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).

11.4 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 (ultra-high 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 l0°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	Grainy
Curdy	Low viscosity
Feathering	Sediment
Gassy	

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 has 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).

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 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 solids 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 ($Ca_3(C_6H_50_7.4\,H_20)$). 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 hydroxymethyl furfural, 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.

11.5 Sweetened Condensed Milk

A description of sweetened condensed milk can be found in 21 CFR 131.120 (CFR 2006):

(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. The finished food contains not less than 8 percent by weight of milkfat, and not less than 28 percent 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.

(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, thus 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. Careful consideration must be given to the functional properties of this

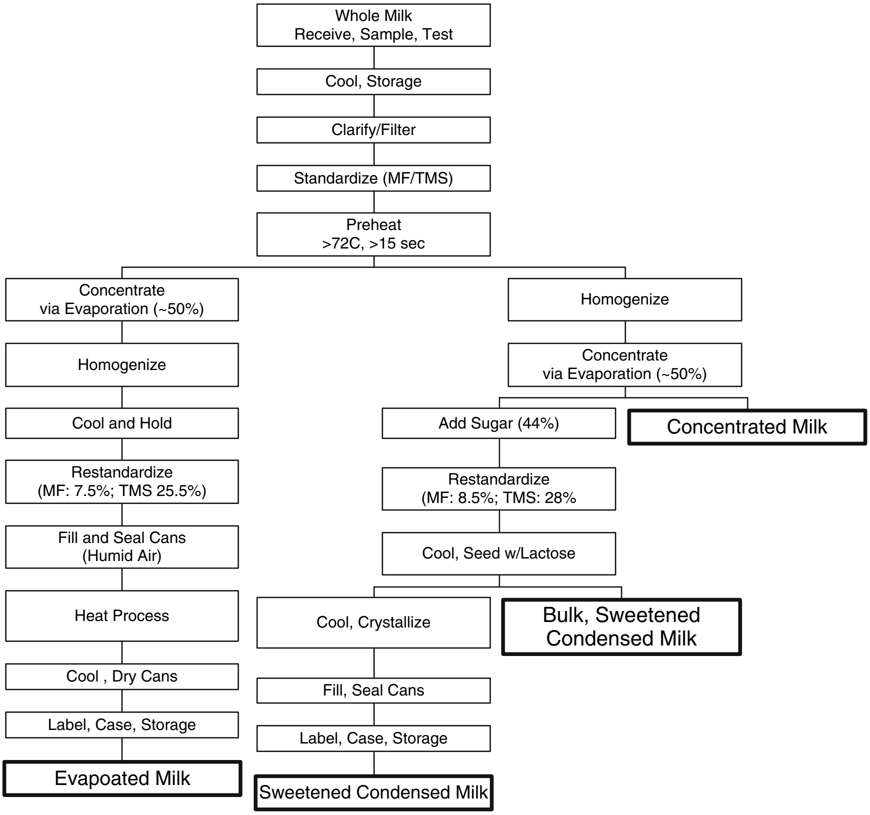

Fig. 11.1 Flow diagram for the manufacture of evaporated and condensed milks

product, but sensory characteristics are also important in the overall process of the quality evaluation of sweetened condensed milk.

11.6 Examination Procedures for Sweetened Condensed Milk

The particular 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 enables the evaluator to best utilize the available time, with greater assurance that the examination is thorough. 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 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 develop 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 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 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.

11.7 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	Strong
Rancid	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 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 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	Sandy (rough, grainy, granular)
Lumpy	Settled
Fat separation	Thickened
Gassy	

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. 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.

11.8 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?"

11.9 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.

11.10 Methods of Producing Nonfat Dry Milk Powder

There are two principal methods of producing nonfat dry milk powder: (1) the roller process (nearly non-existent in the U.S.) and (2) the spray-drying process. Numerous technical developments in the removal of water from 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. One development has served to virtually revolutionize the drying of nonfat milk – the process known as agglomeration or instantizing. This process involves slightly humidifying and then re-drying previously dried milk (referred to as re-wet 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 actual 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 as follows:

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 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 lowfat 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 reliquification 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 and 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, 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.

11.11 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	Instant nonfat dry milk
Dry cream	Lowfat dry milk
Dry whey	Malted milk
Dry whole milk	Modified dry milk products
Dry ice cream or ice milk mix	Nonfat dry milk (roller and spray process)
Dry whey protein concentrate	
Edible dry casein (acid)	Whey protein concentrate

Each of these products may have standards of identity promulgated by the Food and Drug Administration (CFR, 2006), with quality standards set and administered by the U.S. 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 or ice milk, 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(s) 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.

11.12 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 percent but less than 40 percent by weight of milkfat on an as is basis. It contains not more than 5 percent 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) U.S. Extra Grade and (2) U.S. Standard Grade. The grades are determined on the combined basis of flavor, physical appearance, bacterial estimate, coliform count, milkfat content, 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

Table 11.1 Classification of flavor for dry whole milk[1]

Flavor characteristics	U.S. Extra Grade	U.S. Standard Grade
Cooked	Definite	Definite
Feed	Slight	Definite
Bitter	NA	Slight
Oxidized	NA	Slight
Scorched	NA	Slight
Stale	NA	Slight
Storage	NA	Slight

[1] USDA, AMS U.S. Standards for Grades of Dry Whole Milk (April 13, 2001)
"NA" means not allowed at any level.

Table 11.2 Classification of physical appearance of dry whole milk[1]

Physical appearance characteristics	U.S. Extra Grade	U.S. 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

[1] USDA, AMS U.S. Standards for Grades of Dry Whole Milk (April 13, 2001).

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 of the Association of Official Analytical Chemists," published by the Association of Official Analytical Chemists International, 481 North Frederick Avenue, Suite 500, Gaithersburg, MD 20877-2417; by the methods provided in the latest edition of the "Standard Methods for the Examination of Dairy Products," available

Table 11.3 Classification according to laboratory analysis of dry whole milk[1]

Laboratory tests	U.S. Extra Grade	U.S. 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)[2] (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

[1] USDA, AMS U.S. Standards for Grades of Dry Whole Milk (April 13, 2001).
[2] Mild solids not fat basis.

from the American Public Health Association, 1015 Fifteenth Street NW, Washington, DC 20005, or by methods published by the International Dairy Federation, available from the International Dairy Federation, 41 Square Vergate, B-1030 Brussels, Belgium.

11.13 Flavor Properties of Dry Whole Milk

Upon rehydration, ideal dry whole milk 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 and extended or abusive storage conditions. The development of storage-based defects in dry whole milk is most difficult to control or eliminate. A recent study has highlighted the application of descriptive sensory analysis to document the flavor and flavor stability of WMP (Carunchia Whetstine and Drake, 2007). 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/frier 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 dry whole milk. This off-flavor, suggestive of old tallow, renders dry whole milk powder 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.

11.14 Other Properties of Dry Whole Milk

Tactile properties of dry whole milk vary with the method of manufacture, the degree of concentration prior to drying and the particle size and porosity after drying (Hall and 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 dry milk product. 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 dry whole milk. However, when it does occur, dry whole milk 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 dry milk 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 dry whole milk 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.

11.15 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 (2006). 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 percent by weight of moisture, and not more than 1and 1/2 percent 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 may be found by contacting the USDA, Agricultural Marketing Service (see 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 chemical. Conditions under which a "U.S. Grade" is not assignable vary for the different types of nonfat

Table 11.4 U.S. Grade Classifications of Nonfat Dry Milk (reliquified basis) based on flavor and odor[1]

Flavor characteristics	U.S. Extra Grade[2]	U.S. 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

[1] USDA, AMS U.S. Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant).
[2] Instant nonfat dry milk is allowed only as U.S. extra grade.
"NA" means not allowed at any level.

milk. 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 U.S. Standard Grade and/or a direct microscopic clump count in excess of 100 million/g results in nonassignment of a grade. 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 nonfat dry milk 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 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. 11.2).

Fresh, fluid nonfat milk deteriorates with age (as do other highly perishable milk products), generally due to microbial activity. On the other hand, flavor

Table 11.5 U.S. Grade Classifications of Nonfat Dry Milk based on physical appearance characteristics[1]

Physical appearance Characteristics	U.S. Extra Grade	U.S. Standard Grade[2]
Dry product		
Lumpy	Slight	Moderate
Unnatural color	NA	Slight
Visible dark particles	Practically free	Reasonably free
Reconstituted product		
Grainy	NA	Reasonably free

[1] USDA, AMS U.S. Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant).
[2] Applies only to spray and roller process. Only one grade, "U.S. Extra," is recognized for instant nonfat dry milk.
"NA" means not allowed at any level.

Table 11.6 U.S. Grade Classifications of Nonfat Dry Milk according to laboratory analyses[1]

Laboratory tests (or parameters)	U.S. Extra Grade[2]	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
U.S. High heat[3]	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	

[1] USDA, AMS U.S. Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant)
[2] Instant nonfat dry milk may be assigned only one grade, "U.S. Extra."
[3] Heat classification is as follows:
Low heat $\geq$ 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 $\leq$ 1.5 mg undenatured whey protein nitrogen/g dry product

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 nonfat milk may exhibit flavor characteristics inferior to that of fresh, fluid nonfat milk. However, a year-old dry product may be substantially more acceptable in flavor than a 3-week-old fluid nonfat milk.

A noteworthy supplement to the nonfat dry milk (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 U.S. Heat Treatment Classification with definition is as follows:

U.S. High-heat. The finished product shall not exceed 1.50 mg undenatured whey protein nitrogen per gram of nonfat dry milk.

U.S. 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.

U.S. Low-heat. The finished product shall be not less than 6.00 mg undenatured whey protein nitrogen per gram of nonfat dry milk.

The above-mentioned 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

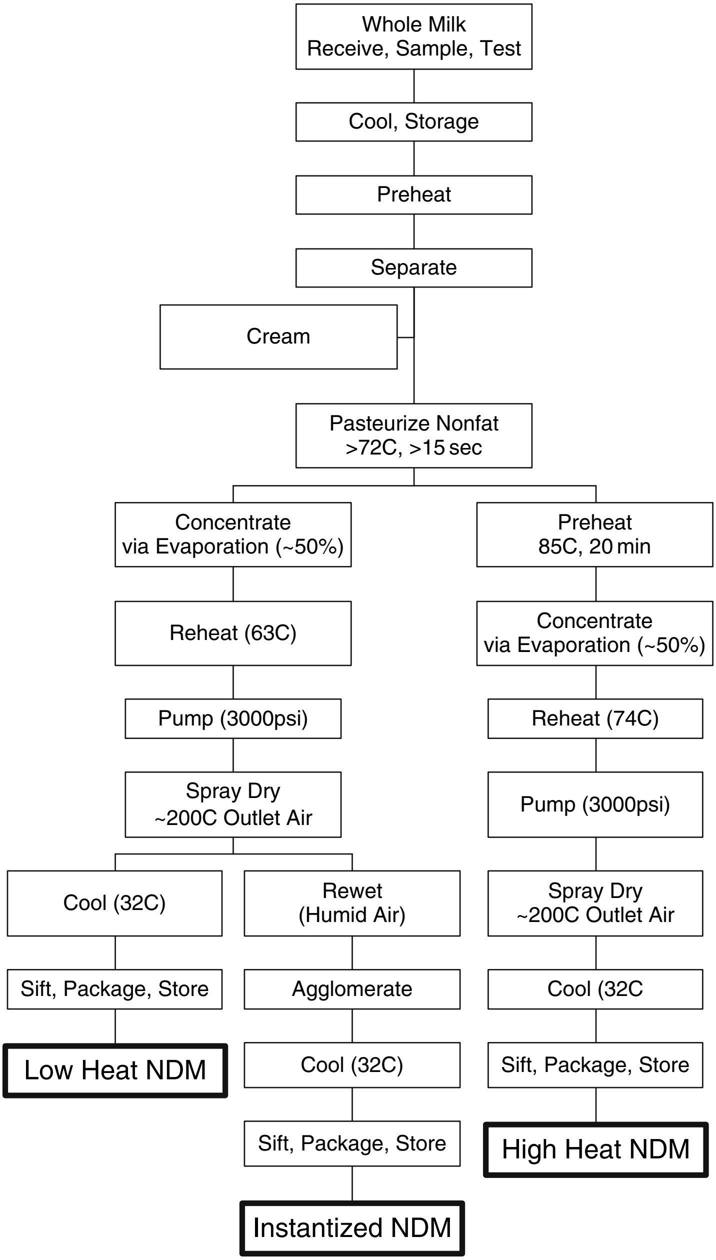

Fig. 11.2 Flow diagram for the manufacture of three forms of nonfat dry milk: low heat, instantized, and high heat

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," available from the American Public Health Association, 1015 Fifteenth Street, NW., Washington, DC 20005.

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 U.S. for use in the manufacture of cheese, and high-heat powder is used primarily in the baking industry.

Whereas U.S. 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.

11.16 Sensory Properties of NDM

Flavor. The flavor of high-quality nonfat dry milk 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 nonfat dry milk have much in common with those of dry whole milk, but differ in their relative importance. Caudle et al. (2005) demonstrated a reduction in consumer acceptance toward products formulated with off-flavored nonfat dry milk powders. Interestingly, Lloyd et al. (2004) demonstrated that even extremely aged samples of nonfat dry milk were acceptable to consumers for use in an emergency. Some common flavor defects of nonfat dry milk include scorched, stale, storage, old and oxidized/tallowy.

Scorched. As in the instance of dry whole milk, 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 nonfat dry milk (NDM). This particular off-flavor is even more quick to occur and distinct in NDM than in dry whole milk. 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 and coworkers (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 nonfat dry milk with such terms as animal-like, wet dog and fryer oil. Additional recent references include Karagul-Yuceer et al. (2001), Karagul-Yuceer et al. (2002), 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 dry whole milks. 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 nonfat dried milk (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.

11.17 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. 11.3). The dried product made by the roller process is much more coarse and less homogeneous, unless it is extensively pulverized after drying.

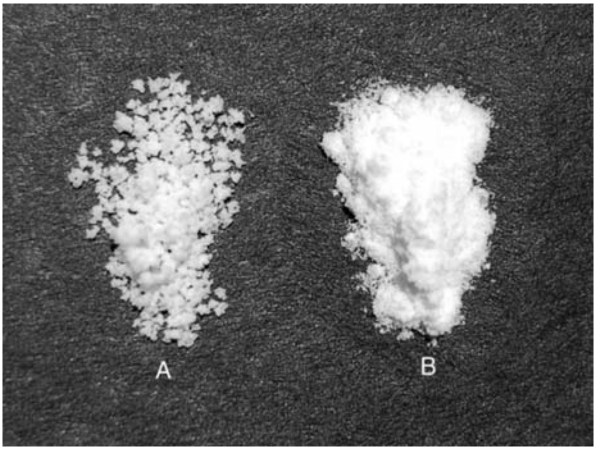

Fig. 11.3 Samples of instantized (**A**) and non-instantized (**B**) nonfat dry milk powders; note the large, porous structures of the instantized product allowing for improved wettability properties as compared to the fine structure in sample B where clumping can readily occur during rehydration

Instant nonfat dry milk 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, 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. 11.4). 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, nonfat dry milk 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

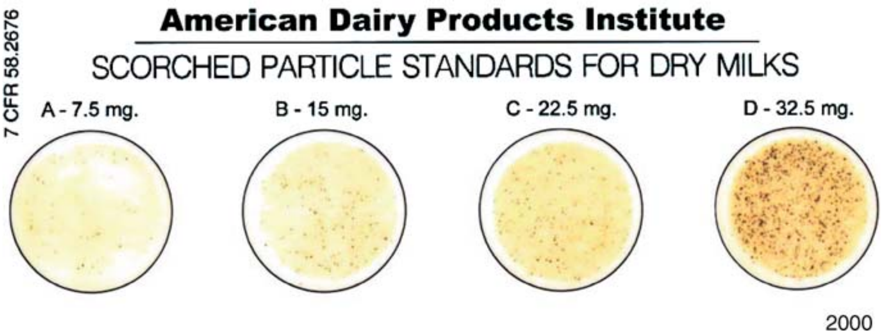

Fig. 11.4 A scorecard depicting standards or grades of dry milk relative to the appearance/mass of scorched particles (ADPI, 2000)

age-darkening (and to a greater intensity) than roller-process powders. However, dry powders made by both processes are susceptible to this defect.

11.18 Dry Buttermilk

The definitions and standards (USDA, Agricultural Marketing Service) 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 percent. 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 chemical.
> (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 percent. 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 chemical.

The two U.S. grades of dry buttermilk and dry buttermilk product, "U.S. Extra" and "U.S. 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 U.S. 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 nonfat dry milk. 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 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

Table 11.7 U.S. Grade Classifications of Dry Buttermilk based on flavor, physical appearance, and laboratory analyses[1]

Quality attributes (or laboratory tests)	U.S. Extra Grade	U.S. Standard Grade
Flavor	NA	Slight
Unnatural	NA	NA
Offensive		
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, %	$\geq$0.10 to $\leq$0.18	$\geq$0.10 to $\leq$0.20
Protein		
Dry buttermilk (min)	30.0	30.0
Dry buttermilk product	<30.0	<30

[1] USDA, AMS U.S. Standards for Grades of Dry Buttermilk and Dry Buttermilk Product (February 2, 2001).
"-NA" means not allowed at any level.

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 U.S. Extra Grade: "Shall be sweet and pleasing, and has no unnatural or offensive flavors."
> For U.S. 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.

11.19 Dry Whey

The U.S. 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, "U.S. 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 U.S. 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 whey will vary with the whey acidity and the drying process. The flavor of good-quality dry whey is usually pleasantly sweet, 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

Table 11.8 U.S. Grade Classifications of Dry Whey based on flavor, physical appearance, and laboratory analyses[1]

Category	U.S. 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

[1] USDA, AMS U.S. Standards for Dry Whey (December 14, 2000).

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 and Rankin, 2006) as well as shelf life estimation (Dattatreya et al., 2007) relative to the development of brown discoloration.

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).

11.20 Edible Dry Casein

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.

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 non-dairy foods such

Table 11.9 U.S. Grade Classifications of Edible Dry Casein (Acid) based on flavor and odor, physical appearance, and laboratory analyses [1]

Category	U.S. Extra Grade	U.S. 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:	≤ 30,000	≤ 100,000
Standard plate count/g	Negative	≤ 2
Coliform count/0.1 g		
Protein content, $N \times 6.38$, 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	≤ 1.0	
(as lactose) %	Negative	
Staphylococcus (coagulase positive)	Negative	
Salmonella in 100 g		
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	

[1] USDA, AMS U.S. Standards for Grades of Edible Dry Casein (Acid) (July 20, 1968).

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 non-enzymatic 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. Recent work to determine the chemical cause of off-odors in rennet casein identified such compounds as guaiacol, indole and ρ-cresol (Karagul-Yuceer et al., 2003).

11.21 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, lowfat 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.

11.22 Dry Cream

The FDA standard of identity for dry cream may be found in 21 CFR 131.149 (April 1, 2006). 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 percent but less than 75 percent by weight of milkfat on an as is basis. It contains not more than 5 percent 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, nutritive carbohydrate sweeteners. Characterizing flavoring ingredients, with or without coloring, 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.

11.23 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 lowfat 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 lowfat 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 lowfat 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.

11.24 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 and non-dairy coffee whiteners. 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.

Another major category of dried dairy ingredients involves the use of membrane separation technologies and includes such products as milk protein concentrate, 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. Recent literature detailing the manufacturing and composition (Smith, 2004) 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.

11.25 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

Product: __________________

Sample No. Date:

Flavor 10	Criticism	Score →
	Acid	
	Astringent	
No criticism	Bitter	
10	Chalky	
	Cooked	
	Feed	
	Fermented	
Unsalable	Flat	
0	Foreign	
	Gluey	
	Metallic	
Normal Range	Neutralizer	
1-5	Oxidized/Tallowy	
	Rancid (Lipolysis)	
	Salty	
	Scorched	
	Stale	
	Storage	
	Unclean/Utensil	
	Weedy	
Physical Appearance 5		Score →
	Dry Product:	
	Caked	
	Dark Particles	
No Criticism	Lumpy	
5	Unnatural Color	
	Reconstituted	
Unsalable	Product:	
0	Churned Particles	
	Dark Particles	
Normal Range	Grainy	
1-5	Undispersed Lumps	
Package 5		Score →
	Ruptured Vapor Barrier	
No Criticism 5	Soiled	
	Unsealed	
Unsalable 0		
Normal Range 1-5		
Laboratory Tests 5		Score →
	Fat (%)	
	Moisture (%)	
No Criticism	Titratable Acidity (% Lactic Acid)	
5	Solubility Index (mL)	
	Bacterial Estimate (Per Gram)	
Unsalable 0	Coliform (Per Gram)	
	Direct Microscopic Clump Count (per g)	

Fig. 11.5 A suggested dry milk product scorecard

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 solution), allowing the product to fully rehydrate (see Lloyd et al., 2004) and sampling the product at the

Scorched Particles (mg)								
Dispersibility (Modified Moats-Dabbah Method. %)								
Phosphatase Test Micrograms Phenol/mL								
Undenatured Whey Protein Nitrogen (mg/g)								
Oxygen Content (%)								
Copper (ppm)								
Iron (ppm)								
Vitamin A (I.U.)								
Vitamin D (I.U.)								
Alkalinity of Ash (mL/100 g)								
Protein Content (%)								
Mesh (Screen %)								
Ash. Phosphorus Fixed (%)								
Lead (ppm)								
Yeast and Mold (per 0.1g)								
Thermophiles (per g)								
Reducing Sugars (as Lactose %)								
Staphylococcus (Coagulase Positive)								
Salmonella (In 100 g)								

Signatures: _______________ ____________________ ____________________

Fig. 11.5 (cont.)

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.

11.26 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, tannic acid; unripe bananas may also be used as a standard. There is an associated

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[1]	2	1	0	0	0
Gluey	2	1	0	0	0
Metallic	4	3	2	1	0
Neutralizer[2]	0	0	0	0	0
Oxidized/tallow[3]y g	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.

[1] 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).

[2] The use of neutralizers is not authorized except in whey.

[3] When an oxidized off-flavor has progressed to the tallowy stage, the assigned flavor score should be "0" (zero).

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).

11.27 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:

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.

Practically free. Present only upon very critical examination.

Reasonably free. Present only upon critical examination.

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 an unhomogeneous 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, non-enzymatic 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 (2002) includes this statement within their General Grading Requirements: “The dry milk product shall be free from extraneous matter as described under Section 402(a) of the Federal Food, Drug, and Cosmetic Act.”

11.28 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 pressure*. 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.

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.

11.29 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 American Dairy Products Institute (2002) addressed the packaging requirements for dried milk products under its General Grading Requirements as follows: "The dry milk product shall be packed in substantial containers suitable to protect and preserve the contents without significant impairment of quality with respect to sanitation, contamination and moisture content under various customary conditions of handling, transportation and storage." 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.

11.30 Laboratory Tests of Dry Milk Products

Certain laboratory tests are indispensable in helping to assess the quality parameters of dry milk. 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 characteristics. Descriptions and procedures used for conducting such assays are included in several well-recognized resources, listed below for reference.

Association of Official Analytical Chemists, International. (2006) Official Methods of Analysis 18th 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)

Scorched Particle Standards for Dry Milks
Whey Color Standards
Lactose Color Standards
ADPI Bulletin 916, "Standards for Grades of Dry Milks Including Methods of Analysis" ADPI Bulletin W-16, "Whey & Whey Products - Definitions, Composition, Standard Methods of Analysis."

The International Dairy Federation (See www.fil-idf.org)

11.31 Methods of Reconstituting Dry Milk for Flavor Examinations

Limited quantities of reconstituted dry milks are used as beverage products in the U.S. However, even if they are used only as ingredients in dairy products or other foods, the sensory properties of reconstituted dry milks 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 milk products for determining their suitability as a food product ingredient. For example, if a poor-quality (off-flavored) nonfat dry milk 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 dry milk may sometimes be incorporated into highly flavored products with little negative impact.

Two types of test situations may arise with dry milk 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 milk 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 reliquified 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 milk 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 one 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 U.S. grade standards.

The American Dairy Products Institute (2002) provided a similar set of directions:

> Immediately after opening the container, examine the samples of dry milk for flavor and odor. The flavor and odor should be determined on the reliquified sample as follows: Add 10 g nonfat dry milk or dry buttermilk or 13 g dry whole milk to 100 ml distilled water and mix thoroughly. Permit sample to stand 1 hr in a glass container with an air tight inert cap; gently stir and determine flavor and odor. Determination should be made with sample at 75°F (24°C).

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).

11.32 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 Cheese

Diane Kussy and Edward Aylward

12.1 Introduction

12.1.1 Pasteurized Process Cheese Consumption

While natural cheeses tend to form free fat and moisture in cooking applications, process cheeses 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 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 run 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 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. Table 12.1 shows some historical production information for process cheeses; process cheese foods and spreads; and cold pack cheeses (International Dairy Foods Association, 2006). Table 12.2 presents U.S. process cheese per capita consumption data for a similar time frame (International Dairy Foods Association, 2006).

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Table 12.1 U.S. production of process cheeses, cheese foods, spreads and cold pack (million pounds)

Year	Process cheese	Process cheese foods and spreads	Cold pack cheese and cheese foods	Total
1980	1,009	653	52	1,714
1990	1,193	876	84	2,152
1995	1,472	832	36	2,340
2000	1,388	854	45	2,288
2005	1,240	991	39	2,270

Table 12.2 U.S. process cheese per capita consumption (pounds)

Year	Process cheeses	Process cheese foods and spreads	Total	Cheese content	Consumed as natural cheese
1980	3.96	3.09	7.05	5.52	12.01
1990	4.79	3.84	8.63	6.81	17.80
1995	5.45	3.25	8.70	7.01	19.90
2000	4.85	3.19	8.04	6.44	23.35

12.2 Product Definitions

Process cheese is defined within Title 21 of the Code of Federal Regulations (CFR) 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. U.S. regulations allow cheese spreads to contain between 44 and 60% moisture; and milkfat must be ≥20%

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.”

Much knowledge and manufacturing 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. Emulsifiers for process cheese are not typical oil:water interface compounds (such as lecithin), but instead, are salts (usually sodium) of organic or inorganic acids. Various sodium phosphates or trisodium citrate are most typical. The function of these emulsifier 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.

12.3 Sensory Evaluation

The application of sensory evaluation of 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 re-processing. 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) 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 U.S. process cheese varieties.

12.3.1 Grading of Raw Materials (7 CFR 58.735)

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 U.S., this source is often granular cheese (21 CFR 133.144), 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 which 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 Chapter 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 Chapter 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 Chapter 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 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 anti-mycotics 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.

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). 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^{TM} 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 U.S. 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 Chapters 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 flavors 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 producing 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). The reader is referred to Chapter 17, which provides an overview of lexicon development and applications to many cheeses and dairy products. Table 12.3 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

Table 12.3 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	Non-specific 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

Table 12.3 (continued)

Attribute	Description	Reference
Cooked	Aromatics of cooked milk	Skim or 2% milk heated to 85°C for 30 min
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)

standards that can help focus product development and quality assurance endeavors.

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: (1) the pertinent dilution factor and (2) for 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 cheese 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 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 excessive lactose. Appearance information from the melt test may therefore lead you 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.

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 want 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 five pound loaf format should have good package conformity. If the package appears squashed or slumped, this is a quick indication of lack of texture. 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 U.S. 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. Process cheese "product" may be identified by a fanciful name not defined in the CFR. Evolution of process cheese varieties and processing methods has historically been proprietary; however, Zehren and Nussbaum (1992) and Fox et al. (2000) present useful and comprehensive background regarding process cheese characteristics and manufacture.

Process cheese emulsions are formed by the action of emulsifying salts on casein. Hydrophobic regions of casein are unfolded and surround fat droplets holding them in a stable process cheese matrix. Emulsifying salts are typically sodium phosphates or trisodium citrate; they are not typical oil-in-water interface compounds such as lecithin or other surface active agents which are used to emulsify margarines.

