Chapter 5
Fluid Milk Products

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5.1 Introduction

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

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

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

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

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

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

5.2 Milk Properties and Handling

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

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

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

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

5.3 Market Milk

5.3.1 Classes of Milk

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

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

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

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

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

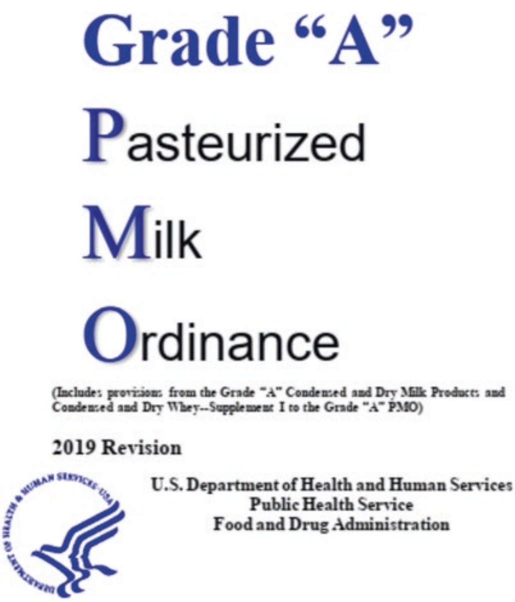

Grade "A"
Pasteurized
Milk
Ordinance
(Includes provisions from the Grade "A" Condensed and Dry Milk Products and Condensed and Dry Whey--Supplement I to the Grade "A" PMO)
2019 Revision
U.S. Department of Health and Human Services
Public Health Service
Food and Drug Administration

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

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

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

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

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

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

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

5.3.2 Grades of Market Milk

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

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

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

5.3.3 Raw Milk

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

5.3.4 Pasteurized Milk

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

5.4 Kinds of Market Milk and Associated Quality Characteristics

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

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

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

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

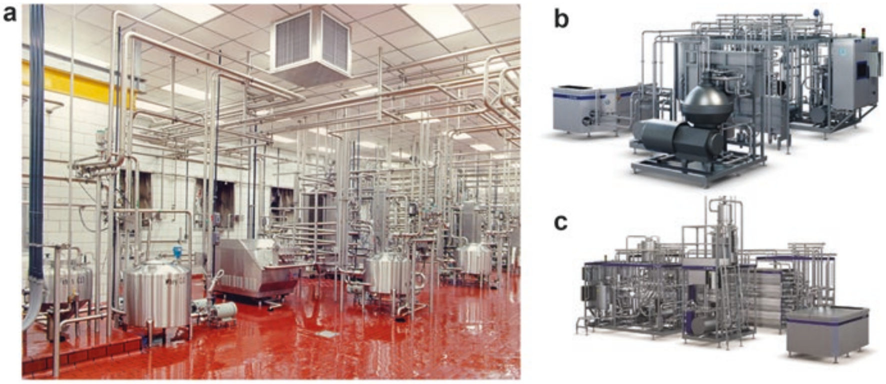
[*]If the milkfat content is 10% or more, or if it contains added sweeteners, the specified temperature shall be increased by 3 °C (5 °F), provided that eggnog shall be heated to at least the following temperature and time combinations:

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.5 Precautions for Evaluating Raw Milk

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

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

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

5.6 The Milk Scorecard

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

Table 5.1 A suggested scoring guide for sediment in processed milk

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

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

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

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

5.7 Some Milk Scoring Techniques

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

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

Sample Score Cards
National FFA Dairy Foods Career Development Event

Form I

Name ______________________
ID Number ______________________

Chapter ______________________
State ______________________

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

Milk Flavor Evaluation

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

California Mastitis Test (CMT)

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

Milk Sediment

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

Problem Solving **Total Score**

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

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

Milk

SAMPLE 1

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

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

SAMPLE 2

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

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

SAMPLE 3

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

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

SAMPLE 4

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

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

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

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

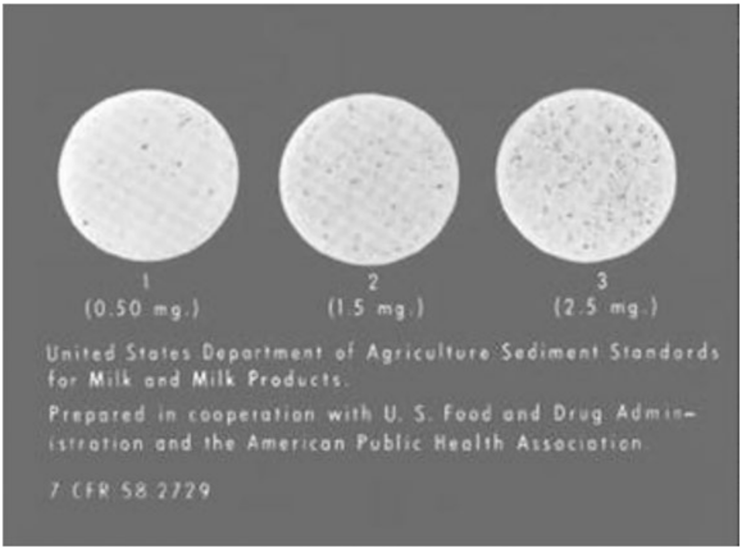


Fig. 5.5 Standard discs that represent known weights of sediment for a given volume of tempered milk sample (one pint)

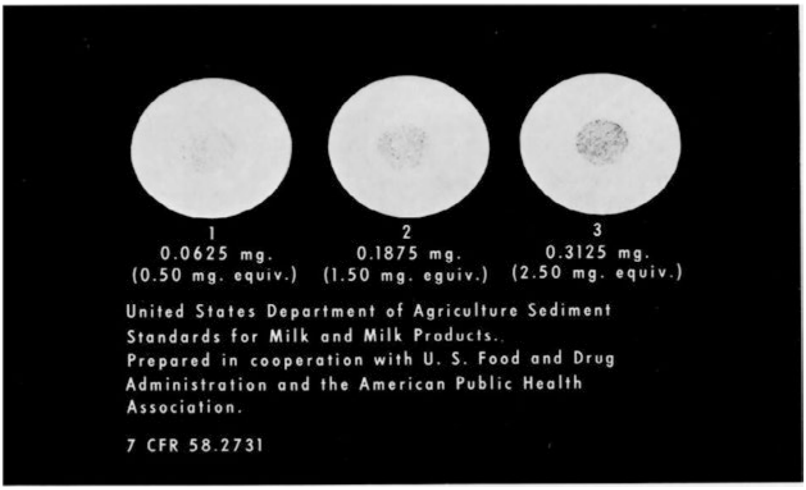


Fig. 5.6 A small grouping of sediment discs that demonstrate various weights of extraneous material per pint of milk

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

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

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

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

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

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

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

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

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

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

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

5.8 Requirements of High-Quality Fluid Milk

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

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

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

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

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

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

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

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

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

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

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

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

Table 5.2 A suggested scoring guide for bacteria in milk

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A B C

Xsense® Control Unit Transmission Tag Display Report

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

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

5.9 Evaluating Milk Flavor

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

From: Hedrick (1955)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 5.8 Distinguishing characteristics of milk off-flavors by category

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

From: Bodyfelt et al. (1988)

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

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

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

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

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

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

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

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

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

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

5.11 Chocolate Milk

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

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

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

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

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

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

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

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

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

5.12 Cultured Fluid Dairy Products

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

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

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

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

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

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

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

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

5.13 Other Uncultured Fluid Dairy Products

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.14 Conclusion

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

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