Chapter 11
Concentrated and Dried Milk Products

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11.1 Introduction

The common characteristic of various types of concentrated milk products is the reduced water content. Generally, water is removed as vapor under reduced pressure (a partial vacuum) at relatively low product temperatures (in the approximate range of 43–80 °C [110–176 °F]). Other nonthermal technologies, such as those involving membrane, have gained significant attention due to improvements in product quality and energy savings (Kotsanopoulos & Arvanitoyannis, 2015). The products in this category vary with respect to (1) the degree of concentration; (2) percentage of milkfat; (3) whether preserved or perishable; (4) the method of preservation (if preserved); and (5) the milk fraction(s) captured. Some forms of concentrated milk products are intended for beverage consumption, while others are primarily used as ingredients in the formulation of various food products. A thorough treatment of the chemical changes manifest in such dairy products as a result of high heat treatments, and long-term storage is available (Fox, 1995).

Currently, a growing volume of milk-derived ingredients is produced for beverage use. With pasteurized milk products of high quality readily available at reasonable prices, US consumers tend to resist purchasing milk products manufactured from rehydrated dairy ingredients. In areas or regions where modern dairy industry infrastructure does not exist, such as those having land, cold-chain, transportation, or resource constraints, dairy foods made from concentrated and dried milk products are more readily accepted and consumed. Considerable research has improved our understanding of the technical problems encountered in manufacturing, storing, and utilizing concentrated and dried dairy ingredients with regard to retaining or improving functional performance and flavor character. Additionally, a growing

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amount of scientific evidence suggesting that specific milk components or fractions have demonstrable nutritional values has further strengthened the market for such ingredients (Miller et al., 1999).

11.2 Concentrated Milk Products

Included here, verbatim and in order of relevance, are several definitions from the US Grade "A" Pasteurized Milk Ordinance (US Department of Health and Human Services, 2017), providing federally recognized definitions of concentrated and dried dairy ingredients:

Milk Products
Milk products include cream, light cream, light whipping cream, heavy cream, heavy whipping cream, whipped cream, whipped light cream, sour cream, acidified sour cream, cultured sour cream, half-and-half, sour half-and-half, acidified sour half-and-half, cultured sour half-and-half, *reconstituted or recombined milk and milk products*, *concentrated (condensed) milk*, *concentrated (condensed) milk products*, *concentrated (condensed) and dry milk products*, nonfat (nonfat) milk, reduced fat or low-fat milk, frozen milk concentrate, eggnog, buttermilk, buttermilk products, whey, whey products, cultured milk, cultured reduced fat or low-fat milk, cultured nonfat (nonfat) milk, yogurt, low-fat yogurt, nonfat yogurt, acidified milk, acidified reduced fat or low-fat milk, acidified nonfat (nonfat) milk, low-sodium milk, low-sodium reduced fat or low-fat milk, low-sodium nonfat (nonfat) milk, lactose-reduced milk, lactose-reduced reduced fat or low-fat milk, lactose-reduced nonfat (nonfat) milk, aseptically processed and packaged milk and milk products as defined in this section, milk, reduced fat, low-fat milk or nonfat (nonfat) milk with added safe and suitable microbial organisms, and any other milk product made by the addition or subtraction of milkfat or addition of safe and suitable optional ingredients for protein, vitamin, or mineral fortification of milk products defined herein.

Milk products also include those dairy foods made by modifying the federally standardized products listed in this section in accordance with Title 21 Code of Federal Regulations (CFR) 130.10-Requirements for foods named by the use of a nutrient content claim and a standardized term.

This definition shall include those milk and milk products, as defined herein, which have been aseptically processed and then packaged.

Milk and milk products that have been retort processed after packaging or have been concentrated (condensed) or dried are included in this (the Title 21) definition only if they are used as an ingredient to produce any milk or milk product defined herein or if they are labeled as Grade "A" as described in Sect. 11.4.

Powdered dairy blends may be labeled Grade "A" and used as ingredients in Grade "A" dairy products, such as cottage cheese dressing mixes or starter media for cultures used to produce various Grade "A" cultured products, if they meet the requirements of this Ordinance. If used as an ingredient in Grade "A" products, such

as those listed above, blends of dairy powders must be blended under conditions which meet all applicable Grade "A" requirements. Grade "A" powder blends must be made from Grade "A" powdered dairy products, except that small amounts of functional ingredients (total of all such ingredients shall not exceed 5% by weight of the finished blend), which are not Grade "A" are allowed in Grade "A" blends when the finished ingredient is not available in Grade "A" form, i.e., sodium caseinate. This is similar to the existing FDA position that such dairy ingredient in small cans of freeze-dried starter culture need not be Grade "A."

This definition is not intended to include dietary products (except as defined herein), such as infant formula, ice cream or other frozen desserts, butter, or cheese.

Dry Milk Products
Dry milk products mean products resulting from the drying of milk or milk products and any product resulting from the combination of dry milk products with other wholesome dry ingredients.