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. Title 7 of 21 CFR contains sensory characteristics that USDA expects of natural cheeses. 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. Other chapters in this book explain the desirable sensory characteristics of milkfat sourced as cream as well as desirable characteristics of dry dairy ingredients.

Some ingredients not of dairy origin may affect process cheese sensory characteristics. Acids may be useful to adjust process cheese pH, but may lead to sharp, acidic or even bitter flavor defects. By raising process cheese pH, emulsifying salts may be associated with soapy or detergent-like flavors in process cheeses. Sugars may impact texture and will provide sweet flavor. Corn syrup solids or maltodextrin not only may aid in achieving target texture, but also bring sweet flavors which may or may not be desirable depending upon customer expectations.

Starter distillate, yeast extracts, the vegetable oil carrier for color or vitamins, anti-mycotics and enzyme-modified cheeses all may influence process cheese flavor. EMC will have the largest impact. 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.

Sensory evaluation of process cheeses often involves creation of a target or "gold standard" process cheese. 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. A lexicon provides a common language and lends itself to the creation of known standards that convey specific flavor characteristics which trained panelists may then identify and quantify in samples of process cheese. 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 12.4).

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.

Table 12.4 Examples of process cheese evaluation scorecards

Sample identification	Describe attributes (appearance; texture; flavor)	Acceptable (A)/ unacceptable (U)
271		
370		
319		

Appearance: shiny; matte; browning; pinking; yellow; orange; greasy; other (describe).
Texture: soft; firm; pasty; brittle; chalky; sandy; other (describe).
Flavor: aged cheese; astringent; barny; browned or toasted; burnt; diacetyl; cardboard; milkfat; sour aromatic; sweet aromatic; unclean; fruity; goaty; moldy; musty; old oil (rancid); soapy; acidic (sour); yeasty; acetaldehyde; brothy; cooked; cowy (phenolic); free fatty acid; nutty; sulfur; whey; other (describe).

Sample identification	Describe attributes (appearance; texture; flavor)	Acceptable (A)/borderline (B)/ unacceptable (U)
271		
370		
319		

Appearance: shiny; matte; browning; pinking; yellow; orange; greasy; other (describe).
Texture: soft; firm; pasty; brittle; chalky; sandy; other (describe).
Flavor: insert your lexicon here.

	Slight	Definite	Pronounced
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 8.4 Sensory Evaluation of Cheese

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Chapter 13
Sour Cream and Related Products

Michael J. Costello

Cultured sour cream containers (cartons and a squeeze bottle) of various sizes and brand labels

13.1 Introduction

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. This chapter will focus on just several of this large segment of spoonable and drinkable cultured dairy

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foods, namely cultured sour cream, crème fraiche, and cultured buttermilk. Yogurt, one major category of fermented milk products, has been reviewed in another chapter. Unfortunately, it is beyond the scope of this book to explore the sensory characteristics of some of the other cultured (soured) milk products and beverages such as kefir, taette, koumiss, curd, etc.

The goal of this chapter is to (1) provide the reader with a list of sensory characteristics found in the preferred or "ideal" sour cream and related cultured milk products; (2) review some of the manufacturing faults that may yield less than satisfactory sour cream and several other fermented milk products; and (3) provide a vocabulary that will assist in communicating the preferred sensory attributes that a quality assurance manager might convey to the production supervisor and/or manufacturing team.

One form of a popular fermented dairy product that recurs under different names but in slightly different forms globally is known in the U.S. by the simple descriptor, "sour cream." Variations from the U.S. 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 soured creams vary accordingly. Cultured sour cream in the U.S. 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 and Mistry, 1997), while 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).

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 foodservice users.

13.2 Standards of Identity for Sour Cream

The U.S. Code of Federal Regulations 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 cultured 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, low-fat, 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." 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." Finally, so-called fat-free 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."

Standards for the minimum titratable acidity remain consistent for all sour cream products – namely $\geq$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).

13.3 Manufacturing Methods

The following discussion describes a typical process for making cultured sour cream. There are certainly variations to the methods described here that may be utilized to yield products that serve niche markets. But most sour creams found in the grocery store dairy case are manufactured by a process closely resembling the one described below.

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 followed by a single-stage homogenization at 14–21 KPa (2000–3000 psi), at a temperature between 40° and 85°C (104–185°F), although this can vary depending upon the fat content and stabilizers used (Lyck et al., 2006). These researchers recommend 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.

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.

The characteristic flavor of a quality sour cream should include a subtle to moderate 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 of the cream. This composition includes fat content, milk solids not fat, and citric acid concentration. The cream must also be free of defects, such as rancidity and auto-oxidation.

Achieving the subtle flavors that we expect of sour cream, crème fraiche, and buttermilk requires a metabolic collaboration between homofermentative and heterofermentative lactic acid bacteria. 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 still yields lactic acid as its primary metabolite, but will also yield technologically significant quantities of flavor compounds such as diacetyl, acetic acid, and acetaldehyde and sometimes, carbon dioxide (Kosikowski and Mistry, 1997; Morgan et al., 1966; Lindsay, 1965). Kneifel et al. in 1992 screened commercially available U.S. mesophilic starter cultures for their respective biochemical, sensory, and microbiological properties for the successful propagation of various cultured dairy foods, including sour cream and cultured buttermilk. 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 sour cream (and likewise cultured buttermilk) is diacetyl (2,3 di-butanone). The so-called buttery note in sour cream 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 the sour cream to be 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 in sour cream, 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 is largely influenced by diet. The milk from cows fed on pasture will contain more citric acid than those fed rations (Davies, 1939). To permit flavor development, federal regulations permit supplementing the product 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 sour cream that lacks acidity.

The citrate transport system requires some acid to be present and indeed 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).

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).

A widely adopted processing variation includes a dual homogenization procedure initially developed by Dr. Guthrie of Cornell University (Kosikowski and 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 U.S. are produced with the application of only the first-stage valve to maximize product viscosity and surface sheen (Kosikowski and 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 and Mistry, 1997).

In order to satisfy a number of consumer and foodservice user demands for functionality and certain aesthetics in sour cream, stabilizers and/or emulsifiers may be added, although they are certainly 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. Caution should be employed when using gelatin though, as even slightly overusing it will yield a body so stiff that it cannot be stirred with a light weight plastic spoon without breaking the spoon handle. More commonly, proprietary blends of stabilizer/emulsifier will also yield sour cream that generally satisfies 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 and Bodyfelt, 1995, 1996; Chen et al., 1999).

Another critical aspect of cultured sour cream manufacture is the requisite need for fastidious post-process sanitation protocols, inasmuch as the presence of numerous Gram negative (i.e., psychrotrophs) produce vast quantities of diacetyl reductase, which readily reduce diacetyl to the flavorless reduction end product, acetyl methyl carbinol (Seitz et al., 1963; Bennett et al., 1964).

13.4 Product Variations

A relatively new and innovative product variation is a “squeezable” form of sour cream. This particular product is thinner and 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 "weaker" form of body, the manufacturer may prefer to employ xanthan gum and/or carboxymethylcellulose (CMC) as body stabilizers. Another variation of cultured sour cream sometimes employed by "organic" manufacturers is the incorporation of additional skim milk powder into the formulation.

By dramatically increasing the milk solids not-fat fraction, the manufacturer can more effectively bind water and inhibit objectionable 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).

13.5 Sensory Evaluation of Sour Cream

13.5.1 Product Packaging

The first sensory consideration when evaluating sour cream is sight, since the package provides the customer with their first insight or information regarding product quality. Sour cream in the U.S. is typically marketed in wide-mouthed polypropylene tubs. Consumer-sized packaging will range from 228 to 455 g (8–16 oz), with some containers weighing as much as 1362 g (3 lb).

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 has no way of knowing if the seal came off when they opened the package or if the seal had been tampered with prior to purchase.

13.5.2 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. The consumer should expect to find an opaque product, with no translucency. This may present a challenge in low and fat-free sour cream products. No “free whey” should be visible either on the surface or in a space between the sour cream and the sidewall of the tub. Free whey is often the result of either an un-stabilized sour cream or a sour cream that would have benefited from a higher heat treatment. This is often a particular problem with low-fat and non-fat versions of sour cream.

Example A in Fig. 13.1 represents a high-quality premium sour cream. Example B is an organic sour cream that contains no stabilizers. The manufacturer of the organic product incorporated an elevated quantity of skim milk powder into the formulation, thus yielding an overly firm and grainy-like sour cream, as shown in Figs. 13.2 and 13.5. Figure 13.2 shows a range of the body attributes found in commercial sour cream. Example C is a thin-bodied, “squeezable” form of sour cream. Example D is a highly stabilized product that, while not nearly as firmly structured as Example B, was still quite firm and a bit slimy or salve-like in the mouth. Example E is a low-fat organic sour cream. Note the close-up view of it in Fig. 13.3. This particular sour cream exhibits both translucency and pockets of whey, as the product partitions into curd and whey. Example F is an improperly stabilized sour cream that has begun to expel a hazy whey “halo.” See close-up in Fig. 13.3.

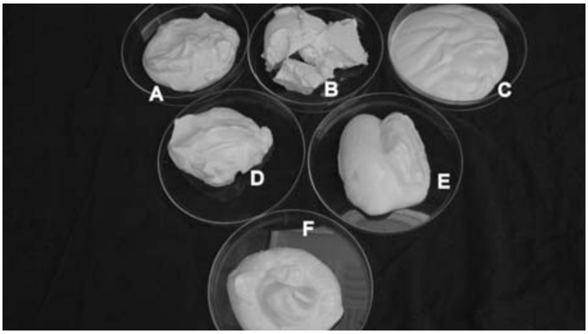

Fig. 13.1 Sour cream examples representing the spectrum of body and texture. Samples **A**, **D**, and **F** fall within the range of expected body and texture; **B** represents an extreme firmness; while samples **C** and **E** appear thin bodied

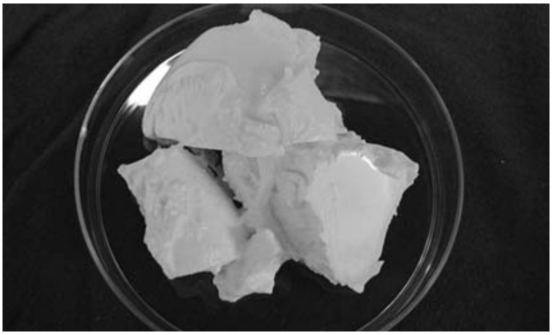

Fig. 13.2 Example of a “too firm” sour cream

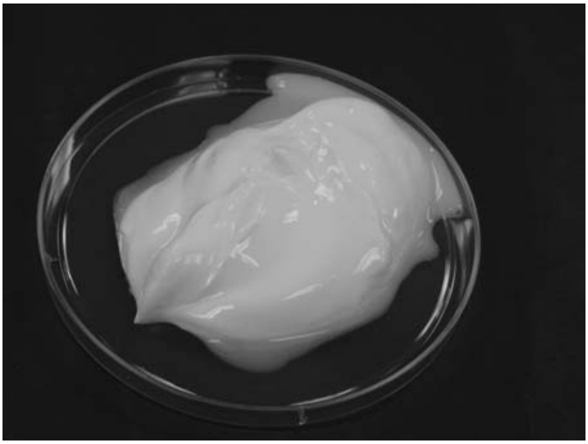

Fig. 13.3 A sour cream displaying a whey "halo"

Fig. 13.4 A sour cream sitting up nicely in the spoon and displaying an "ideal" body

Fig. 13.5 A very firm sour cream on a spoon

A dull surface appearance (one that lacks gloss) can result from the use of chymosin (rennet) to coagulate reduced fat sour cream products. Free whey on the surface is another potential consequence of chymosin usage (Lee and 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.

Another appearance defect that occurs commonly in both light and fat-free sour cream formulations is a general tendency of translucency, which gives away the product's reduced fat composition (Fig. 13.6). Figure 13.7 shows a reduced fat sour cream exhibiting a slight translucency as well as free whey on the surface. Some product manufacturers may include titanium dioxide as a

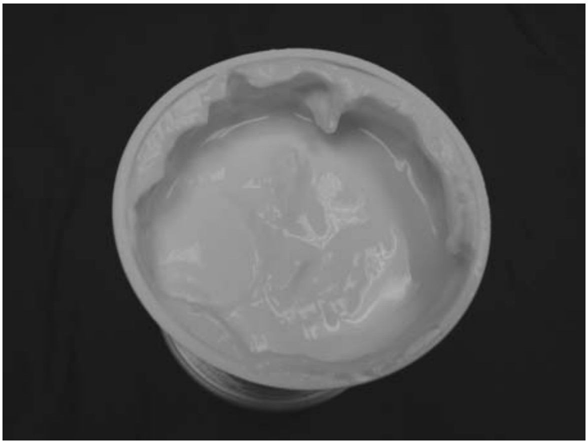

Fig. 13.6 A sour cream exhibiting both translucency and surface free whey

Fig. 13.7 Grainy texture clearly visible on surface. Free whey is visible as well

trace ingredient to impart an enhanced opacity that attempts to better emulate the appearance of full fat sour creams.

13.5.3 Body and Texture

Within the mouth, the texture of sour 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 sour cream products is grainy (or grittiness – depending on particle size); it is characterized by the persistence of small, firm particles within the mouth.

13.5.4 Grainy

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 sour cream with a 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 3/4 capacity (Infanger, 2006, personal communication).

The occasional presence of residual acid cleanser residues (such as peroxyacetic acid) on processing equipment and piping will 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 were coagulated by using chymosin may also exhibit a texture described as "grainy/gritty," "too firm," and/or "lumpy" (Lee and White, 1993).

13.5.5 Viscosity

A number of sometimes-conflicting forces act to yield a wide spectrum of body attributes in retail sour cream. A food service customer might prefer a highly stabilized product that will keep its form when placed on a baked potato long before serving. A manufacturer serving that food service market may distribute the same product to retail customers. Overstabilization sometimes serves as a crutch for the manufacturer that would substitute stabilizers for sound manufacturing protocols, such as homogenization temperatures and pressures.

But consumers are not without their own influence. Attempts to market direct set sour cream have largely failed because the sensory attributes of the resulting product failed to satisfy consumer expectations (Bodyfelt, 2007). The price that finished products command, particularly those perceived as "premium," are influenced by what economists call the "law of marginal utility." This principle dictates that the price that consumers will be willing to pay is based upon their perceived replacement value. As such, it is important for producers, particularly those serving niche markets, to achieve consistency in their product. Figures 13.1–13.5 display the spectrum of viscosities seen in consumer sour cream products. Each of these products satisfies a niche market somewhere.

One variable that needs to be considered when seeking to achieve an "ideal" viscosity 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 and Maynes, 1997). As the temperatures at which sour cream is fermented falls between these ranges, the gel is formed through a blend of these mechanisms and small changes in fermentation temperature could alter the mix gel "alloy" formed, and therefore the functional characteristics might be predicted to change accordingly (Hunt and Maynes, 1997). A weak body or low viscosity can result from low-fat content, low milk solids not fat, 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).

13.5.6 Gassy

Another texture defect occasionally encountered in sour cream is "gassy," due to CO_2 formation. Gassy sour cream 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).

13.5.7 Flavor

Controlled manufacture of sour cream should impart only the most subtle and delicate flavors. As such, flavor defects originating in the raw materials will not

Fig. 13.8 Gas bubbles around the edge of sour cream

be masked in this product's production. Hence, it is essential that the cream used for the manufacture of sour cream be relatively free of flavor defects. Additionally, the utmost care must be taken during the manufacturing stages of sour cream to protect it from development of any off-flavors. The flavor of a high-quality sour cream should be mildly acidic and creamy, with a subtle buttery note (diacetyl). The trend for cultured cream products in recent years has been toward a less acidic flavor (Meunier-Goddik, 2004). Some developing countries wishing to replicate North American-style sour cream may be hindered by the inferior quality of their raw materials. 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 sour cream products.

Certain contaminating microorganisms can contribute to a "flat" (lacks culture aroma) sour cream. *Pseudomonas fluorescens* and *Enterobacter aerogenes* possess acetoin dehydrogenase activity; hence, the unfortunate contamination of the sour cream by these particular pyschrotrophic 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 and 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 sour cream (Hutkins, 2006).

Table 13.1 Body and texture, and appearance defects in sour cream, their characteristics and possible causes

Defect	Characteristic	Cause
Curdy	Exhibits non-homogeneous mouthfeel, and/or contains lumps of firm curd.	Untimely agitation of a weak coagulum in the late stages of incubation. Non-homogeneous 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	Mealiness or small, persistent particles.	Incomplete rehydration of dry ingredients, irreversibly denatured proteins, or final product pH too close to the isoelectric point of casein.
Gel-like	Gelatin consistency.	Excessive use of, or incorrect stabilizer.
Slimy (salvy) or over-stabilized	An unnaturally "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, the handle may readily break in half.	Excessive inclusion of milk solids; or excessive heat treatment of the product base; or over-stabilization.
Too thin	Low viscosity.	Low milk solids levels, and/or insufficient heat treatment of the product base.
Unnatural color	There may be an excess of a yellowish color or the total absence of a creamy-like color.	Excess carotenoid levels in the cream will yield a darker than expected color. Low-fat or fat-free sour cream analogs will often appear unnaturally white or dull in appearance

13.6 Reduced Fat Sour Cream Products

Over recent decades, heightened health concerns have motivated many American consumers to seek reduced fat products for purported health benefits. Nevertheless, the consumer demands that reduced fat products possess sensory attributes that approximate the traditional, full fat versions of familiar foods.

Table 13.2 Some flavor defects found in cultured sour cream, their brief description, and possible causes

Defect	Description	Cause
Acid (high)	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.
Acid (low)	Product lacks the expected subtle to moderate acidity (taste) level.	The product was under inoculated, incubated at too low of temperature, or the fermentation was arrested too soon.
Bitter	An unpleasant 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.
Feed (weed)	An off-flavor suggestive of any high-volume feedstuffs (roughage) fed to lactating cows; i.e., silage, alfalfa, other hays, brewer's or cannery by-products, and occasionally certain grasses. Note: Experienced taster may recognize a specific feed source. Other may perceive within a generic sense.	This flavor defect is 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.
Atypical (foreign)	A descriptive term that denotes an atypical off-flavor, and/or often objectionable for sour cream (i.e., unusual, possibly offensive).	An atypical off-flavor may derive from leaked lubricants (most common), accidental contamination with cleaning chemicals or residual sanitizers.
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.

Table 13.2 (continued)

Defect	Description	Cause
Lacks acidity	Product lacks characteristic sour (acid) taste.	Insufficient fermentation (too high pH (> 5.5).
Oxidized (metallic)	Product exhibits some level of oxidized off-flavor (i.e., from cardboardy, metallic, painty, too fishy); possibly with an associated puckery mouthfeel sensed by the mucous membranes of the oral cavity. Depending upon severity, oxidized off-flavor may manifest itself as wet cardboard or cabbage-like.	Exposure of the milk or cream to transition metal surfaces (i.e., copper, iron, and/or manganese) or their ions deposited on equipment surfaces can yield this defect.
Oxidized (light activated)	Product exhibits some characteristics of "metallic oxidized," but has some distinctive aromatic characteristics suggestive of "burnt hair or feathers." Also, light-oxidized flavor tastes differ depending upon the fat content of the given product (i.e., differences full fat from fat-free products). Light-oxidized fat-free 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.	The two most common causes of rancidity are hydrolysis of triglycerides by contaminating bacteria and rough treatment (over agitation, air leaks, freezing) of the raw milk that facilitates endogenous lipase activity due to fractured fat globule membranes.
Lacks freshness (stale)	A stale, often lingering flavor (with possible associated astringent mouthfeel sensation).	This is often a consequence of the use of aged dry dairy ingredients, most commonly older dry milks and/or whey powders.
Stabilizer/ emulsifier	The source(s) of stabilizer and/or emulsifier ingredients will determine the sensory nature of this particular off-flavor. Commonly, many emulsifiers tend to develop a unique type of "oxidized/chemical-like" off-taste sensation.	Excessive stabilizer and/or emulsifier in the formulation, often occurs when manufacturers of reduced fat or fat-free sour cream analogs attempt to create a creamy mouthfeel. Many emulsifiers contain elevated levels of unsaturated fatty acids, which are quite vulnerable to auto-oxidative deterioration processes.

Table 13.2 (continued)

Defect	Description	Cause
Yeasty	Smells like rising bread dough. Flavor possesses bread-like notes.	Failure to maintain the milk or cream at a sufficiently low temperature, combined with the exposure of processing lines and equipment to dust.
Miscellaneous absorbed	Any number of absorbed flavors	As milk is in large part a colloidal suspension of fat globules and water, it possesses the solvent qualities of both and can absorb almost any aroma from the air. Very often the flavor or aroma and its source are recognizable (like cooking odors) and so their remedy is obvious.

Manufacturers have responded to this demand with uneven success. But, 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.

Sour cream falls 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 its sensory attributes as well as its lower fat content. The perceived sensory deficiencies of reduced fat sour cream are both in flavor and in body and texture.

The body and texture of reduced fat sour cream products are often less creamy-like and seemingly more gelatinous than the full fat product. However, some contemporary manufacturers are producing light sour creams either comparable or even superior to sour creams with prudent formulation and modified manufacturing processes (Durbin, 1996; Thunell et al., 1994). Additionally, 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 thin and ephemeral.

13.7 Summary

Sour cream and its 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 sour cream is largely defined by the consumers who purchase it and who, more importantly, purchase it again if their first sampling satisfies their needs and expectations. Keeping that customer 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.

13.8 Sensory Evaluation of Crème Fraîche

Crème fraîche is the French equivalent of cultured sour cream and is distinguished from the American product primarily in its fat content, the absence of stabilizers, and by its milder flavor (Meunier-Goddik, 2004). Crème fraîche, or more correctly, crème fraîche épaisse fermentée, possesses a fat content between 30 and 45%. The acidity 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.

Full fat crème fraîche is a stable gel that will not separate in most applications. Reduced fat crème fraîche (~15% fat) 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 U.S. grocery shelves and is usually much more expensive than sour cream. One can make a perfectly serviceable 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. The flavor and texture defects, described for sour cream in Tables 13.1 and 13.2, are entirely applicable to crème fraîche.

13.9 Sensory Evaluation of Cultured Buttermilk

Cultured buttermilk is closely related to sour cream in flavor, processing, and microbiology, except for the principle dairy ingredient (i.e., skim or low-fat milk vs. cream or "low-fat" cream). Buttermilk is also related to sour cream from a historical perspective. Before refrigeration had been commercially developed or became commonly available on farms, cream intended for butter manufacture was typically somewhat "preserved" by permitting souring to occur. Since many rural-based creameries only churned 3–5 times per week, the U.S. Department of Agriculture, as late as 1930, advised "ripening the cream" by allowing it to stand at room temperature until it acquired a "glossy appearance and was mildly sour" (White, 1917).

The butter churned from soured cream was presumably more flavorful than our prevailing sweet cream butter of today. In addition, the churning of sour cream yielded a secondary by-product, buttermilk, which inherently contained butter flakes. As a "throwback" to that visual component, a modest amount of contemporary commercial buttermilks may contain added butter flakes to emulate or reproduce the appearance of the earlier period traditional churned buttermilk products. Hence, the buttermilk on today's grocery store shelves is more correctly referred to as "cultured buttermilk." Interestingly, this milk product 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 $\geq$1.0% titratable acidity) (Table 13.3).

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.

Table 13.3 Standards of identity for cultured milk products (Kosikowski and Mistry, 1997)

Product name	Composition[1]
Acidified milk[2]	$\geq$ 3.25% milkfat
Cultured milk[3]	$\geq$ 8.25% solids not fat
	$\geq$ 0.5% titratable acidity
Acidified low-fat milk	$\geq$ 0.5% $<$ 2.0% milkfat
Cultured low-fat milk	$\geq$ 8.25% solids not fat
	$\geq$ 0.5% titratable acidity
Acidified skim milk	$<$ 0.5% percent fat
Cultured skim milk	$\geq$ 8.25% solids not fat
	$\geq$ 0.5% titratable acidity

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

13.9.1 Body and Texture

Since the body and texture of buttermilk is 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 non-uniform, 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 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).

13.9.2 Flavor

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), lacks acidity, lacks freshness (stale), oxidized/metallic, rancid, sauerkraut-like, stabilizer, unclean, and/or yeasty (Bodyfelt et al., 1988).

13.10 Conclusion

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 and 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.

13.11 Historical and Cultural Aspects of Fermented Milk Foods

Humans are neither the only nor the first species to practice “food science” and food preservation. A universally enjoyed sweet is the product of honeybees that collect nectar from flowers or honeydew from aphids and dehydrate it into honey; thus preserving a winter’s worth of food by reducing its water activity. Food dehydration is among man’s first food preservation techniques, and one that was most likely discovered by accident. Fermentation is another of our food preservation practices that is also practiced by another representative of the insect world, gardener ants. The gardener ant cuts and collects leaves that are brought back to the colony to ferment. The ant colony subsequently consumes the mold that decomposes the harvested leaves. These tiny “food technologists” presumably derive benefit from this process by improving both the digestibility and the nutritional value of the leaves.

While mankind employs various fermentation processes as a form of culinary art, acidic fermentations certainly rank among the earliest food preservation practices. Acidic fermentation would have been discovered serendipitously, when milk, or other raw foods, turned sour (soured) without any intervention from mankind. Indeed, it is only recently in human history that humankind has discovered means to arrest microbial action upon food.

Since fermented foods emerged long before humans first applied a chisel to clay tablets to create a record of their activities, we are left to speculate on the specific sequence of events that eventually led humans to intentionally inoculate and ferment food. However, since any harvested food not consumed fresh would undergo microbial deterioration, the sequence of events is not difficult to define. It's probable that mankind empirically learned to make a virtue of inevitability; and they subsequently found that the changes observed in their food could be correlated with either positive or negative sensory attributes. Similarly, they obviously learned that certain physical changes were associated with preservation, while others were simply due to spoilage. Gradually, humans learned through trial and error, along with information sharing with others, to harness the power of food microbiology for their own benefit.

Archeologists place the time of the earliest use of milk fermentation at approximately 8000 BC (Kurmann et al., 1992). Until the European Middle Ages, the so-called let-it-be method of milk fermentation was interfered with minimally. An early publication of the U.S. 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.

One property of milk that facilitated or tempered "safe" souring is the presence of lactose. The galactose-β (1→4) bond is rare in nature and as a consequence, only a few bacteria possess the enzymes to metabolize lactose (Newburg and Neubauer, 1995). Fortunately, one group of bacteria that can cleave this bond and ferment lactose is the harmless, and generally beneficial, lactic acid bacteria. Their metabolic access to milk sugar permits them to outcompete other organisms and quickly produce a hostile environment for most other microorganisms, many of which may be more proteolytic, lipolytic, or unfortunately, pathogenic.

Thousands of years would pass before Antony van Leeuwenhoek (Palm, 1982) focused his invention, the microscope, upon sauerkraut and discovered the "animalcules" responsible for the souring process. Nonetheless, humankind discovered early on that they could exert some control over food fermentations by preserving a small amount of each day's production to "seed" the next batch of product (Steinkraus, 2004; Robinson and Tamime, 2006). Later, food experimenters learned that they could create favorable conditions for beneficial fermentations by preheating, salting, or otherwise manipulating the raw food to create an environment that favored the desired fermentation.

As mentioned previously, fermented foods seem to attract to themselves much of the identity of the culture where they originate. Specialty breads, cheeses and fermented dairy foods, wines, beers, and sausages constitute a group of foods and beverages that are largely defined and respected with a matter of pride and prestige by the specific geographical region where they were created. For example, legend holds that the medieval Italian city-states of Parma and Reggio nearly came to physical blows over the name of the cheese, which we in the U.S. call "Parmesan." However, the cheese's proper name is

"Parmigiano–Reggiano" when it is (1) made from the milk of cows located in Parma or Reggio, Italy; (2) actually made in Parma or Reggio, Italy; and (3) such manufactured cheese meets certain proscribed quality standards, and this appellation is the result of a compromise worked out between the two antagonists.

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Chapter 14
Swiss Cheese and Related Products

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14.1 Introduction

Swiss cheese and related cheese types 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, beige to yellowish rind. Emmentaler is simply called "Swiss cheese" in the United States and is a rindless block (Jenkins, 1996). The main characteristics 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

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In Swiss-style cheeses, eyes (CO_2-formed openings) are expected and contribute to the cheese's visual appeal. The number, size, shape and surface luster of eyes are characteristic for each type of cheese. Extremes in Swiss cheese eyes appearance reflect adversely on workmanship and/or on milk quality. Normal eye formation results from the production of CO_2 in the cheese, usually by propionic acid-forming bacteria and related types. 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 in the aforementioned cheeses. Gas holes in cheeses outside the Swiss-type category are generally considered undesirable because they often indicate the presence of undesirable lactic, spoilage and/or pathogenic microorganisms (*Escherichia coli* and Clostridia). Unintended gas formation in cheeses in the form of either CO_2, H_2 and/or H_2S is typically accompanied by an unclean-like off-flavor.

Microorganisms 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 is *Propionibacterium freudenreichii* ssp. *shermanii*, 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).

14.2 Composition of Swiss-Type Cheeses

U.S. federal standards of identity for Swiss cheese requires 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 are 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 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 drain 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).

Table 14.1 Typical composition of Swiss, Cheddar and common cheeses with eyes (Kosikowski and 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 (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, pliable and display eyes and/or openings (Kosikowski and 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 and Baby Swiss are U.S.-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 U.S. versions of Swiss, Baby Swiss, may be made in a similar fashion to Swiss cheese or in a highly automated fashion. Baby Swiss also contains eyes, but they are much smaller in size than aged Swiss cheese. 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 younger, 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 and 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 14.1.

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 "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 U.S. 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 U.S. 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 and 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 and 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 U.S. 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

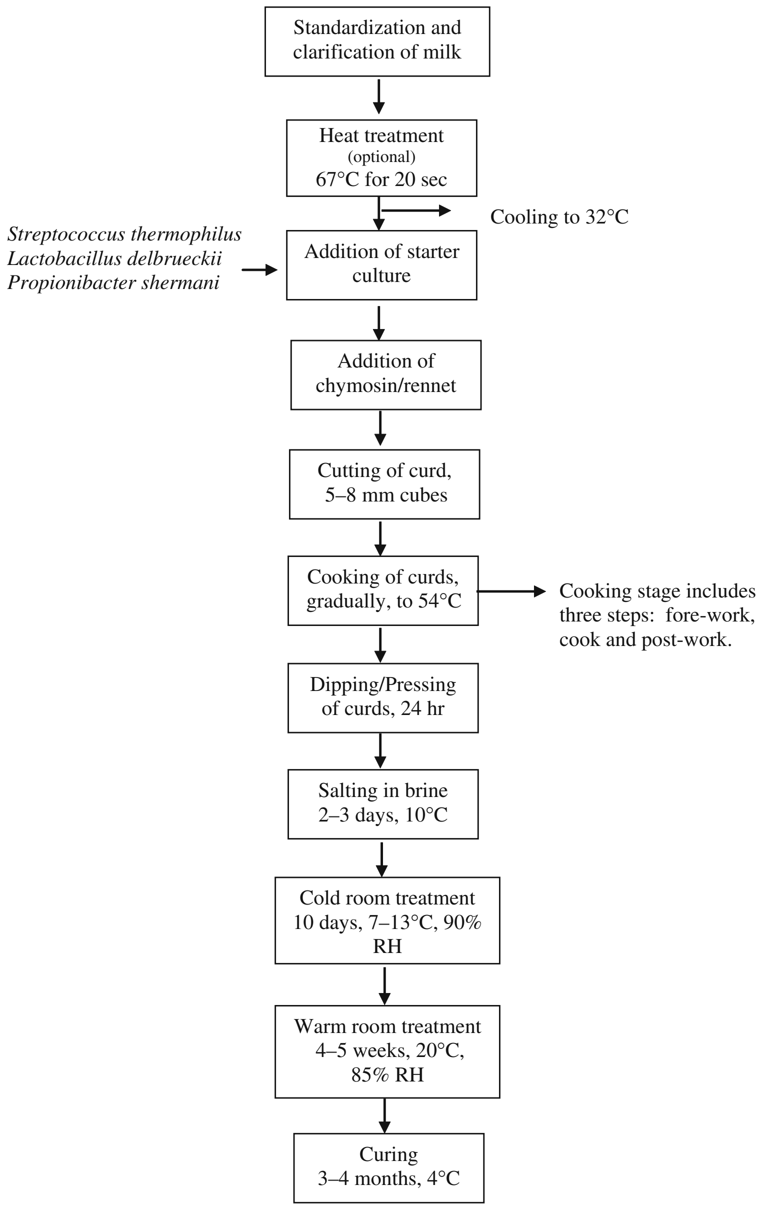

Fig. 14.1 Flow diagram of Swiss cheese production (Adapted from Kosikowski and Mistry, 1997)

approved dairy ingredients may be added to Swiss cheesemilk (benzyl peroxide as a cheesemilk bleaching compound and hydrogen peroxide/catalase for microbial inhibition of cheesemilk). The milk is then inoculated with lactic acid-producing and propionic acid-producing cultures. One or more milk clotting enzymes (rennet of various sources) are 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 and Mistry, 1997). The use of high cooking temperature is responsible for the development of springy, elastic curd of 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. If acid development is insufficient, 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 and 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 Saran™ 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 physico-chemical, enzymatic and microbiological activities within the curd. During the precooling stage, the cheese loses most of the residual lactose, 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 and 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 $(2\,(1/4) = 1/2)$ 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 and 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 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 and 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 and 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 and 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 amino acid converting enzymes (proteases). Plasmin, a native milk protease, shows an effect on flavor perception. 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 the 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 FFAA 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 iso-valeric 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). With regard to Swiss-type cheeses, both 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). According to the make procedure and ripening time, flavor profiles of Swiss-type cheeses may vary. Compared to traditional Swiss cheeses produced in Europe, commercially available Swiss-type cheeses in the U.S. have lower intensities of flavor characteristics. In a study conducted on flavor attributes of Swiss cheese, fifteen commercial Swiss-type cheeses in the U.S. (10 Swiss cheeses, 4 baby Swiss cheeses and one 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 two of fifteen 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 with intense propionic acid fermentation, may lead to late fermentation. 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 and Bachmann, 2004).

14.3.3 Appearance/Eye Formation

The shape, size and distribution of the "eyes" in Swiss cheese are most important as a point of emphasis in sensory evaluation. Swiss cheese 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, and 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 Swiss-type cheese would be criticized severely (Bodyfelt, 1988).

Eye formation is a desirable result of carbon dioxide production through propionic acid fermentation. Swiss cheese 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 carbon dioxide. 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).

14.4 Sensory Attributes of Swiss Cheese

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. U.S. Standards for Swiss cheese or Emmentaler cheese include U.S. Grade A, U.S. Grade B and U.S. Grade C. The grading system differentiates cheeses based on established quality criteria outlined in the U.S. 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:

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

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

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

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 under unsanitary plant conditions. The following section elaborates on the attributes that may be realized in finished Swiss cheese.

14.4.1 Preparation of Cheese for Evaluation

Evaluation of any lots of Swiss cheese 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 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. Swiss cheese in its original, un-cut 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 Swiss 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 Swiss 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 U.S. Standards for Grades of Swiss Cheese,

Table 14.7 Common color and finish and appearance defects in Swiss cheese, 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, improper dressing and salting, non-uniform 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 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

Emmentaler Cheese, as produced by USDA Agricultural Marketing Service Dairy Programs (2001).

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

Table 14.8 Common eye and texture defects in Swiss cheese, 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; improper use 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; abnormal moisture or 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, nut shell 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

provides an alternative to the multiple score cards shown in Tables 14.2 through 14.6. Essentially, every Swiss cheese plant may determine and evaluate cheese quality based upon the methodology appropriate to the setting.

14.4.2 Swiss Cheese Color

With respect to color, the term “slight” refers to attributes that are only detectable upon careful and critical examination, while the presence of a

Table 14.9 Common flavor defects in Swiss cheese, identification and their probable causes

Flavor	Identification	Probable cause
Acid	Sharp and puckery to the taste, characteristic of lactic acid	Excess lactic acid, 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 Swiss flavor	Insipid, practically devoid of characteristic sweet-hazelnut, Swiss flavor	Contamination with other bacteria, inadequate fermentation and proteolysis
Fruity	A sweet fruit-like flavor resembling pineapple, apple or pears	*Pseudomonas fragii* 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 ingredient
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 Swiss 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

"definite" quality defect is not intense, but is nonetheless readily detectable under close examination. Color defects of Swiss cheese 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.

Table 14.10 Common body defects in Swiss cheese, 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

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 Swiss 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 Swiss cheese blocks.

14.4.3 Swiss 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. 14.2).

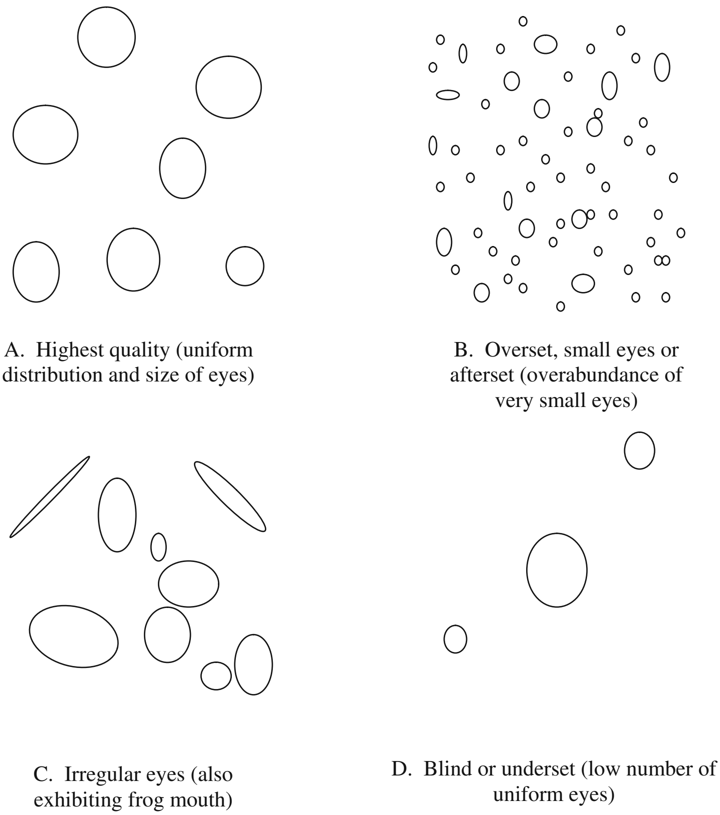

Fig. 14.2 Diagram of various eye development defects common to Swiss and related cheeses

14.4.3.1 Distribution

One sided refers to cheese that is reasonably developed with eyes on one side and underdeveloped eyes on the opposite side Fig. 14.3. This defect is more commonly related to rindless blocks due to lower salt and higher moisture content. One possible reason 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.

Fig. 14.3 Swiss cheese exhibiting relatively good eye development, but uneven and/or one sided distribution

Nesty refers to an overabundance of small eyes in a localized area. 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 Swiss 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, 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" 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;

(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.

14.4.3.2 Number

Blind is a term that describes the absence of Swiss cheese eyes in portions of or in an entire block of cheese Fig. 14.4. 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.

Overset describes an excessive number of eyes present within the cheese Fig. 14.5. 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 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.

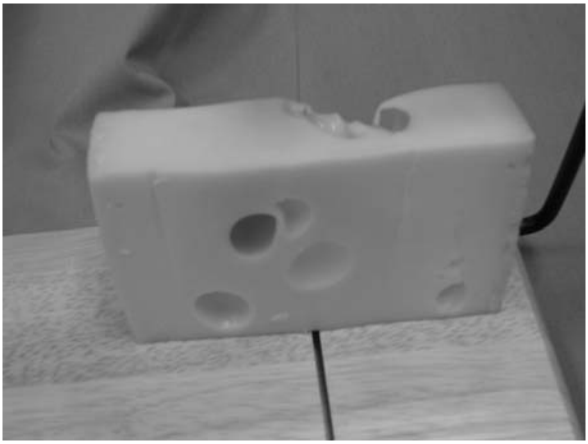

Fig. 14.4 Swiss cheese exhibiting blind/underset defect

Fig. 14.5 Sliced Swiss cheese exhibiting overset, small eyes and/or afterset defects

14.4.3.3 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. Externally, the cheese usually appears torn and deformed. One possible reason for this defect is the growth of Clostridia. However, the problem is not necessarily related to microbial activity, 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. 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.

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.

14.4.3.4 Shape

Cabbage describes those Swiss 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. 14.6. 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. Soft, pasty-bodied cheese cannot withstand pressure and upon cooling after warm room treatment, the eyes fold in upon themselves.

Checks/picks/splits are similar attributes. Checks are small, short cracks within the body of the Swiss cheese. Picks are small irregular or ragged openings within the body of the cheese. Splits are more sizable cracks, usually occurring in parallel layers and usually clean-cut, found within the body of the cheese. "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. Frog mouth can be seen if the Swiss cheese curd is not elastic enough to open normally under pressure to form a smooth, round eye. High-acid milk, over-ripening, improper use of starter cultures, too long forework, and too high cooking temperature are among the reasons for the formation of frog mouth.

Irregular eyes are Swiss 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. 14.7. 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

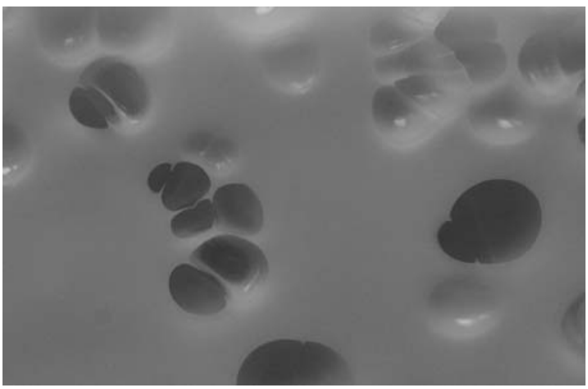

Fig. 14.6 Swiss cheese exhibiting overset, and/or cabbage defects

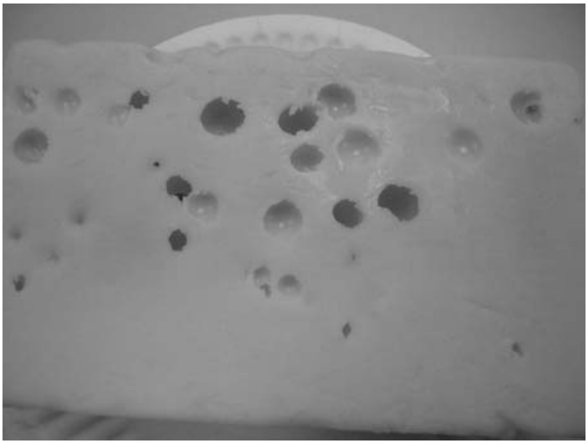

Fig. 14.7 Swiss cheese exhibiting irregular, uneven and/or rough/shell defects

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.

14.4.3.5 Interior Condition

Dull/dead eyes are similar Swiss cheese defects. Dead eyes are developed cheese openings, but have completely lost their preferred glossy or velvety appearance. 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 improper pH, whey drainage, block size, poor-quality milk and poor manufacturing procedures may be observed along with dull and dead eyes.

Rough suggests that the Swiss eyes simply do not exhibit the desired smooth appearing, even wall surfaces. Rough eye is essentially an exaggeration of dull and dead eyes. Insufficient rate and amount of whey drainage is 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 "nut shell" appearance (multi-dimensional) 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.

14.4.4 Swiss Cheese 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.

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.

14.4.5 Swiss Cheese Flavor

Swiss cheese should have a pleasing and desirable characteristic hazelnut-like 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 Swiss 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 Swiss cheese that suggests the sensation of a product lacking freshness (i.e., a cheese made from less than the freshest milk [cheese-milk $\geq$ 4–6 days old]).

Onion/garlic. This distinctive cheese off-flavor 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 after-tastes 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 Swiss-type cheeses, 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 Swiss cheese varieties.

Yeasty. This occasional flavor character of Swiss cheese varieties typically indicates that yeast fermentation has occurred within the cheese; yeast-contaminated Swiss cheese starter cultures may be suspect.

14.4.6 Swiss Cheese Body and Texture

The body and texture of cheese plug samples withdrawn from most Swiss cheese varieties should be reasonably firm, smooth and moderately flexible when bent.

Table 14.11 Proposed score card for the evaluation of Swiss cheese in a cheese plant

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 Swiss 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 & 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

Near the surface, where Swiss cheese is generally drier, the body may be slightly crumbly. A soft and pasty Swiss cheese body is often associated with high moisture or abnormal eye formation and may be accompanied by poor flavor development (Bodyfelt, 1988).

With respect to Swiss cheese body assessment, an 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 Swiss cheese and then working a small piece of the sample between the thumb, index and middle fingers.

Coarse cheese body feels rough, dry and sandy between the fingers and/or in the mouth.

Firm, rubbery or corky Swiss 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.

14.5 Modern Sensory Analysis of Swiss Cheese

Modern sensory analysis practices, detailed in Chapter 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^{TM} 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 5́-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 non-esterified 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 and 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 non-destructive 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 non-destructively 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.

14.6 Conclusion

Swiss cheese has a unique flavor and distinctive eye formation that differentiates it from other types of cheeses. The production of Swiss cheese 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 cheese makers 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 Swiss cheese quality in the market place. Using the provided score cards for the consistent evaluation of produced Swiss cheese 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

Carol Chen, Dana Wolle, and Dean Sommer

15.1 Introduction

Mozzarella is a clean, mild flavored cheese that is primarily used as an ingredient in cooking, rather than as table cheese. In 1970, only 375 million pounds of mozzarella were produced in the U.S., which represented about 17% of natural cheese production. By 2005, mozzarella cheese production rose to over 3 billion pounds or ~34% of total U.S. cheese production (IDFA, 2006). Today, mozzarella is the most common cheese style produced in America, supplanting Cheddar (WMMB, 2007). Furthermore, in the food-service sector, which primarily utilizes various cheeses as an ingredient in prepared foods, mozzarella cheese represents 40% of total cheese volume (WMMB, 2005).

The year 2005 usage pattern for American mozzarella is shown in Fig. 15.1. The food-service and food-processing sectors purchased the bulk of mozzarella, with a relatively low percentage of this cheese type going into retail. These data indicate that the vast majority of mozzarella cheese is consumed outside of the home (i.e., restaurants) or in commercially prepared foods eaten at home. Because so much mozzarella is used as an ingredient, pertinent sensory analysis protocols extend beyond the traditional cheese grading attributes of appearance, flavor and texture (uncooked) to texture assessments that determine product machinability and to descriptions of mozzarella performance in cooked applications.

15.2 Topics in Sensory Analysis for Mozzarella

There are no FDA mozzarella Standard of Identity requirements for flavor, melt or functionality. The 'USDA Specifications for Mozzarella Cheeses' set requirements (flavor, texture, color, finish and packaging) and optional requirements (meltability, color, stretchability and free fat) for the

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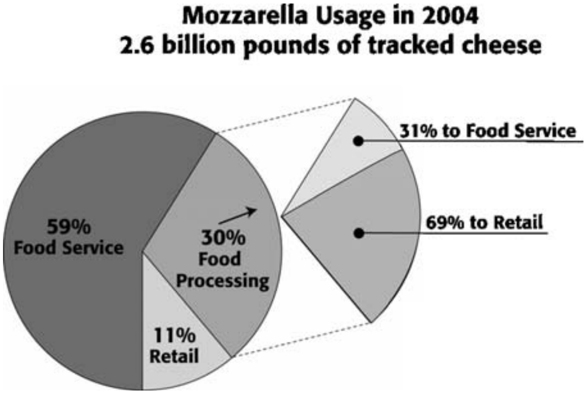


Fig. 15.1 U.S. mozzarella usage in 2004 (WMMB, 2005)

purchase of block, shredded and sliced mozzarella in the U.S. (USDA, 1980). However, due to the varied usage of mozzarella in the food industry the assessment of mozzarella performance has developed additional parameters. The sensory analysis of mozzarella in this chapter can be divided into three topics: cheese grading, prediction of machinability and cooked cheese functionality.

Traditional cheese grading assesses mozzarella varietal appearance, flavor and textural attributes. These evaluations are used to determine or establish mozzarella quality and to predict shelf life. The desirable flavor attributes of all classes of mozzarella cheese include the descriptors: clean, mild taste, slight acid and butter flavors.

Textural assessments can be used to predict how a low-moisture mozzarella will machine, which refers to how the mozzarella will convert from a block to shreds or slices. These types of assessments differ from more traditional cheese grading in respect to the cheese temperature at evaluation and specific textural attributes. Mozzarella cheese texture attributes are evaluated at the temperature at which the given cheese is machined. The key texture attributes of firmness and adhesiveness are defined with reference scales and critical values that can be used to predict successful shredding.

Mozzarella's main usage is as an ingredient on pizza. Sensory evaluation is a flexible tool that is able to assess mozzarella functionality; here the term 'functionality' describes cheese performance when it is cooked. The defined attributes used in the sensory analysis of cooked cheese, which collectively describe functionality, are neither varietal requirements nor considered as defects. The role of sensory analysis is to accurately and repeatably describe cheese performance – after cooking. Assigning an 'acceptable' quality range is essentially the role of the end user of the cheese.

15.3 Categories of Mozzarella

The proposed Codex standards (WHO/FAO) recognize two product categories based on how the mozzarella cheese is used: (1) mozzarella with relatively high-moisture content, which is manufactured for direct consumption and (2) mozzarella with low moisture, which is generally used as a food-product ingredient (Table 15.1).

Mozzarella with high moisture (52–60%) is generally referred to as 'fresh', 'whole milk', or 'traditional' mozzarella and has a high pH (5.6–5.8), high moisture, low salt content (0.1–0.5%) and short shelf life (21 days). In Italy, this cheese is made from either water buffalo or cow's milk, while U.S. production is mainly from cow's milk. Fresh mozzarella is typically made using direct acid addition to acidify the milk rather than bacterial acidification. The product is formed into small balls of varying size: ovolini (egg size), bocconcini (bite size), Ciliegine (small cherry size) and is consumed soon after manufacture.

Fresh mozzarella is usually eaten uncooked, where its delicate milky flavor and soft texture make it well suited for salads, sandwiches or appetizers. One popular use for fresh mozzarella is in *Insalata Caprese*, where alternating layers of fresh mozzarella and sliced tomatoes are topped with fresh basil, olive oil, balsamic vinegar and black pepper. It is not so widely used in cooking

Table 15.1 Proposed Codex standards for mozzarella 262–2007

Milk constituent	Minimum content (m/m)	Maximum content (m/m)	Reference level (m/m)	
Milkfat in dry matter				
With high moisture	20%	Not restricted	40–50%	
With low moisture	18%	Not restricted	40–50%	
Dry matter	Depending on the fat in dry matter content, according to the table below.			
			Corresponding minimum dry matter content	
	Fat in dry matter content (m/m)			
			With low moisture (%)	With high moisture (%)
	Equal to or above 18% but less than 30%		34	
	Equal to or above 20% but less than 30%			24
	Equal to or above 30% but less than 40%		39	26
	Equal to or above 40% but less than 45%		42	29
	Equal to or above 45% but less than 50%		45	31
	Equal to or above 50% but less than 60%		47	34

applications because when heated, the protein matrix shrinks, releasing whey, thus, making the cooked dish overly watery.

Mozzarella with low moisture is a lower pH (5.2–5.4), lower moisture, higher salt product that is manufactured using bacterial starter cultures. It has a longer shelf life due to the lower pH, lower moisture and higher salt content. Low-moisture mozzarella is firm enough to be shredded or sliced and can be cooked without excessive watering off. Low-moisture mozzarella can be manufactured to encompass a variety of browning, stretch and melt properties. These unique machining and cooking properties have led to mozzarella's wide usage. Uncooked low-moisture mozzarella may be consumed as string cheese and in sandwiches. Cooked low-moisture mozzarella serves as a topping for pizza pies, a filling for dishes such as lasagna and can be breaded for serving as an appetizer.

15.4 Definitions of Mozzarella

The FDA in the Code of Federal Regulations (CFRa) recognizes four categories of mozzarella based on composition (Table 15.1). These definitions make no requirements for cheese pH or percentage of salt. Mozzarella and part-skim mozzarella would be classified under the proposed Codex standards as mozzarella with high moisture, while low-moisture (LM) mozzarella and low-moisture part-skim (LMPS) mozzarella would be classified as mozzarella with low moisture (Table 15.2).

In addition to the compositional categories, both the proposed Codex standards and FDA standards define mozzarella as being made using a pasta filata cheese-making process that results in a fibrous structure. However, the FDA standards allow for alternate manufacturing as long as the procedure 'produces a finished cheese having the same physical and chemical properties'. (CFRb).

The FDA Standards of Identity were further expanded to accommodate definitions for lower fat mozzarellas. Low-fat mozzarella is defined as containing 3 g of fat or less per 50 g serving, while fat-free mozzarella contains less than 0.5 g of fat per serving. The term 'reduced fat' does not apply to mozzarella because this compositional profile fits into either the LM or LMPS mozzarella definition.

Table 15.2 Mozzarella standards of identity from the CFR Title 21, Parts 133.155 thru 133.158

	Moisture (%)	FDM (%)[1]
Mozzarella	52–60	≥ 45
Low-moisture mozzarella	45–52	≥ 45
Part-skim mozzarella	52–60	30–45
Low-moisture part skim mozzarella	45–52	30–45

[1] FDM = Fat in the dry matter.

15.5 The Effect of Mozzarella Manufacture on Functionality

Manufacturing practices are developed to produce a cheese that fulfills its end-use applications. There are a variety of manufacturing protocols that can result in production of the desired cheese. The key to the manufacture of desired physical properties of any cheese is to initially establish the desired cheese composition (controlled by milk composition and by curd manipulation [curd formation, heating, stir-out, etc.]) and then by manipulating the interactions between casein molecules. Cheese texture and functionality are directly related to the character of the casein–casein interactions. These interactions are governed by the loss of calcium from the casein (controlled through the rate and extent of acidification at each step), cheese pH and proteolysis during storage (Fox, 1989 Johnson and Lucey, 2006). Proteolysis during storage breaks down casein, resulting in a softer, smoother-bodied cheese that flows more readily when heated. However, if proteolysis is too extensive the cheese will not shred readily. In addition, there will be a loss in the stretch properties of the cooked cheese.

15.6 Manufacture of Mozzarella

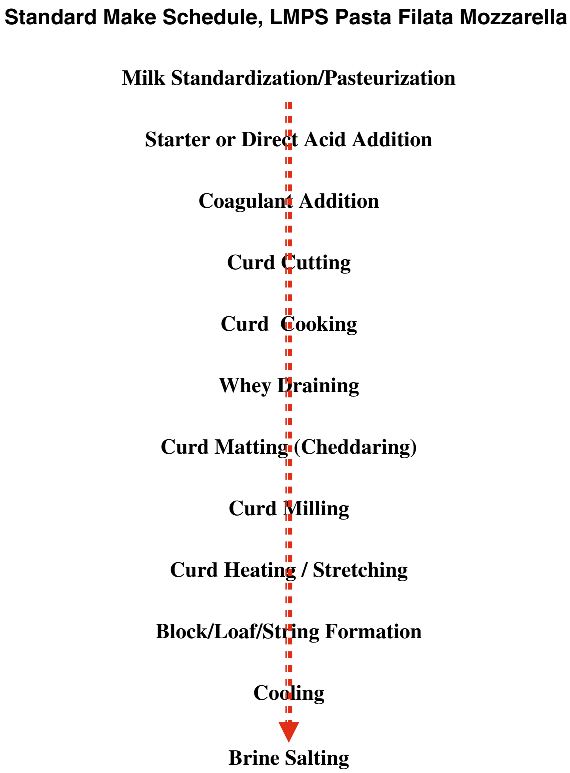
15.6.1 Cheese Milk Quality

The typical flavor for all classes of mozzarella can be described as slightly buttery, slightly salty and slightly milky. Because of the mild, subtle flavor characteristics of this cheese the overall quality of the cheese-making milk is of paramount importance. Any defects in the milk have the potential to carry over into the finished cheese. The raw milk to be used in cheesemaking should have a clean flavor, be as fresh as possible and be low in bacterial and somatic cell counts (USDA, 2002). Quality standards also hold true for any ingredients used in the standardizing of cheese-making milk, i.e., nonfat dry milk (NDM), skim milk, condensed skim or ultra- or microfiltered milk. For example, if the raw cheese milk is high in lipase or protease, the resulting cheese is prone to rancid and/or bitter off-flavors or an excessively soft body. Stale flavors from old NDM are readily carried over into the cheese. If the NDM or condensed skim milks contain scorched particles, they may be visible in the finished mozzarella.