Grade "A" Dry Milk Products
Grade "A" dry milk products mean dry milk products that comply with the applicable provisions of the Ordinance.

Concentrated Milk
Concentrated (condensed) milk is a fluid product, unsterilized and unsweetened, resulting from the removal of a considerable portion of the water from the milk, which when combined with potable water in accordance with instructions printed on the container label, results in a product conforming with the milkfat and milk solids not fat levels of milk as defined in this section.

Concentrated Milk Products
Concentrated (condensed) milk products shall be taken to mean and to include homogenized concentrated (condensed) milk, concentrated (condensed) nonfat milk, concentrated (condensed) reduced fat or low-fat milk, and similar concentrated (condensed) products made from concentrated (condensed) milk or concentrated (condensed) nonfat milk, which when combined with potable water in accordance with instructions printed on the container label, conform with the definitions of the corresponding milk products in this section.

Grade "A" Concentrated (Condensed) Nonfat Milk
Grade "A" concentrated (condensed) nonfat milk means concentrated (condensed) nonfat milk, which complies with the applicable provisions of this Ordinance.

Frozen Milk Concentrate
Frozen milk concentrate is a frozen milk product with a composition of milkfat and milk solids not fat in such proportions that when a given volume of concentrate is mixed with a given volume of water, the reconstituted product conforms to the milkfat and milk solids not fat requirements of whole milk. In the manufacturing process, water may be used to adjust the primary concentrate to the final desired concentration. The adjusted primary concentrate is pasteurized, packaged, and immediately frozen. This product is stored, transported, and sold in the frozen state.

Whey Products
Whey products mean any fluid product removed from whey or made by the removal of any constituent from whey or by the addition of any wholesome substance to whey or parts thereof.

Grade "A" Whey Products
Grade "A" whey products mean any fluid product removed from whey or made by the removal of any constituent from whey or by the addition of any wholesome substance to whey or parts thereof which have been manufactured under the provisions of this Ordinance.

Dry Whey Products
Dry whey products mean products resulting from the drying of whey or whey products and any product resulting from the combination of dry whey products with other wholesome dry ingredients.

Grade "A" Concentrated (Condensed) and Dry Whey and Whey Products
Grade "A" concentrated (condensed) and dry whey and whey products mean concentrated (condensed) or dry whey and whey products, which comply with the applicable provisions of this Ordinance. The words "concentrated (condensed) and dry milk products" shall be interpreted to include concentrated (condensed) and dry whey and whey products.

Title 21 of the CFR Section 131 (2020) contains specific standards of identity and compositionally based definitions for the following products of immediate significance to this chapter, including the following:

131.110 Milk
131.115 Concentrated milk
131.120 Sweetened condensed milk
131.125 Nonfat dry milk
131.127 Nonfat dry milk fortified with vitamins A and D
131.130 Evaporated milk
131.147 Dry whole milk
131.149 Dry cream

All sections are available directly from the US Government Printing Office and online. Although it is beyond the scope of this chapter to reproduce all of these sections in their entirety here, one complete section (131.125 Nonfat dry milk) is included as an example of the type and degree of coverage included in these federal regulatory documents.

11.2.1 Section 131.125 Nonfat Dry Milk

(a) Description. Nonfat dry milk is the product obtained by removal of water only from pasteurized nonfat milk. It contains not more than 5% by weight of moisture and not more than 1 and 1/2% by weight of milkfat unless otherwise indicated.

(b) Optional ingredients. Safe and suitable characterizing flavoring ingredients (with or without coloring and nutritive carbohydrate sweetener) as follows:

1. Fruit and fruit juice, including concentrated fruit and fruit juice
2. Natural and artificial food flavorings

(c) Methods of analysis. The following methods of analysis are from "Official Methods of Analysis," 21st Ed. (2019). Copies may be obtained from the AOAC INTERNATIONAL, 2275 Research Blvd, Ste. 300, Rockville, MD 20850 + 1 (800) 379–2622.

1. Milkfat content: "Fat in Dried Milk – Official Final Action"
2. Moisture content: "Moisture – Official Final Action"

(d) Nomenclature. The name of the food is "nonfat dry milk." If the fat content is over 1 and 1/2% by weight, the name of the food on the principal display panel or panels shall be accompanied by the statement "Contains __% milkfat," the blank to be filled in with the percentage to the nearest one-tenth of 1% of fat contained, within limits of good manufacturing practice. The name of the food shall include a declaration of the presence of any characterizing flavoring, as specified in Section 101.22 of this chapter.

(e) Label declaration. Each of the ingredients used in the food shall be declared on the label as required by the applicable sections of parts 101 and 130 of this chapter.