15.6.2 Manufacture of High-Moisture Mozzarella

Fresh mozzarella is made from either whole milk or partially skimmed milk. See Fig. 15.2 for an outline of mozzarella production. The milk must be pasteurized and can be acidified by direct acidification (acetic or lactic acid, CFRb) or bacterial cultures (*Streptococcus thermophilus* alone or a mix of *S. thermophilus*

Fig. 15.2 General manufacturing outline for mozzarella cheese



and thermophilic *Lactobacilli*). If direct acidification is used, acid is added to cold milk and thoroughly mixed before the temperature is raised and coagulant is added. Acidification is followed by coagulation, cutting of the coagulum into relatively large-sized curd and then minimal cooking. The large curd size, low cooking temperature and short cooking time decrease syneresis and contribute to the high-moisture content. For both cultured and direct acid addition mozzarella, the curd is separated from the whey, heated in warm water, stretched, formed into shapes, cooled and then packaged into dilute brine. The manufacture of direct acidified fresh mozzarella is a relatively short process, typically requiring less than 2 h from addition of coagulant to brining of the cheese.

15.6.3 Manufacture of Low-Moisture Mozzarella, Pasta Filata Style

15.6.3.1 Product Standardization and Fortification

Mozzarella lends itself to a large array of standardization and fortification techniques due mainly to the broad range of moisture and fat values allowed in the mozzarella standards of identity (CFRb). Cream removal or casein addition may be necessary to adjust the casein to fat ratio upward. The casein content is adjusted by the addition of either nonfat dry milk, rehydrated nonfat dry milk, skim milk, condensed skim milk or ultra- or microfiltered milk.

Manufacturing protocols often need to be adjusted to account for elevated lactose from the fortified cheese milk, particularly when the percentage of solids in the milk is greater than typical mozzarella cheese milk level of 11.5%. Residual lactose or galactose in the cheese can have a number of undesirable side effects. Residual sugar may be fermented by potential contaminant microorganisms, resulting in gas generation and flavor defects (fruity and sour). High levels of lactose and particularly galactose remaining in the cheese can also cause significant browning or blistering of the cooked mozzarella.

15.6.3.2 Starter Cultures

The majority of the starter culture used in the manufacture of low-moisture mozzarella is a blend of the thermophilic species *S.thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. The particular type of starter cultures used to make mozzarella can have a dramatic effect on its eventual product functionality. This is partly due to their varied ability to metabolize sugars that may lead to the accumulation of lactose and galactose in the cheese. All strains of *S. thermophilus* and *Lactobacillus* used in mozzarella production release galactose during fermentation (Johnson and Olson, 1985; Hutkins and Morris, 1987; Matzdorf et al., 1994; Rudan and Barbano, 1998). Some strains have the ability to ferment the residual galactose, but only after the lactose has fermented. However, because most manufacturing methods do not allow for fermentation of all of the sugar prior to the pasta filata step, both lactose and galactose will remain unfermented. These residual sugars can then react with protein through Maillard reactions to form brown color.

Cooked mozzarella that contains residual sugar will generate darker brown blisters than cheese containing no residual sugar. Overall blister color is a combination of protein drying/burning and Maillard reactions. To limit or decrease browning, some cheese plants use a culture blend that contains only mesophiles, thereby preventing galactose accumulation during fermentation. Alternately, traditional cultures may be used, combined with either a curd rinse or wash step to remove much of the residual sugar. To ensure that all the sugar is metabolized, additional fermentation time is necessary. Without a rinse to remove residual sugar, too much acid is developed, resulting in a low pH and an acid-tasting cheese. In addition, this low pH leads to cheese that will not flow when heated and will be short instead of elastic when stretched (Guinee et al., 2002; Pastorino et al., 2003).

In recent years many cheese plants have begun using *S. thermophilus* exclusively in mozzarella manufacture. While the resulting cheese will likely brown substantially when cooked, there are two advantages of this culture strategy. First, the relatively high salt sensitivity of this species means that acid development in the cheese can be partly controlled by increasing or decreasing salt addition during manufacture. Second, this particular species is less proteolytic than other cheese culture microbes (Rajagopal and Sandine, 1990 (Obery et al., 1991)), which results in slower protein breakdown and longer product shelf life.

15.6.3.3 General Manufacturing Protocols

Manufacturing techniques used in mozzarella production up to the curd stretching step (pasta filata step) are similar to those used in most other cheese varieties. However, subtle variations in processing steps between plants can result in significant performance differences in the resulting product. Some of the important functional characteristics of cooked mozzarella are melting, browning, stretch, oiling off and chew characteristics. These aforementioned characteristics are in turn heavily influenced by factors such as the extent of proteolysis, rate and extent of acidification, moisture, fat content, salt content and pH.

In particular, the rate of acid production, the amount of acid produced during manufacture and the history of acid production (i.e., the lowest pH value attained in the cheese and at what point in the process this low point was reached) are known to have a critical impact on the performance of the finished cheese. A lower pH causes greater calcium solubilization, thus decreasing the calcium phosphate cross-linking of cheese protein and forming a softer-bodied product that flows readily upon heating. This relaxation of the protein structure enhances proteolysis, thus further softening the cheese (Feeney et al., 2002; Joshi et al., 2003). In contrast, the presence of less acid will allow more calcium retention in the cheese, resulting in tighter cross-linking of the protein structure, with a decrease in proteolysis, and resulting in a firmer, chewier cheese that melts and flows less readily upon heating.

There are also other manufacturing practices that will have an effect on cheese functionality. Mozzarella with the properties of a higher fat content, higher moisture level, lower salt content and a lower pH will tend to have a softer chew, a more complete melt, more stretch and more free oil when baked on a pizza. Traditionally, mozzarella is salt brined. However, some plants will 'presalt' the curd. That is, they add a portion of the salt to the curd, in a dry form, prior to stretching and brining. Brined mozzarella tends to have a tenderer, softer chew, while presalted mozzarella often has a tougher chew characteristic due to interactions between the salt and the protein matrix and to the loss of moisture. In addition, direct application of dry salt to the curd slows culture growth more rapidly compared to brine salting. This results in a slower rate of microbial proteolysis, and thus a firmer cheese.

15.6.3.4 Stretching/Molding and Brining

Mozzarella curd was traditionally hand stretched in hot water. Today, the vast majority of mozzarella is stretched in a machine called a stretcher (or cooker).

Typically, the stretcher consists of a vessel that contains circulating hot water at approximately 72°C (160°F) and one to two stainless steel augers. The augers push and knead the mozzarella curd through the machine, aligning the curd protein to generate a fibrous texture in the cheese. Following the stretching step, the curd is put into a mold or form. Food-service forms usually hold either 2.7 or 9 kg (6 or 20 lb), while forms for retail cheese hold up to 0.45 kg (1 lb). Additionally, small tube-like extruders are used for the manufacture of string cheese.

After being formed or extruded, the cheese is cooled to 15.5°C (60°F) in water prior to being placed into cold (4.2–10°C [40–50°F]) brine at ~ 90% saturation, which facilitates both salt uptake and additional cooling. The size and shape of the cheese loaf, along with the efficiency of the overall cooling process, are very important to the final functionality of the cheese. Slow cooling may allow additional acid development, potentially either positively or negatively impacting cheese flavor, texture or functionality. If insufficient calcium has been solubilized from the casein by the pasta filata step, additional acid development may result in more calcium solubilization and improved functionality. On the other hand, excessive acid development may decrease stretch, flow and shelf life, due to increased proteolysis.

Brine quality is vital to the prevention of flavor defects in mozzarella, since any off-flavors present in the brine will be readily transmitted to the cheese (Lindsay, 1997). A good brine-cleaning regimen, resulting in the removal of residual milkfat, protein and contaminating microbes, will help prevent the development of off-flavors. One strategy gaining increasing acceptance is filtration of the brine, which most commonly uses ultrafiltration membranes. Also, some cheese plants add antimicrobial compounds to the brine to limit bacterial, yeast and mold outgrowth. However, antimicrobials present in high concentration can themselves generate off-flavors. One example is the production of strong-tasting halophenols from the interaction of milk phenols with sanitizing agents (Mills et al., 1997; Schlegel and Babel, 1963, Mottram, 1998). Following the brining step, most mozzarella is vacuum wrapped in a plastic film, stored in a refrigerated room and cooled to ~ 2°C (35°F).

15.7 Manufacture of Low-Moisture Mozzarella, Non-pasta Filata Style

A non-pasta filata low-moisture mozzarella is manufactured without the use of a mixer, molder or brine system. After draining the whey, the curd is salted, hooped and pressed. It is critical that the final cheese has similar composition and functionality to its pasta filata counterpart, to ensure that it will melt, stretch, etc., in a comparable manner. To ensure similar functionality, strategies to control pH and limit proteolysis need to be incorporated into the non-pasta filata manufacturing schedule. The final pH of the cheese should fall within 5.2–5.4, avoiding values beyond this range. Control of pH may be accomplished by washing the residual sugar out of the curd with warm water or by adjusting the initial lactose content of the milk via ultrafiltration or microfiltration. Proteolysis is limited in a pasta filata mozzarella by the mixer/molder step. Internal cheese temperatures reached in the mixer (57–66°C [135–145°F]) inactivate residual milk coagulant and decrease starter culture populations. Limiting proteolysis in a non-pasta filata mozzarella may be accomplished by starter culture selection or by reduction of milk coagulant levels.

Non-pasta filata mozzarella is usually pressed into either 18 or 291 kg (40 or 640 lb) blocks. In addition, non-pasta filata mozzarella does not possess the chicken breast texture seen with traditional, pasta filata product. When cooked, the blister color of a non-pasta filata mozzarella may be yellow-brown, as compared to the dark brown blisters of pasta filata mozzarella. Production advantages of non-pasta filata cheese include the ability of manufacturers with Cheddar plant equipment to make it and the ability to limit trim losses when cutting it into exact weight units.

15.8 Individually Quick-Frozen (IQF) Cheese

An additional product class is made using mozzarella as an ingredient. However, these products contain additional ingredients and thus do not follow FDA standards; thus, they cannot be legally called mozzarella. These additional ingredients (whey proteins, starches, hydrocolloids, melting salts, etc.) are added to stretched LMPS mozzarella curd, in order to increase the moisture content of the final product and to impact its melt, stretch and chew. The product is typically frozen to maintain peak functionality and then thawed shortly before use. Some of the advantages of this product include lower raw material and production costs and the ability to stabilize the product via freezing. Some disadvantages include a very soft chew and stretch and limited shelf life in the unfrozen state.

15.9 Sensory Analysis of Mozzarella

15.9.1 Sensory Analysis of Mozzarella for Cheese Grading

Cheese grading assesses the mozzarella varietal color, appearance, flavor and body/texture. These attributes are indicators of mozzarella quality and shelf life. Mozzarella requires no aging for flavor development, thus grading can be conducted when the cheese is relatively young, at 1–3 days post-manufacture. Mozzarella does require minimal aging for texture development and optimal performance when cooked. During this time, moisture, salt and minerals equilibrate. Thus, texture evaluations that are used to predict cheese performance are conducted at 7–14 days of age. In general, mozzarella is considered to have ideal performance characteristics between 2 and 6 weeks of age.

15.9.1.1 Sample Preparation

From each production vat a sample loaf from near the middle of the run is selected, labeled and stored for analysis. Most mozzarella is stored between 1.5 and 4.2°C (35–45°F); prior to sampling and evaluations, loaves are removed from storage and tempered to about 13.2°C (55°F). The sampling methods for grading take into consideration the moisture and salt gradient from brining. To sample, cut a $^3/_4$ in. wide slice perpendicular from the center of the cheese loaf. Alternatively, a cheese trier can be used to take multiple plugs from different locations in the loaf. If appropriate for the evaluation, compositional gradients may also be overcome by shredding and thoroughly blending the sample.

15.9.1.2 Sensory Evaluation

The first observation by the cheese grader should be of the body characteristics of the cheese. Experienced graders will be able to get a good 'feel' for the cheese body during initial handling and sampling. The cheese may be weak bodied, soft and gummy, which indicates elevated moisture. Alternatively, if the cheese is extremely firm and difficult to cut, it may possess an excessively low-moisture content or a high pH.

The cheese grader should next inspect the cheese for visual defects. Ideally, the grader will observe a uniform, tight-bodied, cream-colored mass with no large openings, discolorations and/or specks. Powdered or condensed liquid milk used to standardize the cheese milk composition may introduce brown or black scorched particles into the cheese. If the residence time in the curd stretcher is too short or if the temperature is too low, there may be areas of different texture or color due to unmelted curd in the cheese body. Alternatively, if the residence time is too long or the temperature is too hot, there may be greenish-yellow-colored swirls in the block, which are indicative of excessive fat losses during processing. If any rework has been reintroduced into the cheese there also may be visible color mottling. Poor stretching and molding practices can lead to excessive cracking in the blocks or large open spaces in the cheese filled either with water or milkfat. Small, uniform holes, often called pin holes, may be evidence of CO_2 gas generation by thermo-tolerant contaminating microbes. If string cheese is being evaluated, a piece should be evaluated for proper fiber structure.

The grader should also perform an initial flavor evaluation of the cheese at this time. Mozzarella should be slightly salty and buttery, with a mild milky flavor. Overall, the flavor should be pleasant and should clean up well without a lingering aftertaste. Because mozzarella is mild flavored, flavor defects present at relatively low levels may still be detectable. Common defects that may be identified by the grader at this point include excessive acidity, lack of salt, flat flavor (lacking buttery or milky notes), rancidity, unclean off-flavors due to old or poor-quality milk or stale off-flavors due to the use of old nonfat dry milk powders for cheese milk standardization. The mouthfeel of the cheese should also be evaluated at this point. Pasta filata cheeses may have a rough or mealy mouthfeel while non-pasta filata cheeses may be smooth but slightly curdy. The degree of chew should be medium in quality, neither overly firm nor too soft.

15.9.2 Sensory Analysis of Mozzarella by the End User: Pizza Chains

For pizza chains, acceptable and consistent performance of the mozzarella they use is vital to their business. However, performance acceptability is not identical for all chains, since most wish to differentiate themselves from their competitors. One way they can accomplish this is through the taste, texture and functionality of their particular mozzarella. For example, either a light or a dark brown color upon baking may be desirable. Or one chain may want a drier appearance to the surface of their baked product with minimal melted cheese stretch, while another desires some free oil release and the formation of long cheese strands upon stretching. Individual end-user requirements can be quite different; therefore, as discussed previously, mozzarella manufacturers must be able to produce and evaluate their products to fit those requirements.

Most pizza chains have developed their own internal quality-assurance protocols to evaluate mozzarella performance upon baking. Important performance attributes are evaluated by trained panelists and include aspects of flavor, melt, stretch, chew, browning and oiling off. As the cheese is evaluated, each attribute is assigned a point value on a standard scale. The range and endpoints of these scales are determined by the needs of the end user. Point values are then compared to preset goals, in order to determine whether the cheese is acceptable, acceptable with improvement or unacceptable.

In some cases the evaluation is carried out at the QA facility of the pizza chain, with the results reported back to the mozzarella manufacturer. However, the chain may also require the manufacturer/supplier to evaluate their cheese prior to shipment. In these instances, adequate cross-training of both QA staffs is required, to ensure that the manufacturer and end user are consistently evaluating performance attributes, and that scoring is in general agreement. Additionally, all the supplies and equipment used to make and bake the pizzas must be standardized, to promote consistent evaluation. Points to consider include the type of crust, the type and amount of sauce, the amount of cheese, the type of shred, oven and pan, the time and temperature of baking and the elapsed time before evaluating the bake performance.

15.9.3 Sensory Analysis of Mozzarella to Predict Machinability

Prior to use in food-service and food-processing sectors, block mozzarella is converted to shreds to facilitate uniform distribution in cooking or slices for deli applications. Commercial shredders (e.g., Urschel) use centrifugal force to fling cheese cubes (~2 in. × 2 in. × 2 in.) into stationery blades. Slicing operations use high-speed rotating blades with minimal surface area to slice mozzarella loaves. Both types of machining require a firm, non-adhesive mozzarella (Chen, 2003). A firm-textured cheese has less deformation and blades can cut shreds or slice cleaner cuts. In the case of shredding, a firm-textured cheese cube maintains a uniform speed and blades can cut shreds the length of the cube. On the other hand, as a soft-textured cheese comes in contact with the blade, it deforms and bends around the blade, slowing the portion of the cheese cube in contact with the blade. The opposite side of the cheese cube is moving faster and has greater momentum. This momentum directs the cube away from the blade before the blade cuts a full cube length producing a shorter, less uniform shred. When slicing, as the blade comes in contact with a soft-textured cheese, the loaf begins to change shape. As the mozzarella loaf deforms, the blade slows. This produces less uniform slices, or partial or ripped slices may also occur. The other key textural property, adhesiveness, has a similar effect on the shredding and slicing of mozzarella. An adhesive mozzarella sticks to the blades, slowing the rate of either the cheese moving through the blade (shredding) or the blade moving through the cheese (slicing). Sensory evaluation of mozzarella may be done prior to machining as an indicator of how the cheese will either shred or slice. This section details quantitative analysis of mozzarella firmness and adhesiveness and how to use this information to predict mozzarella machinability.

15.9.3.1 Sample Preparation

For evaluation, the mozzarella should be cut into designated sized cubes (½ in. or ¾ in. cubes is an appropriate size). Then the mozzarella cubes should be tempered to the same temperature at which the cheese will be shredded or sliced. Typical cheese temperatures for machining and texture evaluation range from 3.5 to 5.5°C (38–42°F). It is critical that the cheese be tempered to the machining temperature as cheese firmness is dependent on temperature: the colder the cheese, the firmer the texture. Mozzarella adhesiveness is not dependent on cheese temperature.

15.9.3.2 Evaluation

Tables 15.3 and 15.4 provide quantitative definitions, scaling, references and critical scores for firmness and adhesiveness texture attributes. When used together, these attributes are indicators of machinability. Since equipment and end-user specifications vary, the actual critical texture scores that determine acceptable machinability may need to be adjusted by individual users. The cheese evaluator must follow elementary guidelines for descriptive sensory analysis to

Table 15.3 Quantitative analysis of firmness

Firmness: Force required to compress the cheese between finger and thumb. Place the cheese cube between thumb and forefinger. Compress cheese cube, do not fracture.

Soft — **Hard**

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
None		Very Slight			Slight		Slight to Moderate			Moderate		Moderate to Very Hard			Very Hard

	1–2 wk	3 mo	Typical Firmness Range
Pasta Filata Style	11.0	9.5	
Non-Pasta Filata Style	12.5	8.5	

References:

1	X-Soft Theraputty Tan
4.5	Medium Theraputty Green
7	Firm Theraputty Blue
9.5	X-Firm Theraputty Flesh
12	Gray Eraser
14.3	Pink Eraser School Select
15	White Eraser

Critical Firmness: > 10.5 indicates acceptable machining

Table 15.4 Quantitative analysis of adhesiveness

Adhesiveness: Degree to which the chewed cheese mass sticks to the roof of the mouth or teeth. Chew cheese sample between molars 15 times. Gather to the palate and evaluate.

Not Sticky — **Very Sticky**

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
None		Very Slight			Slight		Slight to Moderate			Moderate		Moderate to Very Sticky			Very Sticky

	Typical Adhesiveness of Mass Range	1–2 wk	3 mo
Pasta Filata Style		3.0	6.5
Non-Pasta Filata Style		3.0	7.0

References:

0	Polenta
2.5	Quince-paste
5	Feta
7.5	Mashed Potatoes
10	Brownie
14	Processed Cheese Kraft American

Critical Adhesiveness: < 5 indicates acceptable machining ensure accurate quantification and repeatability over time and from facility to facility. Any changes in the above may result in a change in the critical value in which decisions are made.

The evaluator first measures firmness by hand, then adhesiveness by mouth. Firmness is defined as the force required to compress a cube of cheese. The cheese cube is placed between the thumb and forefinger and then compressed, but not fractured. Adhesiveness is defined as the degree to which the chewed cheese mass or particulates stick to the roof of the mouth and teeth. The cheese cube is chewed 12–15 times on one side of the mouth and then the masticated sample gathered on the palate and assessed (evaluated) for the relative amount of cheese stuck to mouth surfaces and the texture scores recorded. A cheese with a firmness score greater than 10.5 and an adhesiveness score less than 5 is likely to exhibit successful machinability.

15.9.4 Sensory Analysis of Shredded or Sliced Mozzarella for Quality

Once the mozzarella has been shredded or sliced and packaged, sensory evaluation is used as an indicator of finished product quality. Mozzarella texture attributes become of secondary importance as the visual, flavor and functional characteristics are the indicators of product quality. General discussions on sensory analysis are more difficult as tolerances of attributes which gauge product quality (i.e., fines, amount of visible flow agent, etc.) vary greatly by type of end user as well as individual differences between end users. An industrial end user, one who will use cheese as an ingredient, requires consistency of cheese usage and specific functional characteristics. Cheese usage refers to ease of mozzarella use in automated food-production lines and the ability for accurate portion control. Factors that affect cheese usage are consistency of shredded cheese size and adhesiveness, presence of clumps and quantity of fines. Shredded cheese should be free of clumped shreds and excessive amounts of fines. In addition to cheese usage issues, an industrial end user may define flavor and functionality (appearance, stretch or melted texture) characteristics. A consumer who purchases a package shredded or sliced cheese makes a quality assessment initially by visual inspection and then by flavor and texture characteristics. This section describes the visual evaluation of shredded and sliced mozzarella. Evaluations of flavor and functionality are covered in the following sections: 'Sensory Analysis of Mozzarella for Cheese Grading' and 'Sensory Analysis of Mozzarella for Performance After Cooking'.

15.9.4.1 Evaluation of Packaging

A visual inspection of packaged shredded or sliced mozzarella cheese starts with an examination of the product seal (Table 15.5). If the packaging

Table 15.5 Attributes of packaged shredded cheese

Attributes of packaged shredded cheeses:
Appearance: proper seal on packaging material, shred size characteristic of package description, even distribution of added ingredients (i.e., seasonings, vegetable pieces), shred size consistency, shredded cheese color, shredded cheese color consistency, amount of fines, amount of visible flow agent, lack of cheese clumping, lack of free moisture (condensation), lack of mold growth, lack of foreign material
Flavor and texture: characteristic for varietal claim (flavor and texture character and intensity), free from off-flavors
Functionality: appropriate appearance, stretch, melt and flavor characteristics

material is crimped or any extraneous matter is caught in the seal, the integrity of the seal is compromised. Next the product description (from package) is matched with the package contents. For example, the size of the shredded cheese or additional flavorings or vegetable pieces should match the product description. Lastly, the product contents are examined for defects. Product defects may include inconsistent color, fines, clumped shreds, mold growth, foreign material or excessive amounts of flow agent. Flow agents are compounds (usually either cellulose or potato starch based) tumbled with shredded cheese, which enable shreds to continuously move through or ‘flow’ through processing and packaging. Post-processing flow agents help prevent clumping or matting of the shredded cheese. When visually assessing the amount of fines or clumps of shredded cheese, the evaluator holds the pouch flat in the palm of the hand and gently bounces the bag. This allows the cheese to settle with fines on the bottom and clumps on the top of the pouch. If this is not possible (due to bag size) a portion of the bag may be poured into a dark pan or plate for inspection. For sliced cheeses, the packaging material must be opened to assess the complete slice. Partial slices or loose cheese in the pouch indicate slicing defects. Assessment of sliced cheese should include ease of slice separation and the integrity of the slice (complete, no corners missing). After visual inspections are complete the cheese may be evaluated for flavor and texture and then functionality (Table 15.6). 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).

Table 15.6 Attributes of Sliced Cheese

Appearance: sliced cheese color, sliced cheese color consistency, distribution of sliced cheese within the packages, lack of free moisture (condensation), lack of mold, lack of foreign material
Flavor and texture: characteristics for varietal claim (flavor and texture character and intensity), free from off-flavors
Functionality: ease of slice separation

15.9.5 Sensory Analysis of Mozzarella Performance After Cooking

Mozzarella in cooking applications requires a different model for evaluation and a unique set of sensory terms in its assessment. Typically, melted mozzarella is evaluated by using pizza as a model. Under this model, melted mozzarella attributes pertaining to cheese performance may readily be evaluated. Other model systems may be developed as mozzarella is used in significant volume in appetizers, breads and a variety of entrees. The attributes described were developed for the use of LMPS and LM mozzarellas, but they are also relevant to low-fat and nonfat mozzarellas.

The goal of this sensory analysis topic is to create a profile that describes melted mozzarella performance. This method of measurement has the flexibility to be used in both quality assurance and in research and development. The cheese evaluator uses defined attributes, then evaluates each attribute and assigns intensity levels. Attributes evaluated are not considered varietal requirements or defects. For example, a typical mozzarella when baked on a pizza exhibits blisters. The presence of these blisters and their color are not required conditions, as some end users desire a moderate amount of brown blisters while others prefer a white, blister-free surface. It is the role of the end user to identify the acceptable range for the functionality attributes. Three main groups of functionality characteristics are evaluated: surface, stretch and melted texture. The same flavor terms used in the grading of mozzarella can be used in the assessment of cooked mozzarella.

Table 15.7 contains a list of functional attributes, definitions and range of observations that may be used to assess the performance of mozzarella when cooked. The list is not complete, nor is every attribute required for all evaluations. The group of attributes assessed is dependent on the specific end use of the melted cheese and preferences of the end users. The ‘range of observations’ listed for each attribute defines the ends of the scale. The specific type of scale (i.e., +/– assessment or 15-point scale), scale references and ranges of acceptability are not provided in the table. These details need to be outlined by the evaluator.

15.9.5.1 Sample Preparations

The most common model for evaluating mozzarella functionality is a cheese pizza with no additional toppings. This minimizes ingredient-to-ingredient interactions and allows the evaluator to focus on the functional aspects of the melted cheese. However, for specific functionality evaluations, cheese may need to be evaluated with additional ingredients. Preparation and cooking details should be as close to end-user specifications as possible: crust thickness, shredded cheese per unit area, type of baking pan, oven type and time/temperature specifications. Important, but not critical, are specifications relating to the shredded cheese size and type of tomato sauce. Prepared pizzas need to be tempered by either refrigeration or freezing. A typical formulation for mozzarella evaluations is as

Table 15.7 Terms Used in the Descriptive Analysis of Cooked Mozzarella

I. Surface Characteristics

Upon removal from oven, evaluate the surface characteristics of the melted cheese. Note the maximum cheese temperature obtained. (*) indicates a temperature-sensitive attribute, these attributes should be observed at a designated cheese temperature(s).

A. Color	
1. Blister color	The intensity of the brown hue on the blisters. [None -Extremely Dark]
2. Opaqueness *	The degree of opacity of the melted cheese. [Translucent - Opaque]
B. Surface Consistency	
1. Free Oil *	The amount of free oil on surface of the melted cheese. [None - Extremely Oily]
2. Free Moisture *	The amount of free moisture on the surface of the melted cheese. [None - Extremely Watery]
3. Blister Coverage	The amount of the surface covered by blisters. [None - - - - – -Complete]
4. Shred Fusion	The degree to which melted shreds are fused. [None - – - - -Complete]
5. Skinning	The quantity or condition of the surface layer of the melted cheese. [None - Strong]
C. Shape	
1. Shred Melt	The degree to which the cheese shred melts. [Shred is original shape - - - - - - Shred Completely Melted]
2. Flow-off Crust	The degree to which the melted cheese flows off the crust. [None - Strong]

II. Stretch Characteristics

All stretch attributes are sensitive. At a designated temperature(s), insert a fork 1 cm into the melted cheese. Slowly pull a strand.

A. Shape	
1. Strand Length	Pull strand until it breaks. Measure maximum cheese strand length. Repeat three times.
2. Thickness	The thickness of the melted cheese strand. [None - - - - - - - - - - - - - - - - - - - Extremely Thick]
3. Tenting	The amount of cheese pulled off the pizza pie which is not part of the strand. [None -Lots]
B. Consistency/Texture	
1. Force to Stretch	The force required to pull a strand. [None - Strong]
2. Roughness	The roughness of the pulled strand. [Smooth - - - - - - - - - - - - - - - - Extremely Rough]

Table 15.7 (continued)

III. Melted Texture Characteristics	
All melted texture attributes are temperature sensitive. At a designated temperature(s), remove the melted cheese off a 1–1 ¼ in. square of pizza.	
A. First Chew	
1. Hardness	The force required to bite through the sample using molars. [Soft -Hard]
B. Chew Down	
1. Liquid Release	The total amount of liquid (both water and oil) released during chewing. [None -Lots]
2. Cohesiveness	Degree to which the sample holds together in a mass. [Loose - Compact]
3. Chewiness	The total amount of energy required to masticate the sample to a state pending swallowing. [Tender -Chewy]

follows: one standard 12 in. par baked crust (ordered from the food-service sector), three tablespoons of tomato sauce and 300 g of shredded cheese. Then cover with plastic wrap and temper to 4.2°C (40°F). Ideally, whole pizza pies should be used in evaluations. Not only do partial pizza pies cook differently, but evaluators can more accurately evaluate the surface characteristics on a whole pizza. Examples of cooking specifications for different types of ovens are as follows: home oven or deck oven (i.e., Baker's Pride® oven), 425°F for 12 min; forced air oven (i.e., Impinger® oven), 500°F for 5 min; or combination forced air/microwave oven (i.e., Turbo Chef® oven), 500°F for 1 min 40 s.

Upon removing the cooked pizza from the oven, the evaluator should note the maximum temperature reached by the melted cheese. Temperatures above or below the norm may indicate under- or over-cooking and can be linked to appearance, stretch or melted texture variations.

15.9.5.2 Surface Characteristics of Cooked Mozzarella

The appearance of the baked pizza provides an immediate quality impression. As a result surface characteristics are the most commonly measured attributes and they encompass a wide acceptability range. Characteristics can be divided into three categories: color, surface consistency and shape of cheese shreds after cooking.

The most commonly assessed surface characteristics are as follows:

Color: blister color, opacity*

Surface consistency: free oil*, free moisture*, blister coverage, skinning, shred fusion

Shape: flow-off crust

*Temperature-sensitive attributes

Surface characteristics are conducted first, prior to stretch and melted texture evaluations. Any disruption to the melted cheese can make the evaluation of surface characteristics more difficult and may change the intensity rating of attributes. Stretch characteristics should be evaluated next, followed by melted texture characteristics. A standard evaluation temperature should be specified for the attributes of opacity, free oil and free moisture. The evaluator should observe each attribute as it pertains to the entire surface of the pizza. This may require a judgment call as to what is the 'median' intensity because the surface of a pizza is not homogeneous. Observations should be made by looking directly over the pizza from a height of about 12 in.

Blister color. Blisters are defined as raised areas on the surface of the baked cheese. Often the blisters appear drier than the surrounding cheese due to the flow of released oil or moisture to lower spots. 'blister color' is defined as the intensity of the brown hue on the blisters and ranges from 'none' (original cheese color) to 'extremely dark'. On the color spectrum brown is defined as a dark tertiary color with a yellowish or reddish hue. The color intensity of the blister is dependent on the extent of the Maillard reaction and/or protein burning. The evaluator should observe the entire pizza for blisters. The color intensity may vary from blister to blister due to cooking inconsistencies. The blister color intensity score is a reflection of the median blister color. The chemical and cooking factors that most influence blister color are residual sugars content and moisture to protein ratio of the cheese, flow agent type and usage, oven type and the maximum cheese temperatures obtained during cooking. Figure 15.3 contain reference images for blister color.

Opacity. Opacity is a measure of the proportion of incidental light that is absorbed by a material. In melted cheese, opacity is mainly influenced by temperature and the state and concentration of fat and/or protein. Fat in the cheese reflects light, thus if the fat content of the cheese is decreased there is less reflective surface area and the cheese appears less opaque.

The attribute 'opacity' is defined as the degree of opacity of the melted cheese and the intensity ranges from 'translucent' to 'opaque'. The evaluator should observe the melted non-blistered cheese on the surface of the pizza for the degree of opacity and score it. The degree of opacity of melted cheese is temperature sensitive. Opacity diminishes upon the cooking and cooling of cheese due to fat coalescence. The coalesced fat has less reflective surface area and the cheese appears more translucent.

The melted cheese opacity can be a distinguishing factor between pasta filata and non-pasta filata style mozzarellas of equivalent fat content. A pasta filata mozzarella will typically be less opaque than a non-pasta filata mozzarella. During the pasta filata cheese-making process, cheese is heated to temperatures where milkfat is completely melted. Upon physical working of the cheese, the fat coalesces between the protein strands. In the non-pasta filata cheese-making process, cheese does not undergo the equivalent heating; fat globules remain numerous and close to their original size. Thus the fat in a non-pasta filata mozzarella has more reflective surface area and the cheese appears more opaque.

Fig. 15.3 Reference image for blister color (*See* Color Plates)

Blister color 'none'

Blister color 'slight to definite'

Blister color 'definite'

Blister color 'definite to pronounced'

Free oil. Free oil is the amount of oil that separates from the cheese mass during cooking. Free oil is released from the protein matrix during cooking and further accumulates as the melted mozzarella cools. During cooking, thermal motion causes movement of the casein strands and the eventual collapse of the casein matrix, allowing fat to leak out and coalesce. The collapse of the casein matrix commences the flow of melting cheese. Thus, a cheese that flows readily upon heating tends to have greater free oil release. Ovens in which cheese temperatures rise sharply (i.e., forced air oven) or where the heating process is disruptive to the protein matrix (i.e., microwave or combination microwave/ forced air ovens) result in more free oil. Out of the oven, the protein matrix shrinks as it cools, squeezing out fat and increasing free oil release. The amount of free oil is temperature dependent and the temperature(s) at which this attribute is measured needs to be specified.

The attribute ‘free oil’ is the amount of free oil on the surface of the melted cheese and the intensity ranges from ‘none’ to ‘extremely oily’. To evaluate the amount of free oil the evaluator, at designated temperature(s), observes the entire pizza pie looking for accumulated oil on the surface. Melted milkfat will appear clear and may pool around blisters. Due to the reflective properties of melted milkfat, observations should be made by looking directly down on the pizza surface.

The amount of free oil is influenced by the same factors that affect cheese melt and flow: pH, FDM (if $> 50\%$) and age of cheese. Other factors that influence free oil release are manufacturing style and oven type. Pasta filata mozzarella typically exhibits twice the amount of free oil compared to a non-pasta filata style mozzarella of similar fat content. The rationale is similar to that for decreased opacity noted in the previous section: The heating and working of the cheese during the pasta filata process promotes fat coalescence. When baked on a pizza, larger pools of fat are then released as the cheese flows.

Free moisture. Free moisture release is the amount of moisture separated from the cheese mass during cooking. Like free oil, free moisture is released during the cooking process and further accumulates as the mozzarella cools. Free moisture is most prominent in young, high-moisture mozzarella where the pH is above ~ 5.40.

The attribute ‘free moisture’ is the amount of free moisture on the surface of the melted cheese and the intensity ranges from ‘none’ to ‘extremely watery’. To evaluate the amount of free moisture, the evaluator, at designated temperature(s), observes the entire pizza pie looking for accumulated moisture. Free moisture will have a thin milky appearance and may pool in low spots or around blisters. Free moisture and free oil may accumulate together. In these situations the evaluators will need to distinguish between the two liquids or may combine these attributes into one.

Blister Coverage. Blister coverage is the amount of the pizza surface that is covered by blisters. The extent of blister formation relates to high surface temperatures in the oven, the localized burning of proteins and the Maillard reaction. Evaporative cooling from the cheese moisture and/or the release of free oil are protective factors. ‘Blister coverage’ is defined as the amount of the pizza surface covered by blisters and ranges from ‘none’ to ‘complete’. Scoring may be recorded as an intensity rating or as a percentage of the surface covered with blisters. Blister coverage is dependent on the age of the cheese, manufacturing style, cooking conditions and oven type. Mozzarella cooked in ovens that utilize forced air typically exhibit greater blister coverage. As mozzarella ages, blister coverage increases. Figure 15.4 contains reference images for blister coverage.

Fig. 15.4 Reference images for blister coverage (*See* Color Plates)

Blister coverage ‘none’

Blister cover ‘very slight’

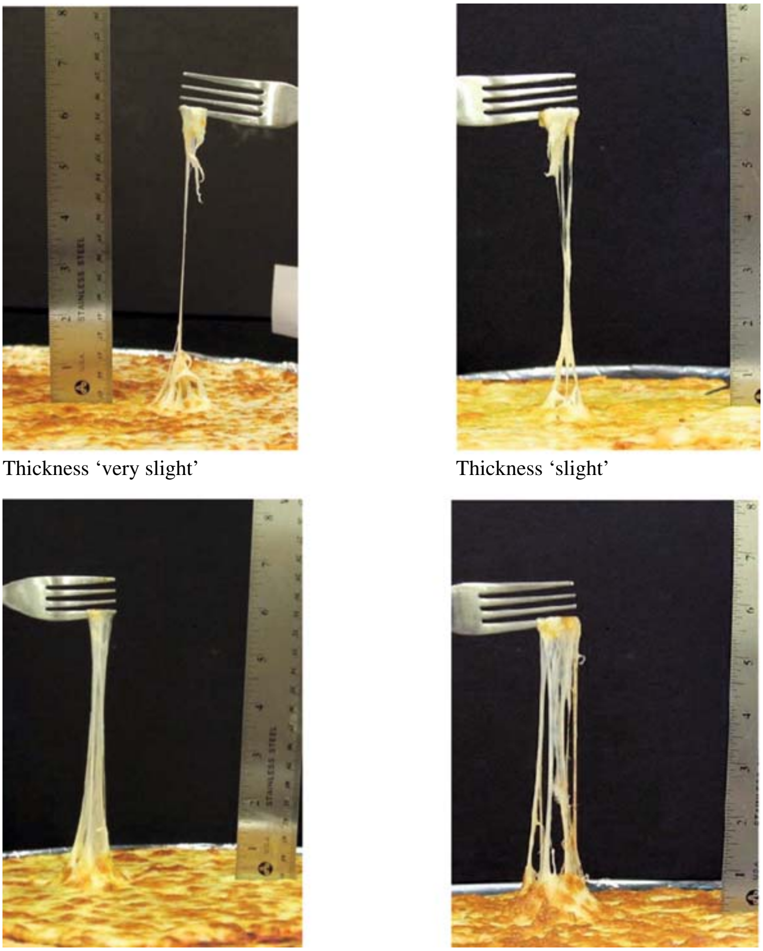
Blister coverage ‘slight’

Blister coverage ‘slight to definite’

Blister coverage ‘definite’

Skinning. ‘Skinning’ refers to the condition of the topmost surface layer of the melted cheese. The intensity of the skinning attribute ranges from ‘none’ to ‘strong’. To evaluate skinning, insert a fork tine into the melted mozzarella in a non-blistered area. Gently pull the fork horizontally. Observe the thickness and toughness of the cheese surface layer. If the surface of the pizza pie is one continuous blister, evaluate the quantity or condition of the continuous blister. The degree of skinning of mozzarella cheese is related to the age of the cheese, cheese composition, manufacturing style, use of flow agent, oven type and cooking conditions (Fig. 15.5).

Shred fusion. ‘Shred fusion’ is defined as the degree to which cooked shreds melt together, with an intensity range from ‘none’ to ‘complete’. A rating of



Thickness ‘very slight’

Thickness ‘slight’

Thickness ‘definite’

Thickness ‘pronounced’

Fig. 15.5 Reference images for thickness 'complete' indicates that all of the shreds have melted together into a single homogeneous mass. To evaluate, observe the pizza for the presence of intact, unmelted shreds. If individual shreds can be distinguished on the pizza, the evaluator assigns an intensity score.

Incomplete shred fusion can be caused by a lack of cheese flow during melting, the use of flow agents, cheese contact with other ingredients or the presence of free moisture or free oil impeding the fusion. For example, mozzarella shreds in contact with tomato sauce exhibit decreased shred fusion. The pH of tomato sauce is considerably lower than mozzarella. When sauce and cheese are in contact, the pH on the outermost layer of cheese drops to below the isoelectric point of casein, generating such strong protein–protein interactions that mozzarella shreds will have limited fusion.

Flow-off crust. 'Flow-off crust' is the degree to which melted mozzarella flows off the crust. This can either be evaluated by observing the flow on a whole pizza pie or cutting the pizza pie in half after removal from the oven and observing the cheese flow off the newly cut edge. The degree of cheese flow is related to cheese composition, use of flow agents and the age of the cheese.

15.9.5.3 Stretch Characteristics of Cooked Mozzarella

Mozzarella's ability to form protein strands requires an intact interconnecting casein network, heat and cheese flow. Stretch is the result of casein–casein interactions that are broken and then quickly reformed at different locations in the casein network. Stretching occurs at a relatively high concentration of intact casein and within a narrow range of colloidal calcium phosphate (Lucey and Fox, 1993). When proteolysis decreases the concentration of intact casein, cheese strands lack continuity and stretch is minimal. If casein–casein interactions are too strong, cheese is more likely to fracture or break than to form strands. This may occur if the stretching temperature is too low or cheese colloidal calcium concentration is too high.

Cooked mozzarella stretch attributes can be divided into shape and texture/consistency categories. All stretch characteristics are temperature dependent; therefore a designated temperature or temperatures should be specified. In addition to a thermocouple, stretch assessment requires a ruler and a fork of designated weight and geometry. Stretch characteristics are assessed by inserting a fork tine 1 cm into the melted cheese between the melted cheese and crust. The fork is then slowly pulled upward. If the cooked cheese surface exhibits skinning, the surface must be ruptured prior to pulling the strand. The attribute 'force to stretch' quantifies the force required to pull a strand of cheese, not the force required to rupture the cooked cheese skin. A typical stretch evaluation begins at 91°C (195°F). The evaluator pulls cheese strand(s) to the point of breakage for the assessment of strand length, force to stretch and roughness. This is followed by strands pulled to cm (6 in.) for the evaluation of thickness and tenting.

The most commonly assessed stretch characteristics are as follows:

Shape: Length, Tenting, Thickness
Consistency: Force to Stretch, Strand Roughness

Length. The most common stretch attribute assessed is strand length or how far the mozzarella strand elongates before it breaks. Due to inconsistencies of the pizza surface, strand length is assessed by averaging three pulls. The evaluator records the maximum length of the cheese strand.

Tenting. Cheese tenting refers to the raised mass or 'cone' of cheese that connects the surface of the pizza to the base of a pulled strand, but which is not considered part of the strand itself. The intensity range for the attribute 'tenting' is from 'none' to 'extreme'. A score of 'none' indicates that all of the pulled cheese was part of the strand and a score of 'extreme' indicates that an extremely large amount of cheese was pulled up along with the strand – giving the pull a tent-like appearance. The appearance of each pulled strand will have a different appearance. The evaluator should observe multiple pulled strands with the intensity score measuring the median cheese tenting.

Thickness. Strand thickness is defined as the thickness of the cheese strand at a height of 3 in. above the pizza surface when the strand is 6 in. long. The intensity ranges is from 'none' to 'extremely thick'. A score of 'none' implies that the strand broke prior to attaining a length of 6 in. This also may be recorded as not applicable (NA). A score of 'extremely thick' indicates that the strand thickness is as thick as the distance the fork tine was inserted into the melted cheese.

Force to Stretch. Force to stretch is defined as the force required to pull a cheese strand, the intensity ranges from 'none' to 'strong'. For this attribute using a fork of designated weight and geometry is critical. Scores of 'none' and 'strong' indicate no force (other than the weight of the fork) and an extreme amount of force is required to pull a strand of cheese. A good reference material to use when quantifying this attribute is the polymer material 'theraputty', which comes in different viscosities.

Strand Roughness. Strand roughness is defined as the roughness of the strand. The intensity ranges from 'none' to 'extremely rough'. The evaluator observes pulled strands for irregularities, breaks or splintering on the surface. An intensity score of 'none' implies that the pulled strand has a smooth silky surface, while 'extremely rough' indicates an extremely rough or splintered surface.

15.9.5.4 Melted Texture Characteristics of Mozzarella

The final class of characteristics that contribute to cheese functionality is melted texture, which is evaluated orally. Textural attributes of melted cheese focus on chewdown characteristics, while attributes for unmelted cheese concentrate on how cheese body breaks down in the hand or mouth (i.e., curdy/rubbery, pasty/sticky, weak).

The most common melted texture attributes evaluated for mozzarella cheese are as follows:

First Chew: Hardness
Chewdown: Liquid Release, Cohesiveness, Chewiness

All melted cheese texture attributes are temperature sensitive. However, cheese evaluation is limited to a cheese temperature range where the cheese is molten, yet not too hot to cause discomfort to the evaluator's mouth. For the typical evaluator, melted flavor and texture evaluations can be conducted between 49 and 67.2°C (120–155°F). Cheese evaluations are conducted by cutting a cooked pizza into 1–1.25 in. squares using a rotary cutter. At the appropriate temperature(s) the squares of melted cheese are peeled off the crust and evaluated.

Since the textural attributes of melted cheese are very important to the end user, sample preparation and temperature(s) at evaluation should not be limited to one value. This is especially true considering the wide variety of food-service applications of pizza pies. For example, the cooked pizza may be served directly to the customer, packed in an insulated box for up to 30 min or placed under infrared warming light for an extended period of time prior to the customer receiving the pizza. The same mozzarella will have a different textural profile for each scenario. The end user may determine that the mozzarella texture is acceptable under one condition, but not another.

Hardness. Melted cheese 'hardness' is defined as the force required to bite through the sample using the molars. The intensity of hardness ranges from 'soft' to 'hard'. To evaluate, fold the cheese square into quarters, outer surface inward (can be done in the mouth). This precise folding of the cheese is designed to lessen the impact of blisters or skinning on the measured parameter. Place the folded cheese between the molars and completely bite through the sample. Evaluate the force required to bite through the sample. Examination of this attribute may require cooler temperatures (49–57°C [120–135°F]) in order to adequately differentiate between samples. At higher temperatures (60–67.2°C [140–155°F]) cheese is more molten and variations in cheese hardness are less evident.

Several factors influence the hardness of melted cheese: protein content and pH (increases as protein increases), age of cheese (decreases with age), usage of flow agents (variable, but generally increases as flow agent increases), cooking specifications and oven types.

Liquid release. 'Liquid release' is defined as the amount of liquid, both oil and water, expressed from the melted cheese sample after chewing. It is assessed by chewing the cheese sample a specific number of times (typically 10–15), then pressing the bolus (chewed mass) against the palate. The assessor then evaluates the volume of expressed liquid. The intensity of Liquid release ranges from 'none' to 'lots'. The number of chews needs to be specified, as the amount of liquid released increases in a nonlinear manner as chewing proceeds. Specifically, initial chews release the highest volume of liquid, while the rate of liquid release decreases as chewing progresses. To avoid mixing excessive saliva into the released liquid the cheese should be chewed on only one side of the mouth.

Several factors influence the liquid release of melted cheese: fat content (decreases with content), age of cheese (decreases with age), cooking specifications and oven types.

Cohesiveness. The 'cohesiveness' of mass is defined as the degree to which a cheese sample holds together or adheres to itself after chewing. Cohesiveness is evaluated by chewing the cheese sample a specific number of times (typically 10–15) on one side of the mouth, then gathering the sample to the palate and evaluating. The mass will range from being entirely in loose particles ('loose') to forming one continuous, compact mass ('compact').

Factors that most affect cohesiveness of melted cheese include the composition and pH, manufacturing style and cheese age (increases with age).

Chewiness. 'Chewiness' is the total energy required to chew a sample and ranges in intensity from 'tender' to 'chewy'. Chewiness is a product of cheese cohesiveness, hardness and springiness. As these three factors increase, chewiness increases, although they may increase or decrease intensity independently from one another, thus making chewiness a difficult attribute to assess. For example, as cheese ages it becomes softer (decreasing chewiness) and more cohesive (increasing chewiness). To score, the evaluator must assess the total effort or exertion required to masticate the sample.

Several factors influence the chewiness of melted cheese: protein content (increases with content), cheese pH, age of cheese (decreases with age), usage of flow agents (variable, but generally increases), cooking specifications and oven types.

15.10 Conclusion

Mozzarella has become the most common cheese style produced in the U.S. Because mozzarella is a relatively mild-flavored cheese that does not develop much additional flavor during aging, in some respects the sensory evaluation of this cheese variety is straightforward compared to other cheeses. On the other hand, since mozzarella types are highly functional cheeses used in a variety of cooking applications and are often subjected to mechanical shredding or slicing prior to use, the comprehensive sensory evaluation of this cheese variety encompasses cheese performance characteristics not typically encountered for other cheeses. As a result, the overall sensory evaluation of mozzarella cheese is a complex, dynamic process involving judgments of flavor, body, texture, machinability, bake performance. In addition, accurate predictions must be made of changes in cheese performance as it ages. Only through a combination of training and experience can analysts become proficient and reliable judges of mozzarella.

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Chapter 16
Latin American Cheeses

Jonathan Hnosko, Stephanie Clark, and Diane Van Hekken

16.1 Introduction

Latin American cheeses, also know as Hispanic-style cheeses, are a category of cheeses developed in Mexico, Latin America, and the Caribbean. Some cheeses were developed using milk from native domestic animals while others were based on European cheese recipes brought over with the introduction of European cattle and since been modified to accommodate local preferences and cheese-making conditions (Van Hekken and Farkye, 2003). Latin American cheeses have become increasingly popular in the U.S. in the twenty-first century (Fig. 16.1; NASS, 2001, 2005a, b, and 2006; IDFA, 2006). According to the U.S. Census Bureau (2006), people of Hispanic or Latino ethnicity currently represent an estimated 14.8% of the U.S. population. As the Hispanic population increases in the U.S., so does the market potential for Latin American cheeses grows as well (Path, 1991). For example, in 2006, over 82 million kg (181 million pounds) of Latin American cheeses were manufactured in the U.S. – a tremendous increase over the 30 million kg (67 million pounds) produced in 1996 (NASS, 2007).

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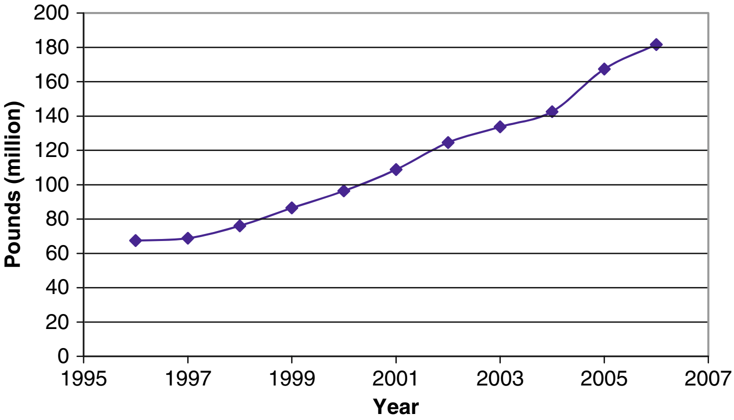

Fig. 16.1 Annual production trend for Latin American cheeses in the U.S. (adapted from NASS, 2001, 2005a, b, and 2006)

16.2 Latin American Cheeses: Overview

Latin American-style cheeses reflect their European origins include Manchego, Idiazábal, Roncal, Quartirolo, Queso de Bola, and Queso Prato (Fox et al., 2000; Kosikowski and Mistry, 1997). Other Latin American cheeses use descriptive names such as the most familiar Queso Fresco (fresh cheese), Queso Blanco (white cheese) (Kosikowski and Mistry, 1997), Panela (basket cheese), Asadero (suitable for roasting), Queso Anejo (aged cheese), Queso de Prensa (pressed cheese), and Queso Enchilado (cheese covered in chili pepper powder or paste). Still others refer to the region where they were developed, such as Queso Chihuahua (northern Mexican state; Fig. 16.2), Oaxaca (southern Mexican state; Fig. 16.3), and Cotija (town in the Mexican state of Michoacan)

When researchers investigated consumer awareness of Latin American cheeses in California, Queso Fresco was the most recognized (popular) of the cheeses and the most commonly tasted among consumers (n = 119; Geilman and Herfurth-Kennedy, 1992). The other options listed on the survey were

Fig. 16.2 Queso Chihuahua displayed in a variety of forms on tortillas

Fig. 16.3 Oaxaca displayed in a variety of forms on tortillas

Queso Chihuahua, Queso Panela, Asadero, Anejo, Cotija and Manchego. Consumers (47%) also indicated that they would use Latin American cheeses if they knew how to use them and the presence of these cheeses in the grocery stores would influence 32% of the respondents to try them.

The cheeses are traditionally made from raw milk and are often highly salted (Kosikowski and Mistry, 1997). Since many cheeses native to Latin America evolved by trial and error in regions where high mountains separate valleys, a number of similar cheeses may have different names, and cheeses of the same name often are not exactly the same in flavor, texture, or cooking properties (Kosikowski and Mistry, 1997). Although some countries (such as Mexico) have developed Standards of Identities for some of their cheeses, others do not. The diversity in names often makes it difficult to accurately classify a given cheese, especially if the country of origin and manufacturing protocol is unknown. This chapter will focus on five of the most popular and common Latin American cheeses found in the U.S., Queso Chihuahua, Queso Fresco, Queso Blanco, Cotija, Oaxaca, and Manchego.

Latin American cheeses can be classified as soft, semi-hard, and hard varieties based on composition (Table 16.1). Latin American-style white cheeses are either rennet-set (enzyme coagulated) or directly acidified (acid precipitated) and may be made with or without the use of starter cultures (Torres and Chandan, 1981). Cheeses classified as soft make up the majority of Latin American cheeses and are high-moisture varieties including the rennet-set Queso Fresco and Queso Blanco and the acid-precipitated Queso Blanco (Van Hekken and Farkye, 2003). Curd formation via acidification (precipitation) is usually accomplished with additions of food-grade lactic, tartaric, citric, phosphoric, or acetic acids (Torres and Chandan, 1981).

Semi-hard Mexican-style cheeses are rennet-set and include varieties such as Queso Chihuahua (also called Queso Menonita) and Queso Manchego, and the pasta filata-style Oaxaca. The smallest group of Latin American cheeses is the hard cheeses, which are low moisture cheeses that are usually aged. Cotija, the most popular of the hard Latin American cheeses, is a rennet-set cheese, which, if aged for 6–8 months, is called Cotija Añejo; Queso Añejo is an aged skim milk cheese that exhibits a distinct crumbly texture. Cotija generally has

Table 16.1 Typical setting method and mean composition of some Latin American cheeses

Cheese	Setting method	Fat (%)	Moisture (%)	Salt (%)	pH	Reference
Queso Fresco	Rennet-set; cultures optional	18–29	41–59	1–3	5.3–6.5	Hwang and Gunasekaran (2001) and Path (1991)
Queso Blanco	Acid-set or rennet-set	15–19	50–61	2.0–3.9	5.3	Siapantas and Kosikowski (1967)
		23–26	53–59	1.9–3.3	6.5	Arispe and Westhoff (1984)
		15–20	50–56	2.0–2.5	5.2–5.5	Farkye (2004)
Queso Chihuahua	Rennet-set; cultures optional	31–35	37–46	1.0–1.5	*	Tunick et al. (2007), Van Hekken et al. (2006), and Van Hekken et al. (2007)
Cotija	Rennet-set; thermophilic cultures	*	41–44	4–5	4.9	Bruhn (1986)
		28–31	35–42	>4	4.7–5.5	Guisa (1999) and Path (1991)
Oaxaca	Rennet-set; cultures optional	18–30	40–48	0.8–1.9	5.0–5.6	Van Hekken and Farkye (2003)
Manchego	Rennet-set; cultures optional	26	40	1.5	5.8	Fox et al. (2000)
Cotija	Rennet-set; thermophilic cultures	*	41–44	4–5	4.9	Bruhn (1986)
		28–31	35–42	>4	4.7–5.5	Guisa (1999) Path (1991)

*Not reported.

a rancid flavor, which is typically enhanced by the addition of lipase to pasteurized milk.

Since there are no current U.S. Standards of Identity for composition of Latin American cheeses, naming and accurately describing them can be challenging (Bolton and Frank, 1999; Van Hekken and Farkye, 2003). Understanding compositional, manufacturing, and quality properties (such as sensory flavor and texture, and rheology) of the traditional cheeses will help classify and identify the cheeses of Latin American style that increasingly appear in the U.S. market.

16.3 Safety Concerns

Raw milk may contain pathogenic bacteria such as *Salmonella*, *E. coli*, and *Listeria*, which have been linked to many foodborne illness outbreaks (FDA, 2006). Therefore, the Code of Federal Regulations dictates that cheese made from raw milk must be held at no less than 1.7°C for at least 60 days (CFR, 2007). 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 U.S. only if they are made from pasteurized milk (FDA, 2006).

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, U.S.-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 and 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 (Clark et al., 2004; Path, 1991). Because soft Latin American-style cheeses (fresh) are not aged, they rarely develop acidic conditions whereby unwanted bacterial growth may be inhibited (Linnan et al., 1988). 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 Composition and Production of Latin American Cheeses

16.4.1 Queso Fresco

Queso Fresco is a soft, high-moisture cheese made throughout the Americas, also known as Queso de Puna or Queso de Maracy. It is a rennet-set cheese that contains 41–59% moisture, 17–21% protein, 18–29% fat, 1–3% salt, and has a pH from 5.3 to 6.5 (Hwang and Gunasekaran, 2001; Path, 1991). Pasteurized whole milk or 2% fat milk is treated with lactic acid mesophilic starter cultures (0.25%) and chymosin (0.02%) and briefly agitated. The milk coagulates in approximately 35 min, and the curd is cut into cubes (Kosikowski and Mistry, 1997; Clark et al., 2001). In traditional cheesemaking, no cook step is used. When pasteurized milk and starter cultures are used, a cook step may be added to control the level of culture in the final cheese. Traditionally, curds are finely milled before salting to enhance the crumbliness of the final cheese (Higuera-Ciapara, 1986) although stirring the dry curd to dry and break up the curds prior to salting is also used (WCDR, 2007). Curds may be salted in whey (Clark et al., 2001) or after complete drainage (Kosikowski and Mistry 1997). The final pH should be 5.2–5.7 (Clark et al., 2001; Kosikowski and Mistry, 1997). Cheeses are typically pressed for up to 16 h in round molds to acquire traditional shape. To augment crumbling properties, cheeses can be pressed for 1 h, removed from press, hand crumbled, then returned to the press for further pressing (personal communication).

16.4.2 Queso Blanco

Queso Blanco is a soft to semi-hard cheese. It contains 49–53% moisture, 15–25% fat, 20–25% protein, 2% lactose, and 0.8–4% salt (Kosikowski, 1977; Van Hekken and Farkye, 2003), which suggests considerable variability in the marketplace (Table 16.1). With its name implying “white” in color, Queso Blanco is often made from goat or sheep milk in Latin America. The milk of these species is naturally white due to the presence of vitamin A instead of beta-carotene. The natural yellow color of cow milk used to make Queso Blanco can be bleached by using benzoyl peroxide (Kozikowski and Mistry, 1997). This cheese may be coagulated by two different methods, either by the addition of organic acids or with rennet (Kosikowski, 1977). The acid-set cheeses are very popular in Latin American and Caribbean countries and are also known as Queso del Pais and Queso de la Tierra (CDR, 2007). Standardized milk is heat treated above pasteurization temperature, 80–85°C for up to 5 min prior to acidification to pH 5.3 with hot acetic, citric or tartaric acid, or lime juice (Farkye et al., 1995; Fox et al., 2000; Kosikowski and Mistry, 1997). The curd is allowed to settle before the whey is drained. The curd is stirred to prevent matting, salted, and mixed again. The curd is scooped (or dipped), molded and pressed overnight at room temperature prior to packaging. Alternatively, lactic acid cultures may be added to milk at 32°C, and rennet is used to coagulate the milk. If the cheese is made with rennet, it is also known as Queso de Matera and Queso Paseurizado (Fox et al., 2000). Though similar cheeses, perhaps the biggest difference between Queso Blanco and Queso Fresco is the fine milling of the Queso Fresco curds prior to salting to enhance crumbliness.

16.4.3 Queso Chihuahua

Queso Chihuahua, developed by the Mennonite communities in the state of Chihuahua, Mexico, is a semi-hard, minimally aged (consumed within 4 weeks of manufacture) variation of young Cheddar cheese (Van Hekken et al., 2007). Official Mexican standards require that Queso Chihuahua should contain a minimum of 22.0% protein and 25.0% fat, and a maximum of 45.0% moisture and 3.0% salt (Direccion General de Normas, 1994). Surveys of the cheeses in Mexican markets report 36–44% moisture, 30–34% fat, 24–28% protein, and 1.0–1.5% salt (Tunick et al., 2007, 2008; Van Hekken et al., 2006, 2007). Traditionally, Queso Chihuahua was made with raw milk without starter cultures although, as concerns for food safety increase, pasteurized milk is replacing raw milk (Tunick et al., 2007). When pasteurized milk is used, it is inoculated with mesophilic lactic acid bacteria before rennet is added. The milk gel is cut into cubes up to 25 mm (1 in.) in size and is cooked, drained of whey, and cheddared similar to Cheddar cheese methods. The curd is coarsely milled (1–3 cm) prior to dry salting and pressed.

16.4.4 Cotija

Cotija is the most popular of the hard, aged Latin American cheeses. It contains 35–42% moisture, 23–30% fat, 28–31% protein, and 4% salt (Guisa, 1999; Path, 1991). This rennet-set cheese is made using whole or part skim bovine or caprine milk, mesophilic and thermophilic starter cultures, and high cooking temperatures. Exogenous lipases typically are added to enhance lipolysis. The curd is cut using

1 cm knives and the whey is drained. The curd is either mixed thoroughly during salting or milled prior to salting to break the curd into small pieces. Once molds are packed, the curd is pressed for a minimum of 1 day and aged for 3–8 months.

16.4.5 Oaxaca

Oaxaca is a fresh pasta filata cheese often referred to as the Mozzarella of the Latin American cheeses. It contains 40–48% moisture, 18–30% fat, and 1–2% salt with a pH 5.0–5.6 (Van Hekken and Farkye, 2003). It can be made from whole or partly skimmed bovine or caprine milk with or without starter cultures. The rennet-set milk gel is usually cut into large cubes (2 cm [3/4 in.]) and then drained without cooking. Near pH 5.1–5.4, the curd is then heated and stretched in a pasta filata step. The curd is stretched into long ropes, salted with coarse salt and wrapped like a ball of twine. The formed balls can also undergo a brining step. Oaxaca is typically sold without aging. Its flavor is similar to 'green' Mozzarella (unpublished).

16.4.6 Manchego

For Appellation of Origin (AO) or Protected Designation of Origin (PDO) status, Manchego must be made from ewe milk in the Castilla-La Mancha region of Spain (Cabezas et al., 2005). However, other non-PDO Manchego-like varieties are made with the milk of other species (Fox et al., 2000). Artisanal Manchego is made with raw milk (no starter cultures), while commercial Manchego is made with pasteurized milk inoculated with mesophilic starter cultures. Coagulation is induced by the use of calf rennet. Curds are cooked to about 38°C (100°F), molded and pressed for up to 16 h. Cheeses are given characteristic side markings by binding in basketwork wrappings for about 30 min after pressing. Manchego is brine-salted and aged for at least 2 months at 10–15°C (50–59°F) and 85% relative humidity (Fox et al., 2000). A non-PDO Manchengo made in Mexico has little similarity to PDO versions. It is closer to Gouda or Monterey Jack in body and flavor.

16.5 Sensory Evaluation of Latin American Cheeses

Identifying and defining descriptors of foods is important (Drake, 2004), thus attending to these issues for Latin American cheeses, which have received less attention than the more traditional dairy foods discussed earlier in this text, is relevant. Tracing particular sensory attributes back to specific source compound(s) is a particularly appealing prospect of flavor evaluation (Drake et al., 2007). In the same vein, correlating rheology of a cheese to sensory texture evaluation also enhances the understanding of the cheese quality traits

(Brown et al., 2003; Drake et al., 1999a, b). Some of these techniques have been used for evaluation of Latin American cheeses in recent years, but additional research is needed in this evolving area.

16.5.1 Queso Fresco

Queso Fresco is a white to cream-colored soft, crumbly cheese described as having a mild fresh milk flavor (Van Hekken and Farkye, 2003) and slightly salty taste (Path, 1991). It is, perhaps, the most widely studied of the Latin American cheeses with respect to sensory characteristics. Many of the techniques used in evaluation of Queso Fresco should be considered, with potential modifications, when investigating other Latin American cheeses. The crumbling properties of Queso Fresco are an important textural feature and are vital to consumer acceptance, since this cheese is often crushed and sprinkled on foods before being consumed (Hwang and Gunasekaran, 2001). The end use of the product is an important consideration in sensory evaluation of this cheese type. Descriptors such as creaminess, crumbliness, and firmness are terms often used by sensory panelists to evaluate Queso Fresco, while hardness, elasticity, adhesiveness, spreadability, fracturability are used for texture profile analysis of this cheese type (Hwang and Gunasekaran, 2001).

In an intensive study (Hwang and Gunasekaran, 2001) on eight commercial Queso Fresco cheeses, the results of conducting (1) descriptive sensory analysis by panelists, (2) texture profile analysis, (3) shear tests, (4) compression tests, and (5) particle analysis clearly indicated that manufacturing procedures (especially curd milling) resulted in small curd particles and enhanced crumbliness in Queso Fresco made with unhomogenized milk. Furthermore, the number of particles estimated by the previously indicated method was considered the best single, objective measure of Queso Fresco crumbliness (Hwang and Gunasekaran, 2001).

While the sale of fresh, unripened, raw milk cheese is illegal in the U.S., these products are sometimes more appealing to the target demographic than their pasteurized counterparts with respect to sensory characteristics (Clark et al., 2001). Sandra et al. (2004b) examined the potential of a novel technology, high hydrostatic pressure (HHP) to assist in production of Queso Fresco with pasteurized milk cheese similar in sensory characteristics to raw milk Queso Fresco. Adequate maintenance of crumbling properties was paramount, and this specific parameter was the focus of a thorough investigation of sensory aspects. Three methods of analysis were performed on samples: descriptive analysis, texture profile analysis, and compression test. Crumbliness was defined in this study as "the ease by which the sample breaks apart during manipulation by rolling the sample using replicated circular movements, with the thumb, forefinger, and middle finger, 5 times." While there were a few attributes in which each sample was significantly different from the others (irregularity in appearance, springiness before breaking, crumbliness and cohesiveness during breaking, and sticky residuals after breaking), the HHP cheese was not significantly different from the control for most attributes, except color (Sandra et al., 2004). This indicates that Queso Fresco may be treated with HHP without experiencing a deterioration of quality.

Since sensory analysis indicated that the HHP-treated raw milk cheese was similar to the control cheeses in most attributes evaluated (crumbliness included), it stands to reason that further exploration of HHP to Queso Fresco manufacture is warranted. However, Hnosko (2007), who conducted studies using combined microbial inoculation and HHP, showed that HHP was not entirely suitable for Queso Fresco. While greater than a 5-log bacterial reduction was possible by treatments between 400 and 500 MPa for 5–25 min, desirable crumbling properties were unacceptably compromised under these treatment conditions. Therefore, HHP was not recommended for Queso Fresco applications.

16.5.2 Queso Blanco

Queso Blanco is a white cheese, creamy, salty, and acidic in flavor (Kosikowski, 1977; Fox et al., 2000), which resembles young, high-moisture Cheddar with good slicing properties. Instrumental analysis of these slicing properties may be useful in determining product quality.

Flavor compounds in Queso Blanco include acetaldehyde, acetone, isopropanol, butanol, and formic, acetic, propionic, and butyric acids (Fox et al., 2000). The relative importance and impact of these compounds on consumer acceptance and preference should be investigated. The pH of Queso Blanco ranges from about 5.2 to 4.9, which may be due to lactose fermentation by heat-stable indigenous bacteria (Torres and Chandan, 1981). In acid-set Queso Blanco, choice of coagulating acid and how it is added are critical to cheese flavor and functionality (Parnell-Clunies, 1985a, b). Glacial acetic acid and citric acid are the most commonly used acids (Torres and Chandan, 1981; Parnell-Clunes, 1985a, b; Farkye et al., 1995; Kosikowski and Mistry, 1997) giving the cheese acceptable acid flavor (Farkye et al., 1995). Queso Blanco has flow resistance upon heating owing to the inclusion of whey proteins that gel upon heating of the cheese milk, which lends this cheese well to deep-fat frying in batter (Fox et al., 2000). End use of the cheese is always an important consideration for sensory evaluation. The parameters of the finished cheese should be compared with the acceptability of the final product (post-consumer-typical preparation).

Farkye et al. (1995) evaluated the textural properties of Queso Blanco-type cheeses variously made using acetic, lactic, and citric acids. The researchers determined that textural parameters were influenced by acid type, which influenced whey separation from curd. Parameters such as hardness, fracturability, chewiness, and gumminess were highest for cheese made with acetic acid and lowest for cheese made with lactic acid. For Queso Blanco cheese, evaluation of the aforementioned physical parameters lends themselves well to instrumental analysis. Springiness and cohesiveness were not dependent on acid type. Selection of the acids used for the manufacture of Queso Blanco-type cheeses can be used to meet specific qualities desired by consumers.

16.5.3 Queso Chihuahua

Queso Chihuahua is described generally as “mild to tangy” in flavor (Kosikowski and Mistry, 1997) and exhibiting a pale yellow color and firmly packed curds with minimal air pockets between major curd divisions (Van Hekken et al., 2007). Recent research using descriptive analysis to evaluate the flavor of cheeses manufactured in the Chihuahua region indicates a mild flavored cheese with the most prominent flavor notes being salty, sour, diacetyl, cooked, whey, bitter, and milkfat; no flavor attribute intensity scored over 3 using a 15-point universal intensity scale (Van Hekken et al., 2006). The traditional raw milk cheeses are more sour and bitter than the cheeses made with pasteurized milk and commercial starter cultures. Raw milk cheeses also have a slight “prickle” mouthfeel that is absent in the pasteurized versions. Statistical evaluation to verify these sensory profiles would be helpful in establishing the impact of manufacturing technique on product characteristics. The cheese flavor profile is stable throughout the Mexican seasons although a few brands show some slight variations in bitter and cooked flavors in cheeses made in the spring season. A descriptive panel trained in product-specific texture analysis found Queso Chihuahua to place in the middle range of scoring for 11 designated texture parameters, including “hand, first bite,” and “chewdown” descriptors as described by Drake et al. (1999a). Queso Chihuahua is described as a firm but not hard cheese with some springiness, typical of a semi-hard cheese with 40% moisture. Instrumental analysis may prove helpful in better understanding this cheese. The texture profile showed that cheeses made in the winter season were softer and that raw milk cheeses were less elastic in late summer.

Rheological properties of Queso Chihuahua were also conducted in conjunction with the sensory evaluations (Tunick et al., 2007; Van Hekken et al., 2007). Pasteurization caused more uniform cheese body than did raw milk. Rheological properties of the Queso Chihuahuas were similar to Brick and Colby cheeses with respect to cohesiveness values, which were intermediate between Brick and Mozzarella in springiness and similar to Colby in chewiness, although the rheological properties varied significantly among the different brands with overlapping ranges for the individual RM (raw milk) and PM (pasteurized milk) cheese brands. Overall, the body and texture of PM cheeses were harder, chewier, and more cohesive, but had lower viscoelastic values than the RM cheeses. For all of the cheeses characterized, Queso Chihuahua was considered most similar in rheological properties to fresh Colby cheese (Van Hekken et al., 2007).

16.5.4 Cotija

Cotija is the hard, aged Mexican cheese often referred to as the "Parmesan of Hispanic cheeses." It has poor melting properties (Van Hekken and Farkye, 2003) and is typically grated in preparation for sale. Sensory evaluation of such a product should obviously occur with the food in the form most likely to be encountered or utilized by the consumer or foodservice user. With a high salt content and added lipases, Cotija is noted for its strong, sharp, or pungent aroma with salty and free fatty acid flavor notes. Outside of a few food safety and market survey studies (Path 1991; Genigeorgis et al., 1991) and sales literature (which describe the flavor as "robust"), limited quantitative information is available on the sensory quality traits of Cotija. Sensory evaluation of Cotija cheese with panelists should include explorations of unique flavor and aroma considerations. The monitoring of melting properties of this cheese type may be important; hence, instrumental analysis of this product's grating properties should conceivable be considered.

16.5.5 Oaxaca

Oaxaca has a milky, creamy, buttery, slightly acid flavor, and a stringy texture; hence it is somewhat similar to Mozzarella or string cheese. It has excellent melt and stretch properties, which may prove to be useful focus points for sensory observations. Like Cotija, there is limited information about this cheese type's quality traits.

16.5.6 Manchego

Manchego cheese is traditionally a semi-hard pressed and ripened cheese. While Spanish Manchego is traditionally made from sheep milk, Mexican Manchego cheese is made with pasteurized cow's milk and calf rennet (WCDR, 2007). Because of the variety of milk sources (cow, goat, sheep) available for the production of Latin American cheeses, flavor and aroma characteristics for each variety manufactured from various sources should be considered and investigated. Tavaria and Malcata (2000) reported highly variable microbial content of Sera da Estrela cheeses from varying geographical regions in Spain. Cabezas et al. (2005) studied the chemical, microbiological, and sensory differences between raw and pasteurized cheese milk Manchego cheeses produced at two different dairies. Few chemical or microbiological differences were indicated for the cheeses made at the two different dairies, but differences in nitrogen fractions and free fatty acid content were found. Certain and varied odor attributes, primarily, contributed to the differentiation of the cheeses.

Rheological characteristics of four raw milk (artisanal) and four pasteurized milk (industrial) Manchego cheeses were evaluated by uniaxial compression and descriptive sensory analysis (Viñas et al., 2007). The cheeses could be distinguished by manufacturing method (artisanal or industrial); industrial cheeses were more homogeneous in body and texture than the artisanal cheeses, regardless of ripening time. The authors concluded that the eating and cutting properties of Manchego cheese depend not only on conditions of curd formation and handling but also on storage conditions. Application of partial least squares (PLS) regression to texture attributes measured instrumentally enabled prediction of most of the texture attributes evaluated in the Manchego cheeses. The same researchers (Cabezas et al., 2006) showed that PLS regression could adequately predict the odor and taste characteristics of artisanal and industrial Manchego cheeses, based on physicochemical parameters, proteolysis variables, and organic acids. The authors suggested that proteolysis was the primary factor influencing aroma and taste. Water soluble nitrogen, total nitrogen, casein fractions, pH, citric acid, and acetic acid contributed most to aroma and taste characteristics of the industrial and artisanal Manchego cheeses.

16.6 Conclusion

Latin American cheeses are rapidly becoming more popular in the U.S., and a continuation in the rise of production is expected as the Latino population increases in the U.S. As interest increases for Latin American cheeses, consumers will want to know more about available cheeses. This increase in awareness requires producers to increase their knowledge of their products. Sensory evaluation of texture, taste, and aroma are essential for determination of consumer acceptability and preference.

With variation by country and region, naming and classifying Latin American cheese can be difficult. Not only would an emphasis on standardizing the nomenclature of Latin American cheeses be helpful to consumers but it would also assist scientific investigation of each cheese and the application of findings to improve the quality and acceptability of Latin American cheeses. Suggested considerations for investigating the sensory properties of Latin American cheeses include (1) determination of cheese end use or typical consumer preparation (i.e., crumbling, slicing, melting); (2) evaluation of aroma, flavor, and texture parameters of importance to consumers; (3) evaluation of typical make procedures in various countries and regions; and (4) variability in milk source (or quality) used for cheesemaking. All of the aforementioned aspects, and numerous other considerations, influence the diverse physical and chemical properties of finished cheeses and the sensory qualities of the final products. Future study, applied and basic research efforts, and introduction of and standardization protocols for the manufacture of Latin American cheeses are areas that have great potential for improving the consistency and quality of this popular category of cheeses.

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Chapter 17
Modern Sensory Practices

Mary Anne Drake

17.1 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 most 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 with the marketing of dairy foods, some means of sensory measurement is 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 1940 s 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 and Heymann, 1999). 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, 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.

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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 made, just as the same situation would apply with 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.

17.2 Types of Sensory Tests

The sensory analysis of dairy products can be categorized into three basic categories or groups of tests (Fig. 17.1). 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

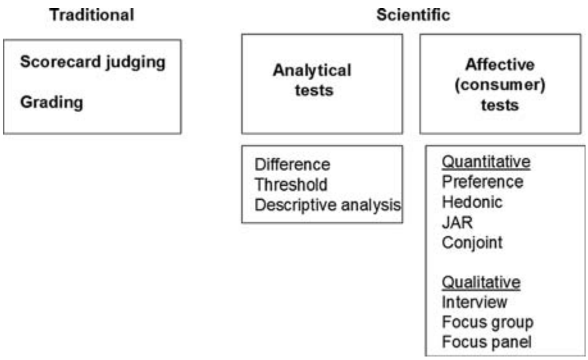

Fig. 17.1 Groups of sensory tools available for dairy foods

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 and Drake, 2004; Bodyfelt et al., 2008). These tools are dated at best and flawed at worst and should not be used within 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. 17.1). Within each of these categories are groups of sensory tools for specific objectives.

17.2.1 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. 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 and Heymann, 1999). 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 similar to a difference test, but generally requires larger numbers of panelists (>75) (Meilgaard et al., 2007).

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. 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 and Heymann, 1999; Meilgaard et al., 2007).

17.2.2 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 and Heymann, 1999; Meilgaard et al., 2007). 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 are determined by having subjects wear noseclips when taking a mouthful of the sample, followed by removal of the noseclip 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).

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 proper and consistent testing procedure. This includes an appropriate threshold test method, an appropriate number of panelists, and 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 and Heymann, 1999). 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. Often listed as the minimum recommended number of individuals is 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), noseclips 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.

17.2.3 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 development of a powerful instrument to document sensory properties. The various techniques and approaches for the conduct of descriptive analysis are reviewed elsewhere (Lawless and Heymann, 1999; Murray et al., 2001; Delahunty and Drake, 2004).

Relevant to the objective of this book, it is worthy to address and demonstrate how trained panel results differ from dairy products judging. Figures 17.2–17.5 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*

Cheese 1	A	Sl. Bitter Sl. flat
Cheese 2	A	Sl. Bitter Sl. flat

Fig. 17.2 Grades of two 16-kg blocks of 3-month Cheddar cheese. Grades were provided by a licensed USDA grader

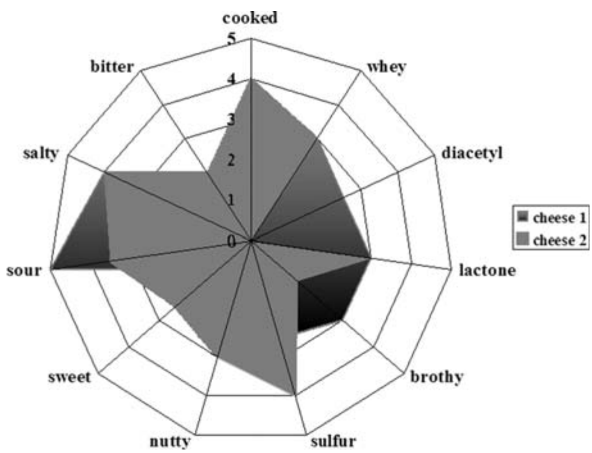

Fig. 17.3 Descriptive sensory profiles provided by a trained descriptive panel for the two 16-kg blocks of Cheddar cheese in Fig. 17.2

Fig. 17.4 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

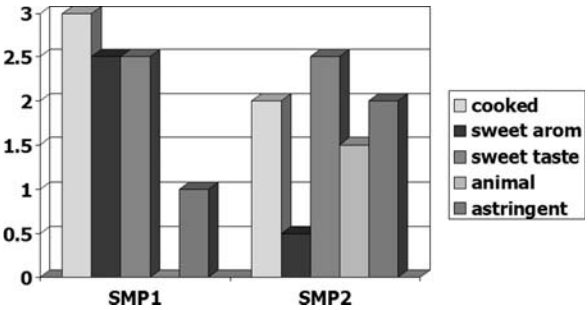

Fig. 17.5 Descriptive sensory profiles provided by a trained descriptive panel for the two SMP in Fig. 17.4

functions as a qualitative and quantitative instrument used to document sensory properties of different foods. Figures 17.6–17.8 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. 17.3 and 17.5). 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* (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. 17.6–17.8). For example, Figs. 17.6 and 17.7 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

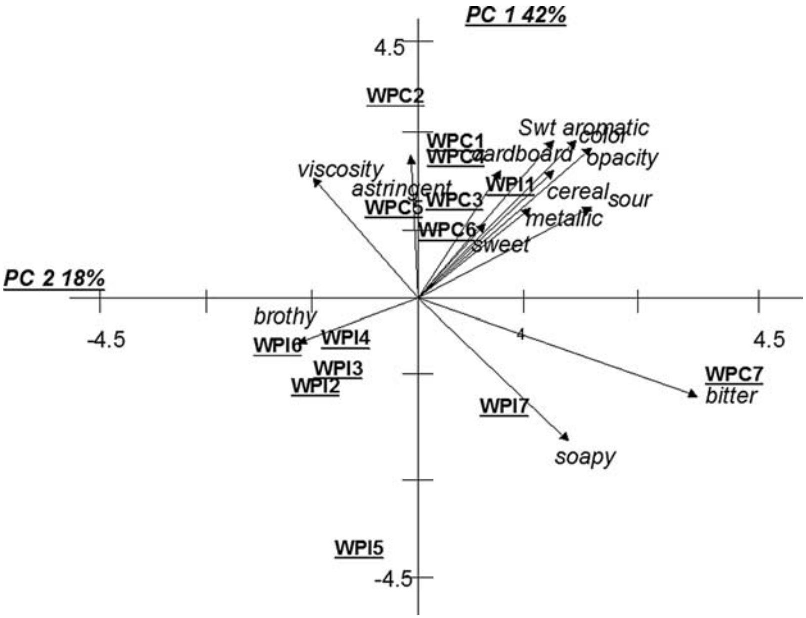

Fig. 17.6 Principal component biplot of descriptive analysis of whey proteins (PC1 and PC2) (Taken from Russell et al., 2006). *PC* – principal component, percentage following PC in parenthesis explains amount of variability depicted by each principal component on each axis, *WPC* – whey protein concentrate, *WPI* – whey protein isolate, Swt aromatic – sweet aromatic

individual whey proteins from one another. A quick glance at Fig. 17.6 tells us that WPC80 and WPI were differentiated from each other as groups (exception – WPC7) and that the differences between 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 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. 17.8 documents trained panel texture differences among 20 Gouda cheeses of different ages (Yates and Drake, 2007). The reader is referred to Lawless and Heymann (1999) or Meilgaard et al. (2007) 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

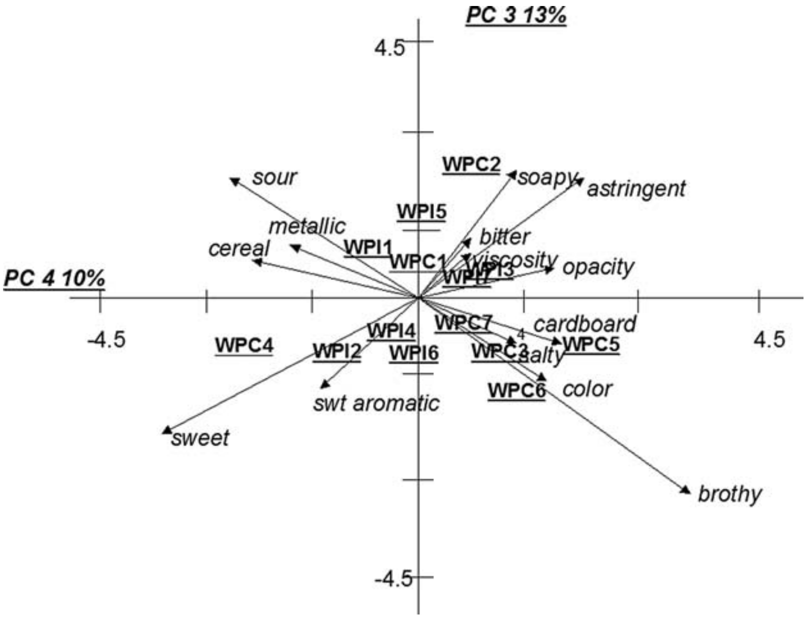

Fig. 17.7 Principal component biplot of descriptive analysis of whey proteins (PC3 and PC4) (Taken from Russell et al., 2006). *PC* – principal component, percentage following PC in parenthesis explains amount of variability depicted by each principal component on each axis, *WPC* – whey protein concentrate, *WPI* – whey protein isolate, Swt aromatic – sweet aromatic

relationship to physical or instrumental measurements is to have clearly defined terms for sensory attributes (Drake and Civille, 2003). 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 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 17.1 and 17.2 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

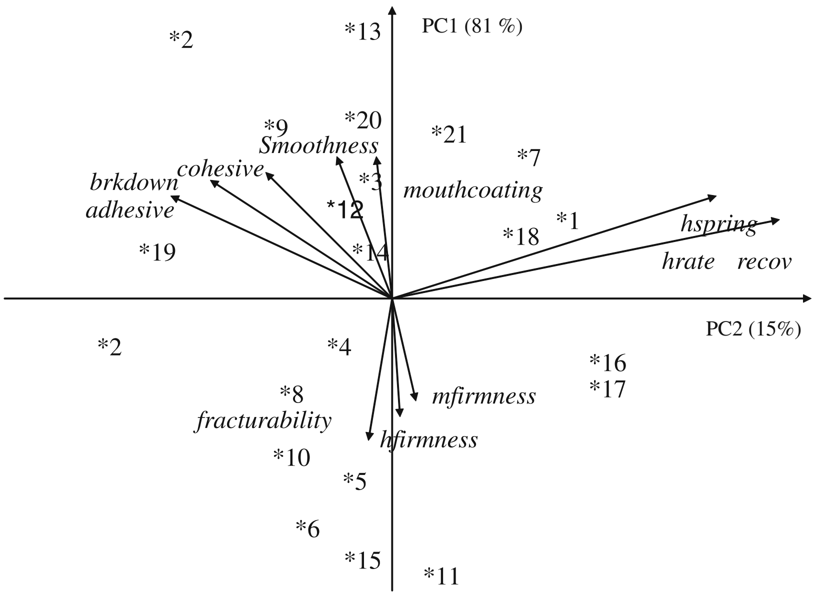

Fig. 17.8 Principal component plot of descriptive texture attributes of Gouda cheeses. *PC* principal component. *Numbers* represent cheeses, mfirmness – firmness in the mouth, hfirmness – firmness by hand, hrate recov – rate of recovery determined by hand, hspring – springiness determined by hand, smoothness – smoothness of the chewed mass, cohesive – cohesiveness of the chewed mass, brkdown – degree of breakdown

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 17.9 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.

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, and Parmesan with minor modifications (Liggett et al., 2008; Table 17.3). Drake et al. (2002) demonstrated that the defined language could be used by panels at multiple locations to provide

Table 17.1 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
Smoothness of mass	Evaluate the smoothness of the chewed mass	Parmesan = 1 Feta = 3 Muenster = 8 Sharp Cheddar (Kraft) = 10 Velveeta™ = 14

Table 17.1 (continued)

Hand evaluation terms	Definition	References
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)

Table 17.2 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, 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)

Table 17.2 (continued)

Descriptor	Definition	Reference
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)

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, 2006b; 2007). 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 and Drake, 2007).

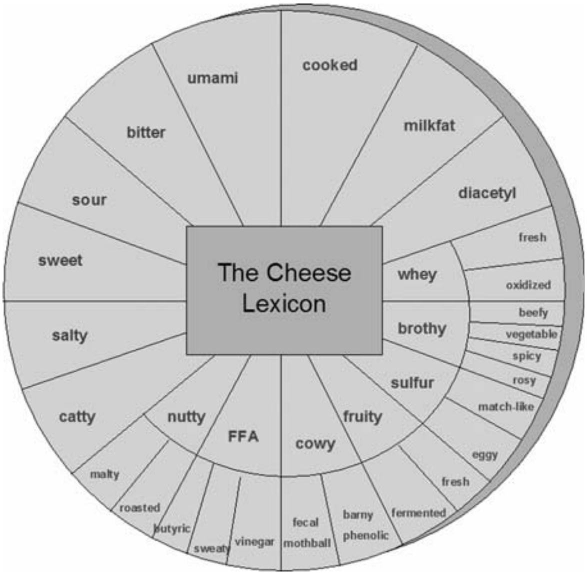

Fig. 17.9 Graphical representation of the basic and advanced levels of the Cheddar cheese flavor lexicon (Table 17.2)

Table 17.3 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., 2007

Another important application of descriptive analysis, other than enhanced product understanding and identification of relationships to instrumental analyses, is to 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 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 and Sanchez, 1998; Krause et al., 2007; Thompson et al., 2004; Young et al., 2004; Lawlor and Delahunty, 2000; Xiong et al., 2002; Murray and Delahunty, 2000a, 2000b; Richardson-Harmon et al., 2000). The power of these studies is that specific consumer groups with specific likes and dislikes are identified. Figures 17.10 and 17.11 demonstrate the application of this technique to Cheddar cheese and butter, respectively.

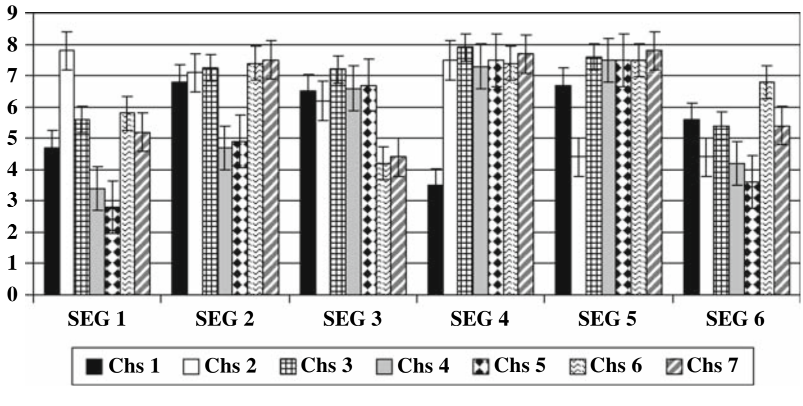

Fig. 17.10 External preference map of combined consumer data ($n = 240$) with descriptive analysis results for 7 different Cheddar cheeses. Six consumer segments with distinct liking profiles for 7 selected Cheddar cheeses were identified (Taken from Young et al., 2004)

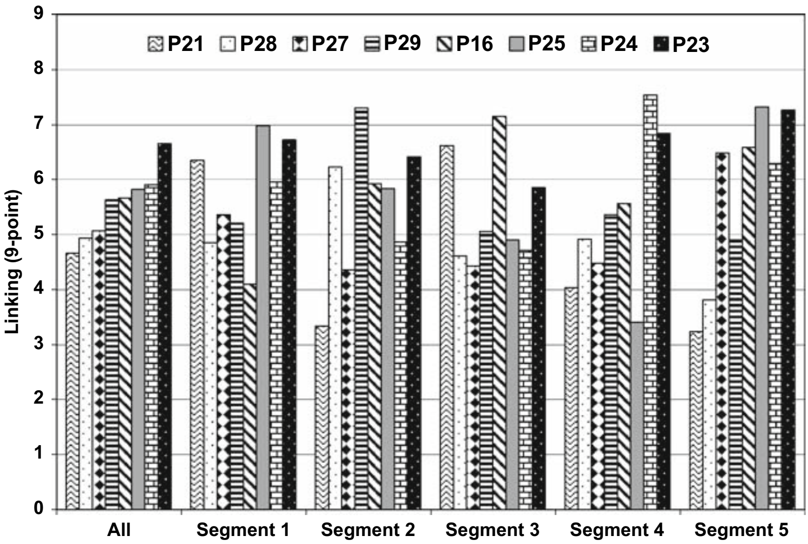

Fig. 17.11 Overall acceptability scores for 6 butters (P16, P21, P23, P24, P25, P27) and 2 spreads (P28, P29) within different identified consumer segments. Liking profiles for the 8 products are distinct for each consumer segment (Taken from Krause et al., 2007)

17.2.4 Affective or Consumer Tests

17.2.4.1 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. 17.17). 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., 1999; 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 and Heymann, 1999; Meilgaard et al., 2007; Resurreccion, 1998).

Quantitative tests are the best-known group of tools, with preference and acceptance testing the most used subset within this classification (Lawless and Heymann, 1999; Meilgaard et al., 2007). *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 preference (preference ranking). The test is generally 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. 17.12). This scale is bipolar – the anchors are dislike and like – and has been widely used since its invention in the 1940s (Schutz and 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 and 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. 17.13). 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 and Cardello, 2001; Greene et al., 2006) (Fig. 17.14). 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 and Pages, 2004). Instead, degree of liking and/or degree of disliking should be scaled on distinct unipolar

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. 17.12 Numerical and verbal representations of the 9-point hedonic scale

intensity scales (Fig. 17.15). 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 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. 17.16) (Lawless and Heymann, 1999). This test is often used in product development or optimization studies since the experimenter can probe if a specific product attribute (such as sweetness or chocolate flavor) is "just about right". There are a limited

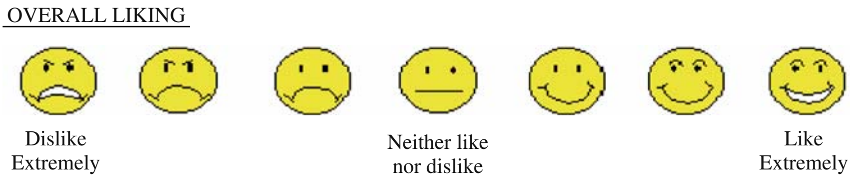

Fig. 17.13 Seven-point smiley face scale used with children or with individuals that do not speak or read English. Faces are converted to numerical values (1–7) for data analysis

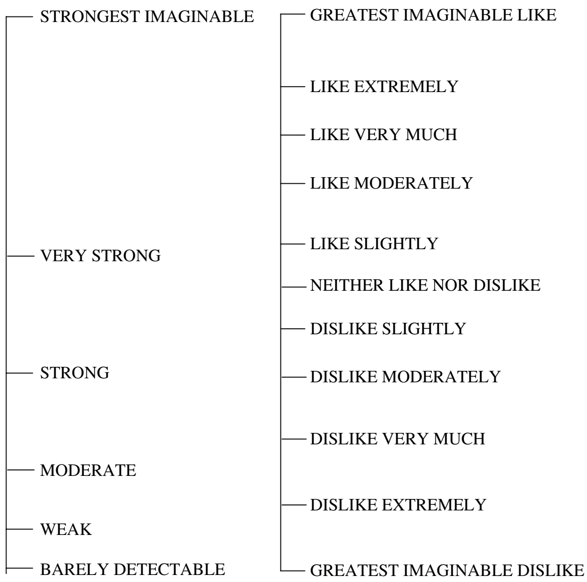

Fig. 17.14 Labeled affective magnitude (LAM) scales for measuring intensity and liking

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. 17.15 Unipolar scales for scoring liking and disliking separately

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. 17.16). 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.

Conjoint analysis is another group of quantitative consumer tests 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

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. 17.16 An example of a just-about-right (JAR) scale for sweetness intensity followed by an example of obtaining similar information using category scales

consumer, conjoint analysis does not require actual products. 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 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.

17.2.4.2 Qualitative Consumer Tests

The final group of consumer research tools are qualitative instruments. Using these tools, insights into consumer perceptions/needs/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 videotaped 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

1. Gender: _______ female _______ male

2. Age:

_______	less that 20	_______	35 – 39
_______	20 – 24	_______	40 - 45
_______	25 – 29	_greater than 45	
_______	30 – 34		

3. What is your yearly income?

_$0 – 10,000 _$40,000 – 60,000
_$10,000 – 20,000 _greater than $60,000
_$20,000 – 40,000

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	_______	at least 2 – 3 times per month
_______	a few times per year	_______	at least once per week
_______	at least once per month	_______	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	_______	Texture
_______	Flavor	_______	Sweetness
_______	Color	_______	Availability

Fig. 17.17 An example of a demographic screener used with consumer acceptance testing of drinkable yogurts

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 and Heymann, 1999; Meilgaard et al., 2007; Kreuger and 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 and Vickery, 2004; Sherlock and Labuzza, 1992; McNeill et al., 2000; Kosa et al., 2004; Boon et al., 2005; Keim et al., 1999). 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 and 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.

17.3 Common Misuses/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 and Civille, 2003; Foegeding and 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 should be polled to make sound conclusions regarding liking or preference (Lawless and Heymann, 1999).
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.

17.4 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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Appendix A
Basics of Grade "A" Raw Milk Sampling, Grading, and Transport

The licensed milk hauler occupies an important position in the dairy industry (U.S. Food and Drug Administration 1999, 2003; NARA 2007). The hauler represents both the seller (producer) and buyer (processor) of milk supplies intended for fluid or manufactured products use. The judgment, actions, and decisions of this key individual impact (1) representative sampling, (2) the measurement of both quantity and quality of milk (which have a direct effect upon milk payment), (3) compliance with food safety requirements, and (4) the quality of dairy products made from the milk (Bodyfelt et al., 1988).

To be competent, a bulk milk hauler should possess several attributes and skills in addition to being able to drive safely and competently handle a truck and trailer. First, it must be recognized that the hauler is a food handler; one's appearance and personal sanitation habits should definitely reflect this role. Cleanliness, neatness, integrity, a "spirit of fairness," and "attention to detail" are additional personal attributes that are indicative of a milk hauler's ability and performance.

More specifically, the milk hauler must be able to accurately determine the milk volume (or weight) of bulk milk tanks and be able to aseptically collect, identify, and properly care for "official" milk samples. Hence, the hauler should be familiar with farm tank installation and the factors that affect the accurate measurement of milk, sampling, milk abuse, and temperature control. It is most helpful if the hauler can identify certain causes of milk quality problems and then offer suggestions to the dairyman for corrective action.

Ideally, milk haulers should possess a keen sense of smell and be able to identify the more objectionable milk off-flavors (odors) because aroma observation (see Appendix B) is one of the first and most critical steps in the process of milk collection. This person also needs to have an appreciation of the role of cleanliness and sanitation in the handling and protection of milk. Additionally, the hauler must be able to clean and sanitize all equipment and "tools" entrusted to his or her care.

The milk hauler is the most appropriate communication link between the milk producer, the milk marketing cooperative, and the milk processor. A milk hauler's awareness and knowledge of many aspects of farm milk collection and handling, the determinants of good milk quality, and essential sanitation and hygiene requirements are factors that can lead to an increased level of understanding and trust between the milk producer and the dairy processor.

"To accept" or "to reject" a given tank of milk at the farm is essentially an "all-or-none" type of decision; this is undoubtedly the most important form of decision-making required of the milk hauler (who is simultaneously a milk sampler/grader). Training and experience play an important role in the development of capable milk haulers.

A.1 Milk Hauler (Receiver) Defined

A "milk hauler" or "receiver" is defined as a person who, in the course of their employment, accepts bulk milk or milk products (ingredients) from a producer, milk plant, receiving or transfer station and transports such commodity to a milk or dairy products plant.

Milk haulers must constantly:

1. Be alert – always be observant for details or signs of shortcomings and oversights related to sanitation and/or milk quality.
2. Be willing to assume their reasonable share of responsibility.
3. Day to day, maintain positive relationships with milk producers.
4. Demonstrate integrity – always measure and sample milk with equity.
5. Exercise a keen sense of smell (and perhaps even taste in some instances).

A.2 Licensing of Milk Haulers

In most states of the U.S., all persons involved in the transporting or hauling of bulk milk from producers to processing plants (or transfer stations) must be licensed (U.S. FDA 1999 and 2003). Actual licensing arrangements vary among the states. The purpose of licensing is (1) to make certain that a milk hauler is qualified to accept, measure, sample, collect, and transport farm bulk milk samples in such a manner that the results of one's activities are reliable, accurate, and equally fair to the producer and processor and (2) to help insure continued satisfactory performance by the hauler. Techniques and practices of milk haulers are regularly inspected or reviewed by state and/or federal inspectors or sanitarians.

A.3 Milk Hauler Responsibilities

Milk hauler/shippers conduct the following procedures at the farm:

A. Check the bulk tank milk for odor and appearance. Bulk milk is expected to be free from objectionable off-odor, exhibit no curdled appearance, no floating foreign material (i.e., sediment), and no separated milkfat particles.

B. Check bulk milk temperature. The thermometer must periodically be certified for accuracy, and the bulk milk must legally be $<7°C$ ($<45°F$) (some states are even more stringent).
C. Measure bulk milk volume. The milk hauler must turn off the tank agitator, make sure the milk is quiescent, ensure that there is no foam on the SS measuring stick, check that the "milk line" is straight across, and read the tank volume twice.
D. Then agitate the bulk milk tank contents for the specified or required minimum time (typically >5 min).
E. Meanwhile, connect the milk transfer hose.
F. Observe for possible sediment content within the bulk milk (and/or on the emptied tank walls and bottom surfaces).
G. Sample the bulk milk. An aliquot of the universal milk sample must be sent to an approved testing laboratory, generally within the state where the milk is collected (for analyses such as milkfat, bacterial standard plate count, and somatic cell count). Additional aliquots of the universal sample may also be analyzed at the processing plant (for milkfat, protein, titratable acidity, freezing point, *E. coli*/coliform, somatic cell count, standard plate count, laboratory pasteurization count, and/or heat resistant spore-forming psychrotrophs (baccilli), etc.).
H. Pump the bulk milk into the tanker.
I. Disconnect the transfer hose, and rinse the emptied bulk tank. J. Rinse the emptied bulk tank.

Regardless of who washes and sanitizes the truck and/or trailer tanks and accessories, the milk hauler is ultimately responsible for equipment cleanliness and sanitization. Generally, facilities for circulation cleaning (CIP) of the tanker and pump are available at the milk plant receiving stations of most milk plants. Many state regulatory agencies require that cleaned tankers be indicated with a designated or "official" tag to reflect the date, time, place, and the person responsible for overseeing or performing the milk tanker cleaning procedures.

A responsible milk hauler will not assume that automated washing (CIP) systems are foolproof. A hauler must check that (1) all ports are open on the spray ball or tube, (2) the CIP system cycles solutions correctly, (3) water rinse and detergent solutions are supplied properly, (4) appropriate temperatures are reached and maintained, (5) the "spray" solutions reach all critical or intended surfaces, and (6) that the tank interior and milk transfer equipment are actually "clean." Pump and valve parts that cannot be satisfactorily cleaned in-place (or cleaned out-of-place (COP)) must be cleaned manually (by hand). Stainless steel and other milk contact surfaces are usually considered clean when (1) rinse water slips (sheets) in a continuous layer from top to bottom of the surface and moisture droplets do not appear, (2) a "squeaky" noise results when clean, dry finger tips are pressed against the dry surface, and (3) the dry equipment surface is bright and shiny with no visible waterstone, milkstone, or blue discoloration. By contrast, when water drains by a pattern of distinct "patches" or random moisture droplets appear on the surface, it is most indicative of an unclean surface.

A.4 Required Equipment and Supplies

Any milk hauler must have the proper equipment and supplies to perform the stipulated requirements of milk sampling, transfer, and transport. This includes:

1. Tank truck with appropriate milk transfer equipment (pump) that complies with the official 3A Standards Committee guidelines and is properly cleaned and sanitized.
2. Appropriate sampling equipment and supplies: sample transfer device (e.g., dipper, sterile straws, etc.), sample containers (bags, bottles), sanitizing solution, and an insulated sample case with support racks.
3. An accurate (± 1.2°C [2°F]) non-breakable dial thermometer with a dial range of –4 to 54°C (25–125°F).
4. Refrigerant (ice) required to keep samples between 0 and 4.4°C (32–40°F).
5. Waterproof, indelible marking pen for helping identify samples.
6. A supply of milk weight receipt forms and a pen or pencil to record all required information (milk quantity, temperature, date, etc.).
7. A watch or other timing device, to insure minimum bulk milk agitation time.
8. Single-service paper towels and a bright flashlight are helpful items.
9. A stainless steel or plastic cup of about 60–120 mL (2–4 oz) capacity for tempering (warming to 32°C [90°F]) milk samples for more critically checking the odor of "suspicious" samples.

All milk contact surfaces of the tank truck and transfer equipment must be constructed of approved materials and be readily cleanable, in good condition, and accessible for inspection. The overall sanitary condition of the tank truck, milk contact equipment, and other items used by the milk hauler are subject to inspection by a milk sanitarian on a regular basis.

A.5 Milk Weights and Other Records

The milk hauler has the responsibility for maintaining an important written record of milk quantity, temperature observations, and other pertinent information with each bulk tank collection. Generally, the milk weight record (receipt) contains provisions for recording the following minimum information:

1. Date of collection
2. Time of pick-up
3. Producer name and/or number
4. Sensory quality (odor, appearance, etc.)

5. Milk temperature
6. "Dipstick" or gauge reading
7. Converted milk weight (lb)
8. Name of milk buyer
9. Hauler's signature (and license number)
10. Specific reason(s) for milk rejection (if rejected)

A.6 Milk Grading

In most state jurisdictions of the U.S., the milk hauler is required to grade each collection (pick-up) of Grade "A" fluid milk with respect to its "sensory quality," within his or her capacity as a licensed milk grader. If a given collection (lot) of milk is determined by the hauler/grader to be "unacceptable," and thus rejected as being unsuitable for Grade "A" milk use, a designated record form must be completed by the grader (hauler). This official "rejection" form usually identifies (1) the producer (by name and/or number), (2) the usual milk marketing agent (cooperative, if appropriate), (3) the date and time, (4) the quantity of milk, and (5) the cause or reasons for rejection as Grade A milk (U.S. FDA, 1999, 2003 and NARA 2007).

As a rule, licensed milk haulers and graders are expected to be somewhat familiar or acquainted with some of the following criteria for the effective determination of milk quality:

1. The official regulatory agency "sampling" and "compliance" periods for Grade "A" raw milk.
2. Abnormal milk standards (maximum somatic cell count per milliliter).
3. General methods of examining milk for abnormal composition.
4. Sediment testing procedures and official sediment standards.
5. Test alternatives for bacterial inhibitors (i.e., antibiotics and sanitizers).
6. Bacterial standards for Grade "A" raw milk for pasteurization (for both the farm level and commingled milk supplies).
7. Bactericidal treatment (sanitization) of sampling equipment.
8. Importance of personal cleanliness and health practices in performance of tasks and duties as a milk sampler/grader.
9. The general technical, human safety, and sanitation requirements for milk tanker loading and unloading.
10. Application of aseptic technique in the collection of "official" milk ("universal") samples.
11. The purpose or intent of various milk quality tests that the cooperative marketing agency and/or processor may have implemented for specific milk quality incentive (bonus) payment (or penalty) programs.
12. A need to exhibit knowledge of and the ability to comply with ongoing changes and interpretations of applicable laws and regulations.

A.7 Pasteurized Milk Ordinance

Grade "A" products are manufactured on farms and in plants following Grade "A" standards outlined in the FDA/USPHS Pasteurized Milk Ordinance (PMO). The PMO is "an ordinance to regulate the production, transportation, processing, handling, sampling, examination, labeling, and sale of Grade 'A' milk and milk products; the inspection of dairy farms, milk plants, receiving stations, transfer stations, milk tank truck cleaning facilities, milk tank trucks and bulk milk hauler/samplers; the issuing and revocation of permits to milk producers, bulk milk hauler/samplers, milk tank trucks, milk transportation companies, milk plants, receiving stations, transfer stations, milk tank truck cleaning facilities, haulers, and distributors; and the fixing of penalties (U.S. FDA 2003)."

A summary of some of the sections of the PMO, those directly related to milk quality, are included here. Section 1, "Definitions," includes very basic and clear legal dairy definitions. Section 2, "Adulterated or Misbranded Milk or Milk Products," includes a clear statement that nobody shall sell adulterated or misbranded milk or milk products. Section 3, "Permits," states that if one wishes to sell Grade "A" milk or milk products, a permit must be held (including producers, distributors, bulk milk hauler/samplers, milk tank trucks, milk plants, receiving stations, etc.). Section 4, "Labeling," states that all labeling shall be in accordance with the Federal Food, Drug and Cosmetic Act as amended by the Nutrition Labeling and Education Act of 1990.

Section 5, "Inspection of Dairy Farms and Milk Plants," outlines that all dairy farms, milk plants, receiving stations, milk tank truck cleaning facilities, transfer stations, etc. where milk or milk product are intended for consumption must be inspected according to the following schedule:

- prior to issuance of a permit
- hauler/sampler techniques are inspected every 24 months
- milk tank truck/hauler are inspected every 12 months
- tank truck cleaning and transfer stations are inspected every 6 months
- dairy farms are inspected every 6 months
- milk plants and receiving stations are inspected every 3 months

Section 6, "The Examination of Milk and Milk Products," outlines when and how examination of milk and milk products should take place. The reader is encouraged to either acquire a copy or become familiar with the 17th Edition of *Standard Methods for the Examination of Dairy Products* (Wehr and Frank 2004).

Section 7, "Standards for Grade'A' Milk and Milk Products," details how all Grade "A" raw milk for pasteurization, ultra-pasteurization or aseptic processing and all Grade "A" pasteurized, ultra-pasteurized or aseptically processed milk and milk products shall be produced, processed to conform with the chemical, bacteriological and temperature standards, and sanitation requirements of this section.

The remainder of the PMO is related to issues indirectly related to milk quality and thus are not summarized here.

A.8 Processing Plant Procedures

Once milk gets to the milk plant (dairy processing facility), several tests are required by the PMO to assure food safety and wholesomeness of milk. A test conducted at the facility that is required, but not directly related to milk sensory quality, is drug residue (antibiotics) testing. Assessments directly or indirectly related to milk quality include titratable acidity, acid degree value, microbiological (total aerobic count and coliform count), and somatic cell counts (Table A.1).

Table A.1 Chemical, physical, bacteriological, and temperature standards for grade "A" milk and milk products

	Grade "A" raw milk and milk products for pasteurization, ultra-pasteurization or aseptic processing
Temperature	Cooled to 10°C (50°F) or less within 4 h or less of the commencement of the first milking, and to 7°C (45°F) or less within 2 h after the completion of milking. Provided that the blend temperature after the first milking and subsequent milkings does not exceed 10°C (50°F)
Bacterial limits	Individual producer milk not to exceed 100,000/mL prior to commingling with other producer milk. Not to exceed 300,000/mL as commingled milk prior to pasteurization
Drugs	No positive results on drug residue detection methods as referenced in Section 6 – Laboratory Techniques
Somatic cell count*	Individual producer milk not to exceed 750,000/mL
	Grade "A" pasteurized milk and milk products and bulk shipped heat-treated milk products
Temperature	Cooled to 7°C (45°F) or less and maintained thereat
Bacterial Limits**	20,000/mL, or g***
Coliform[#]	Not to exceed 10/mL. Provided that in the case of bulk milk transport, tank shipments shall not exceed 100/ mL
Phosphatase[##]	Less than 350 milliunits/L for fluid products and other milk products by the fluorometer or Charm ALP or equivalent
Drugs**	No positive results on drug residue detection methods as referenced in Section 6 – Laboratory Techniques which have been found to be acceptable for use with pasteurized and heat-treated milk and milk products
	Grade "A" pasteurized concentrated (condensed) milk and milk products
Temperature	Cooled to 7°C (45°F) or less and maintained thereat unless drying is commenced immediately after condensing
Bacterial limits	Refer to 21 CFR 113. 3(e)(1)[###]

Table A.1 (continued)

Coliform	Not to exceed 10/mL. Provided that in the case of bulk milk transport, tank shipments shall not exceed 100/mL
Drugs**	No positive results on drug residue detection methods as referenced in Section 6 – Laboratory Techniques that have been found to be acceptable for use with aseptically processed milk and milk products
	Grade “A” aseptically processed milk and milk products
Temperature	None
Bacterial limits	Refer to 21 CFR 113. 3(e)(1)[###]
Drugs**	No positive results on drug residue detection methods as referenced in Section 6 – Laboratory Techniques that have been found to be acceptable for use with aseptically processed milk and milk products
	Grade “A” Nonfat Dry Milk (maximum values)
Butterfat	1.25%
Moisture	4.00%
Titratable acidity	0.15%
Solubility index	1.25 mL
Bacterial estimate	30,000/g
Coliform	10/g
Scorched particles disc B	15.0/g
	Grade “A” whey for condensing
Temperature	Maintained at a temperature of 45°F (7°C) or less, or 63°C (145°F) or greater, except for acid-type whey with a titratable acidity of 0.40% or above, or a pH of 4.6 or below
	Grade “A” condensed whey and whey products
Temperature	Cooled to 7°C (45°F) or less during crystallization, within 48 h of condensing
Coliform	Not to exceed 10/g
	Grade “A” dry whey, Grade “A” dry whey products, Grade “A” dry buttermilk, and Grade “A” dry buttermilk products
Coliform	Not to exceed 10/g

*Goat milk 1,000,000/mL.
**Not applicable to acidified or cultured products.
***Results of the analysis of dairy products which are weighed in order to be analyzed will be reported in # per gram (refer to the current edition of the SMEDP).
[#]Not applicable to bulk shipped heat-treated milk products.
[##]Not applicable to bulk shipped heat-treated milk products; UP products that have been thermally processed at or above 138°C (280°F) for at least 2 s to produce a product which has an extended shelf life (ESL) under refrigerated conditions, and condensed products.
[###] 21 CFR 113.3(e)(1) contains the definition of “commercial sterility.”

Somatic cell counts are required on bulk milk. High somatic cell counts can be an indication of mastitis; wherein Lymphocytes, neutrophils, and epithelial cells increase, and blood plasma enzymes such as plasmin enter the milk. Plasmin breaks down casein and thus less is available for cheese curd, which leads to reduced cheese yield and quality. Low somatic cell count (<750,000 sec/mL) is required for milk acceptance. Titratable Acidity (TA) is an optional test conducted at the processing plant. A lactic acid measurement of 0.12–0.17% is desirable. Acid Degree Value (ADV) is an optional lab test conducted to indicate the activity of lipase and accumulation of free fatty acids. High values indicate rancidity (can be noted by average consumer). High values are a result of fat globule membrane breakage, free fatty acids release due to excessive agitation or freezing of milk, temperature cycling or freezing of milk. Normal milk levels are 0.25–0.40 mg KOH/g fat; and <1.0 mg KOH/g fat are desirable.

References

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Wehr, H.M. and J.F. Frank. 2004. *Standard Methods for the Examination of Dairy Products*, 17th Edition. American Public Health Association, Washington, DC. 570p.

Appendix B
Milk Flavor Quality Training Exercise (or Clinic) for Bulk Milk Haulers and Dairy Field Services Personnel

B.1 Objectives

This milk flavor quality assessment exercise (or clinic) is conducted in a manner that attempts to reflect the "type of decision-making that personnel must make" at the point and time of bulk tank milk collection. Training, experience, and good judgment, plus some "practice" on the part of licensed milk haulers, appropriate supervisors, and dairy field staff personnel help lead to the best and most *reliable milk quality acceptance/rejection decisions* for assurance of high-quality milk from the farm and therefore for dairy products manu facturing (Bodyfelt et al. 1988).

B.2 Clinic Procedure

In an appropriate training/tasting location, 10 prepared, pasteurized milk samples are presented for testing each clinic participant's ability to grade for flavor quality (i.e., odor and/or taste). For each of the 10 samples, the participant has one of three choices to determine:

1. In your judgment, if the given no. ___ sample exhibits *no off-flavor* (no objectionable off-taste), then place an _X_ mark in the ACCEPT column opposite the sample no.
2. If you have some reservation or *doubt about the flavor quality* of the given sample, then place an X_ mark in the QUESTIONABLE QUALITY column.
3. Without any doubt in judgment, you determine that the given milk sample is *unacceptable in flavor* on the basis of an objectionable off-odor and/or off-taste – so indicate by marking with an X_ mark in the REJECT column.

A blank form and an example of a completed form are included in Tables B.1 and B.2.

Table B.1 A blank Practical Milk Flavor Training Exercise Form. Place an X_ mark in only one column per sample

Sample No.	ACCEPT	QUESTIONABLE QUALITY	REJECT	Name the Flavor Defect (Optional)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Table B.2 An example of a completed Practical Milk Flavor Training Exercise Form. Place an X_ mark in only one column per sample

Sample No.	ACCEPT	QUESTIONABLE QUALITY	REJECT	Name the Flavor Defect (Optional)
1.	X			Slight alfalfa feed
2.			X	***Acid (sour)***
3.		X		Strong feed flavor
4.	X			None
5.	X			Very slight grass silage
6.			X	***Definite rancid***
7.	X			Sweet, clean, pleasant
8.		X		Slight lacks freshness
9.	X			Possibly slight flat
10.			X	***Metallic oxidized***

Reference

Bodyfelt, F.W., Tobias, J. and Trout, G.M. 1988. Appendices I. In: *The Sensory Evaluation of Dairy Products*. Van Nostrand Reinhold, New York. pp. 532–533.

Appendix C
Measurement of Hydrolytic Rancidity in Milk

C.1 Hydrolytic Rancidity Test (Acid Degree Value [Thomas et al. 1955])

C.1.1 Apparatus and Reagents

1. Centrifuge – Babcock centrifuge that will receive an 18 g, 8% milk test bottle may be used. An unheated centrifuge is satisfactory.
2. Boiling water bath – Water in the bath should be at a depth sufficient to cover the base of the test bottles.
3. Tempering bath – This should be controlled to within a temperature range of 54–60°C (129–140°F).
4. Glassware – The glassware required consists of the following: a standard 18 g, 8% milk test bottle; a 1 mL tuberculin-type syringe with a No. 19 needle; a 50 mL graduated syringe with a No. 15 needle or a standard 17.6 mL milk pipette; a 50 mL Erlenmeyer flask; and a 5 mL microburette.
5. BDI Reagent (Bureau of Dairy Industry Reagent) – Thirty grams of Triton X100 (a nonionic surface-active agent manufactured by Rohm and Haas Co., Philadelphia, PA) and 70 g of sodium tetraphosphate are made up to a 1 L with distilled water. This reagent is used since it will not change the physical or chemical properties of the milkfat; also it quickly and effectively de-emulsifies milkfat.
6. Alcoholic KOH – To 50 g of KOH add 50 mL of distilled water (50% KOH solution) and swirl until completely dissolved. Next, mix 1.08 mL of 50% KOH into 500 mL of ethanol and standardize to a 0.02 N alcoholic KOH solution. This solution should be standardized frequently against standard potassium acid phthalate (or other suitable standards).
7. Indicator solution – Prepared by dissolving 1 g of phenolphthalein in 100 mL of absolute ethanol.
8. Absolute ethanol.
9. Petroleum ether – Boiling point range 30–60°C (86–140°F).
10. 50% aqueous methanol – This reagent consists of equal volumes of chemically pure methanol and distilled water.

C.1.2 Recovery of the Fat

1. Place 35 mL of the milk sample in an 18 g, 8% milk test bottle. The milk may be transferred to the bottle by either a 50 mL syringe or a standard 17.6 mL milk pipette.
2. Next, add 10 mL of BDI reagent to the milk sample and mix thoroughly. (It is important to use only 10 mL of BDI reagent in the 35 mL of whole milk, since the acid degree value of the sample could decrease with an increased amount of reagent.)
3. Place the bottle and contents into a gently boiling water bath. Agitate the bottle contents thoroughly, after 5 min and again after 10 min in the water bath.
4. After 15 min in the boiling water bath, centrifuge the bottles for 1 min. Sufficient 50% aqueous methanol is then added to bring the top of the fat column to the 6% graduation. Centrifuge for an additional 1 min.
5. Place sample bottles in the tempering bath (54-60°C (129-140°F)) for 5 min. The water level should be equivalent to the height of the fat column.

C.1.3 Titration

1. Transfer 1 mL of the tempered milkfat from the test bottle into a 50 mL Erlenmeyer flask (by use of a 1 mL syringe and a No. 19 needle). Note: It is preferable to weigh 1 g of milkfat into the flask by use of an appropriate top-loading balance.
2. Dissolve the extracted fat by the addition of 10 mL of petroleum ether and 5 mL absolute ethanol into the flask. Add 10 drops of indicator solution.
3. Titrate to the first definite color change with the standardized alcoholic KOH solution (0.02 N) by use of a 5 mL microburette.
4. Express results in terms of acid degree value (ADV). The ADV is equivalent to the number of milliliters of 1 N base required to titrate 100 g of fat.

C.1.4 Calculations

1. If milkfat was measured volumetrically (pipetted), determine the actual grams of milkfat in the sample titrated by multiplying the milliliter of milkfat by the specific gravity of tempered milkfat (0.90):

$$(\text{mL milkfat} \times 0.90 = \text{g of milkfat})$$

2. Calculate the ADV as follows:

$$\frac{\text{mL of KOH used in titration} - \text{mL used in titrating "blank"} \times \text{NF} \times 100}{\text{Wt. (g) of milkfat from sample}} = \text{ADV}$$

NF = normality factor of the alcoholic KOH solution.
"Blank" = the titration value of the fat solvent (in the absence of fat and by use of five drops of phenolphthalein indicator). "Blank" determinations should be run on each new batch of solvent, and then retitrated at frequent intervals thereafter.
Example
Assume that 0.75 mL of milkfat required 0.70 mL of alcoholic KOH (normality factor of 0.0203) and that the blank titration value = 0.03, then

$$\frac{(0.70 - 0.03) \times 0.0203 \times 100}{0.75 \times 0.90} = \frac{0.67 \times 0.0203 \times 100}{0.675} = \frac{1.36}{0.675} = 2.014 = \text{ADV}$$

The ADV should be expressed only to the second decimal place (e.g., ADV = 2.01 for above example).

C.1.5 Interpretation of ADV Results

Milk drawn freshly from "normal" or typical cows should exhibit ADV's ranging from 0.2 to 0.5. Commonly, hydrolytic rancidity may be detected by experienced judges when the ADV equals 1.3–1.6. Consumer complaints are likely to develop (about milk off-flavor) when ADV results in the region of 2.0 or higher.

When ADVs of producer milk samples approach 0.8–1.0 (or higher), there is justification for investigation of the conditions related to the harvesting, handling, and transporting the milk. Although it is quite unlikely that hydrolytic rancidity will be detected by sensory procedures at this ADV level, the milk in all likelihood is approaching the "threshold of trouble."Any abusive or "triggering" conditions of milk handling should be identified, minimized, or eliminated.

Lipase activation is favored by any milk-handling conditions that produce foam (when milk is within a temperature range of 27–32°C (80–90°F)).

C.2 Modified Copper Soap Solvent Method (CSM [Shipe et al. 1980])

C.2.1 Reagents

1. Copper reagent – consists of a mixture of 5 mL triethanolamine and 10 mL 1 M aqueous $Cu(NO_3)_2 \cdot 3\,H_2O$, diluted to 100 mL with a saturated NaCl solution. The pH should be adjusted to 8.3 with 1 N NaOH. This mixture needs to be stored in the dark at room temperature. Expected stability is about 5 months.

2. Color reagent – a 5% sodium diethyl dithiol-carbamate solution in *n*-butanol.
3. Solvent – chloroform:heptane:methanol (49:49:2).
4. Solubilizing reagent – ethylene diamine tetra acetate (EDTA), disodium salt, 8% wt/vol in distilled water.

C.2.2 Procedure

1. A 0.1 mL aliquot of 0.7 N HCl is added to 0.5 mL of milk sample in a 16 × 125 mm test tube. This mixture is shaken on a vortex test tube mixer.
2. Then 2 mL of the copper reagent and 6 mL of the solvent are added.
3. The sample and reagents are shaken for 30 min in a rotary Eberbach (or equivalent) shaker at 240 rpm.
4. Next, sample tubes are centrifuged for 10 min at 1940 × g in an International Model HN centrifuge (or equivalent).
5. Then 3.5 mL of the solvent layer are transferred to an acid-washed test tube that contains 0.1 mL of the color reagent.
6. Color development is measured at 440 mμ within 1 h (after mixing tube contents).
7. Any type of spectrophotometer may be used (e.g., Bausch and Lomb Spectronic, 20,400-3 system, etc.).
8. Results are reported in terms of the absorbance or the concentration of free fatty acids expressed as meq/L of milk. Development of a standard curve based on palmitic acid is suggested for converting absorbance to meq FFA/L of milk.

References

Shipe, W.F., Senyk, G.F., and Fountain, K.B. 1980. Modified copper soap solvent extraction method for measuring free fatty acids in milk. J. Dairy Sci. 63:193.

Thomas, E.L., Nelson A.J., and Olson, J.C., Jr. 1955. Hydrolytic rancidity – A simplified method for estimating the extent of its development. Am. Milk Rev. 77(1):50.

Appendix D
Measurement of the Autoxidation of Milkfat

D.1 The Thiobarbituric Acid (TBA) Test (Dunkley and Jennings 1951)

D.1.1 Reagents

1. Trichloroacetic acid (TCA) solution is prepared by adding 1 g TCA to each 1 mL distilled water.
2. 95% ethanol (in distilled water).
3. TBA solution prepared by dissolving 1.4 g 2-thiobarbituric acid in 95% ethanol and taking to 100 mL volume. Facilitate solubilization of the TBA by heating in a 60°C (140°F) water bath.

Note: TBA solution undergoes deterioration easily; hence, it should not be stored longer than 3 days prior to use.

D.1.2 Procedure

1. Pipet 17.6 mL of a milk sample into a small flask fitted with a glass stopper.
2. Warm flask contents to 30°C (86°F).
3. Add 1.0 mL trichloroacetic (TCA) solution.
4. Add 2.0 mL 95% ethanol.
5. Stopper the flask and shake contents vigorously for 10 s.
6. After 5 min, filter the flask contents through no. 42 Whatman paper.
7. To 4.0 mL of clear filtrate, add 1.0 mL of TBA solution into another flask.
8. Stopper the flask, mix contents, and place into a 60°C (140°F) water bath for 60 min.
9. Cool to room temperature.
10. Determine optical density at 532 mμ (Beckman DU spectrophotometer preferred), using distilled water as a reference (blank).

Table D.1 Relationship between sensory evaluation and intensity of oxidized off-flavor and optical density readings of milk

Flavor score	Flavor description	Range of optical density (532 mμ)
0	No oxidized off-flavor	0.010–0.023
1	Questionable to slight oxidized	0.024–0.029
2	Slight but consistently detectable	0.030–0.040
3	Distinct or strong oxidized	0.041–0.055
4	Very strong oxidized	$\geq$ 0.056

Notes:
1. Strongly oxidized milk will generally yield an optical density in the range of 0.06–0.10.
2. Multiple determinations of a given sample are often reproducible within ± 0.003 optical density units.
3. Contamination of milk samples with copper up to about 0.5 ppm does not affect TBA test results (King and Dunkley 1959).
4. The TBA test may have some value for monitoring the extent of a light-activated off-flavor of milk.

D.1.3 Interpretation

King (1962) observed a direct relationship between sensory evaluation of the intensity of an oxidized off-flavor and optical density readings of milk filtrates (Table D.1). The TBA test may also be used to monitor the effect of oxygen content of milk over increasing storage time and varied oxygen content with respect to oxidized off-flavor (Schroder 1982).

References

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Appendix E
Copper Sensitivity Test for Assessment of Milk Susceptibility to Autoxidation (Bodyfelt et al. 1988)

E.1 Procedure for Detecting Milk Susceptible to an Oxidized Off-Flavor (MIF 1967)

1. Prepare a 0.01 molar solution of copper sulfate by dissolving 2.496 g of $CuSO_4$ 5 H_2O in 1000 mL of distilled water. Each 0.1 mL of this solution, when added to 10 mL of milk, is equivalent to 0.1 ppm of copper.
2. Prepare a series of four tubes, each containing 10 mL of the milk to be tested, and add 0, 0.2, 0.5, and 1.0 mL of the 0.01 molar $CuSO_4$ solution.
3. Shake and hold overnight at 10°C (50°F) and taste (or smell) for the characteristic flavor. Heat the milk to 71°C (160°F) and cool just before tasting to protect the taster (from the health risks of raw milk).

E.2 Interpretation

1. If any of the first three test tubes in the test series shows an oxidized off-flavor, it is unlikely that such milk can proceed through processing without picking up sufficient additional copper to cause an off-flavor (e.g., this milk is susceptible to the development of an oxidized off-flavor).
2. If only the last (1.0 mL) tube in the series exhibits the off-flavor, the given milk is on the "threshold" and may present quality problems, depending on how much has been undertaken to eliminate copper from all equipment.
3. If none of the test tubes shows the off-flavor, in all likelihood the milk may be processed without difficulty, assuming that there is little or no copper contamination.
4. If any final products from the plant exhibit a copper-induced oxidized off-flavor (even though the raw milk supply shows no off-flavor when the maximum amount of copper was added (1.0 ppm)), attention must be given to finding and eliminating any copper exposure in the processing plant.
5. If off-flavors are found in the raw milk supply, apply the copper sensitivity test to milk from individual herds to identify specific troublesome sources. When the herd (or herds) are identified, check farm conditions with particular attention to the following: any equipment with potential sources of

copper, iron, or manganese; pipe lines of milker units for air leaks; and note the operating temperature and the recovery rate of the bulk tank. Especially look for the presence of any copper tubing in hot water lines, heating (or heat recovery) coils, or white (monel metal) fittings within CIP cleaning systems.

References

Bodyfelt, F.W. 1988. Appendices. In *The Sensory Evaluation of Dairy Products*. Bodyfelt, F.W. Tobias, J. and Trout, G.M. Van Nostrand Reinhold, New York. pp. 540–541.

Milk Industry Foundation (MIF). 1967. *Milk Plant Operators Manual*. Washington, DC. p. 900.

Appendix F
Preparation of Samples for Instructing Students and Staff in Dairy Products Evaluation

Michael Costello and Stephanie Clark

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.

F.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 manufacturing 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 USDA 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).

The instructor may find it useful to adulterate milk samples to the intensity level of "pronounced" (Table F.1) for the introductory student, and then reduce this concentration once the student's palate has been trained to identify the given attribute.

Table F.1 Milk attribute recipes (per ~600mL)

Off-flavor	Procedure for producing the sought off-flavor
Acid (sour)	Add about 2% volume of cultured buttermilk to fresh milk. However, the student may find the diacetyl that is present in most buttermilk confusing. Alternatively, add 6–7 mL of a 10% lactic acid solution to the milk.
Bitter	Add 2–2.5 mL of a 0.1% quinine sulfate solution to ~600 mL of milk, which will yield milk with a bitter off-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 custard-like 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 in water) to 600 mL of milk will impart a pronounced feed flavor upon the milk. An expanded intensity range is a result of variability in the strength quantity of the tea.
Flat	Add about 20% water to 2% milk.
Foreign/ chemical	Add about 2 mL of a 200 ppm chlorine solution to 600 mL of milk immediately before presenting to the student. This off-flavor does not remain "stable," so it cannot be prepared ahead of time.
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 to 600 mL of milk to yield a pronounced defect. Alternatively, add 1 mL of a 1% stock solution of food grade ethyl hexanoate to 600 mL of milk.
Garlic/onion	Add 2 mL of a 1% garlic powder mix (in water) to the milk. Alternatively, add a clove of garlic to infuse for about 2 h; then either decant the milk or retrieve the clove.
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. Also, the lacks freshness attribute may be approximated by adding 10–15 g of skim milk powder to 600 mL of milk.
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 will quickly produce light-oxidized milk. Alternatively, 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) 5–7 min = slight intensity; (2) 9–10 min = definite, and (3) 13–15 min = pronounced.
Malty	Add 1 g of malt powder to warm milk and swirl until thoroughly dissolved. Add this mixture to fresh milk so that the final concentration is about 1 g of malt powder per liter. Alternatively, 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 ~ 600 mL quantity of a base milk for producing a range of intensities (i.e., slight, definite, and pronounced) of simulated "malty" milk.
Metal oxidized	Immerse a copper penny or a copper wire in milk overnight. Alternatively, 24 h before use, add one or two drops of a 1% solution of copper sulfate to 600 mL of milk and leave in a refrigerator. This attribute takes about 8 h to develop.

Table F.1 (continued)

Rancid	Add 0.5 g of lipase powder to ~600 mL of milk, agitate and hold at 21°C (70°F) for an hour. Alternatively, 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 ~600 mL milk base.
Salty	Dissolve 0.25–0.5 g of table salt into 600 mL of milk.
Unclean (spoiled)	One alternative is to combine rancid, fruity, and bitter milks. By using lipase to produce rancid milk may yield the unclean (or spoiled) defect as well. Most commercial milks will eventually become naturally "spoiled" or unclean (≥7–10 days beyond 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.

F.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 ice cream's coldness 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, the instructor may find that introducing flavor attributes to students by means of using unfrozen ice cream mix is most helpful (Table F.2). The basic mix described just below should provide a suitable foundation for highlighting or focusing on flavor attributes.

Basic mix recipe: 12% fat mix, with 10% sugar, and 4% high fructose corn syrup.

Combine 620 mL whole milk, 180 mL 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, mix 800 mL light cream with 60 g of sugar, 25 g CSS or 25 mL HFCS and 0.5 mL 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.

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 texture. However, a simpler approach for maintaining anonymity is to pre-dip the ice creams from the original containers onto

Table F.2 Recipes for off-flavors in ice cream mix

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 if any particles or chunks result.
High flavor	Add 1 mL vanilla extract to 200 mL of basic mix.
High sweetness	Add 5 g of sugar to 200 mL of basic mix.
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" 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 deteriorates with age; thus the maturity 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	The metal oxidized variant is called for, so utilize metal oxidized milk or cream as the base.
Salty	Add 1 g of table salt to 200 mL basic mix.
Syrup flavor	Add 5 g of HFCS to 200 mL basic mix.
Whey	Add 10 g of whey powder to 200 mL basic mix.

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 sensitive, original ice cream samples.

F.3 Butter

As previously noted in Chapter 6, buttermaking 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 (Table F.3) stock butters purchased directly from either butter manufacturers or retails sources.

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 counter top

Table F.3 Recipes for off-flavors in butter

Off-flavor	Procedure for producing off 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 aside an agar slant of the yeast microorganism *Streptomyces odorifer*.
Oxidized	Store in a refrigerator aliquot sticks of butter lightly wrapped in paper, ranging from 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 Romano or blue cheese.
Storage	Select grocery store "house brand" butters to either refrigerate for 4–6 months or frozen for 8–12+ months, and then examine for a range of storage-like flavors. Alternatively, identify a rarely cleaned refrigerator and store the butter in it for a few weeks until enough of the aroma has penetrated to emulate this butter off-flavor.
Whey	"Whey butter" may not often be available in may parts of the U.S. or Canada under that label. However, it can occasionally be found in specialty food stores or even in neighborhood grocery stores, possibly labeled as either "Old Fashioned" or "Irish style" butter.

kitchen mixer. Similarly, acid, bitter, feed, scorched (cooked), etc. "defects," may be produced by adulterating the cream as described above for either milk or ice cream and churning that cream into butter.

F.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 USDA 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 F.4).

Regarding the appearance, color, and/or body and texture attributes of creamed cottage cheese, most of them can be observed in commercial products.

The appearance attributes "free whey" and "free cream" are easily produced within the laboratory if not readily found in commercial products. Free cream may be replicated by simply spooning enough cream onto the curd on the plate to create a so-called cream halo.

Table F.4 Recipes for off-flavors in cottage cheese

Off-flavor	Procedure for producing the off-flavor
Bitter	Add 2–3 mL 0.1% quinine sulfate to a pint of cottage cheese to yield a pronounced bitter flavor.
Cooked	Heat ingredients to be used for dressing to 80°C (176°F) for 15 min in a double boiler.
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. One may also 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 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 fatal 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 to react at room temperature for an hour or in the refrigerator for 24–48 h. Alternatively, for "last minute preparation," finely ground Romano 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.

The free whey defect can be simulated by removing enough cottage cheese from the container that a moderate well is formed. The container with then 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. F.1).

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. F.2).

Fig. F.1 Creating an observation plate of cottage cheese that exhibits "free whey"

Fig. F.2 Cottage cheese prepared for tasting by transfer to a secondary container

F.5 Yogurt

Unless you have the facilities and are comfortable with your yogurt making skills, you will be best served by surveying the yogurts available in your area, and identifying those with distinct and repeatable sensory attributes.

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 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. F.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

Fig. F.3 Yogurt placed inside taped container to conceal brand

Fig. F.4 Preparing yogurt for visual evaluation on the plate

plate without breaking the curd (Fig. F.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.

F.6 Cheddar Cheese

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 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.

References

Rosenberg, M., Tong, P.S., Sulzer, G., Gendre, S., and Ferris, D. 1994. California cottage cheese technology and product quality: An in-plant survey. 1. Manufacturing process. Cult. Dairy Prod. J. 29(1):4–12.

Appendix G
Names and Addresses of Organizations and Useful Websites

The following names and addresses and websites are included to enable the reader to quickly access organizations that are involved in assessing, regulating, or promoting dairy products.

Agricultural Marketing Service (AMS)
http://www.ams.usda.gov/

American Dairy Science Association
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
http://www.sfsan.fda.gov/list.htmL

Centers for Disease Control and Prevention (CDC)
1600 Clifton Road
Atlanta, GA 30333
1-800-311-3435
http://www.cdc.gov/

Code of Federal Regulations (CFR)
http://www.access.gpo.gov/cgi-bin/cfrassemble.cgi?title=200021

Collegiate Dairy Products Evaluation Contest
http://ams.usda.gov/dairy/cdpec/coach_corner.htm

Department of Health and Human Services (HHS)
200 Independence Avenue, S.W.
Washington, DC 20201
http://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
http://www.ift.org/cms/

International Dairy Foods Association (IDFA)
1250 H Street, N.W., Suite 900
Washington, DC 20005
202-737-4332
http://www.idfa.org/index.cfm

National Conference on Interstate Milk Shipments
123 Buena Vista Drive
Frankfort, KY 40601
502-695-0253
http://www.ncims.org/index.htm

National Dairy Council
http://www.nationaldairycouncil.org/nationaldairycouncil/sitemap

Pasteurized Milk Ordinance (PMO)
http://www.cfsan.fda.gov/~ear/pmo03toc.htmL

U.S. Food and Drug Administration (FDA)
5600 Fishers Lane
Rockville, MD 20857-0001
1-800-463-6332
http://www.fda.gov/

U.S. Public Health Service (PHS)
http://www.phs.gov/

Index