11.3 Sensory Considerations

Concentrated milk and derived milk products intended for use as a reconstituted beverage milk or as an ingredient in other applications are generally evaluated for sensory properties in a manner similar to the native, unconcentrated milk product by first reconstituting it with good-quality potable or even distilled water. Many concentrated dairy products may also be evaluated without reconstitution with the caveat that some tastes and aromas are generally more readily noticed after reconstitution or rehydration even after dilution with water. The phenomenon of improved detectability of concentrated milk product sensory attributes may relate to the entrainment or binding of flavor-active compounds within the dried protein and lactose-based particles such as are found in nonfat dry milk powder. Due to the generally higher sweet and salty background flavors of milk concentrates, dilution of the concentrate to the original composition provides a more typical set of test conditions for sensory evaluation. It is a generally accepted ideal that the reconstituted product should emulate its native counterpart in flavor, mouthfeel or consistency, and appearance. In addition to flavor defects, any visible evidence of immediate discoloration, thinning or thickening, particulate formation, or other abnormalities should be noted as defects (Hammer, 1919; Hunziker, 1949; Sommer & Hart, 1926). A generally accepted practice for preparing milk-derived powders

for sensory evaluation suggests that an approximately 10% wt/wt solution in distilled water is adequate (Drake et al., 2003; Carunchia-Whetstine & Drake, 2007).

In the mid-1960s, considerable interest was generated in the market potential of a 3:1 sterile concentrated milk, although only relatively small quantities were actually produced. The major sensory problems of this product involved shortcomings of both taste and mouthfeel. The off-flavors that regularly developed in these products during storage were unique and somewhat difficult to describe given their absence from native milk. Judges commonly labeled these off-flavors of sterile milk concentrates as stale, caramel-like, or a combination of stale/caramel defect. These particular off-flavors could be associated with the browning reaction of heated milk (Arnold et al., 1966; Muck et al., 1963) and may not have been too far off of those encountered in commercially sterile milk (Zabia et al., 2012). Any possible future success of sterile milk concentrates will depend on processors' ability to prevent flavor and functional deterioration during storage.

Descriptive terminology as applied to concentrated milk products is somewhat confusing; hence, a review of several key terms should be helpful. For example, what is the difference between concentrated, condensed, and evaporated milk when the products' composition in all three cases may be identical? Evaporated and concentrated milk are clearly defined in the CFR, as is sweetened condensed milk. But what kind of product is referred to by the term "unsweetened condensed milk"? This confusion may be eased somewhat if it is assumed that "evaporated milk" represents a special type of sterile concentrated product, for which the composition and processing are clearly defined. A reasonable suggestion and historical industry convention is to reserve the term "concentrated" for products of beverage quality and use the word "condensed" when the milk product is primarily intended as an ingredient in cooking, baking, candy-making, or food manufacture.

In addition to meeting the legal composition and chemical requirements, high-quality evaporated milk should be creamy white in color, have a relatively viscous body, be uniformly smooth in texture, and possess a relatively mild, pleasant flavor free of noticeable off-aroma. Furthermore, the container should present an attractive appearance and exhibit a neat, well-applied label; the ends of the can or general integrity of any packaging should appear well-finished and show no evidence of tampering or misformation. The overall examination of the product includes flavor, body, and texture/viscosity and appearance (color, fat separation, and serum separation). Outside of other physicochemical or microbial parameters, the examination of evaporated milk may consider the following attributes:

Coffee whitening properties
Color
Container integrity
Curd tension
Fat separation
Fill of container
Film formation (protein "break")
Flavor

Gelation
Lactose crystallization/sandiness
Sedimentation
Serum separation
Viscosity
Whipping quality

Instrumental assessments of concentrated milks require the use of colorimeters, viscometers, electric mixers, and other specialized laboratory equipment. Sensory assessments employ scorecards or rating scales through either highly trained panelists or untrained consumer panels as defined in other chapters of this text. As with other commodities, dried and concentrated dairy foods are routinely evaluated by expert judges or graders, as are employed by USDA, using language published within specific standards of identities or product specifications. An example (see American Dairy Products Institute, 2002) may include such language as "Reconstituted Extra Grade dry whole milk flavor shall be sweet, pleasing and desirable. It may possess a slight feed flavor and a definite cooked flavor. It shall be free from undesirable flavors."

11.4 Examination Procedures for Evaporated Milk

Establishment of a clearly crafted protocol for examining evaporated milk can facilitate the evaluation of numerous samples and allow more defensible assessments over time. The steps outlined in the following paragraphs have been found most helpful in evaluating sample sets of evaporated milk (Bodyfelt et al., 1988).

Undue agitation should be avoided when cans of the product are transported to the laboratory. The product should be carried in an upright position and be placed vertically on the table to avoid remixing any possible precipitates (sediment) or fat layers into the product.

Examination of the can appearance should be done without lifting the can from the table. The upper end of the can should be noted for the degree of polish and seam integrity; the attractiveness of the label and the evenness of its application should be observed. The evaluator should insert a knife under the label and cut it from top to bottom. After partially or completely removing the label, the judge should note the condition or integrity of the can, especially with respect to freedom from rust spots or dents.

With an edge-cutting can opener, the evaluator should almost cut around the entire periphery of the upper end of the can and turn back the lid. By opening a can in this manner, both the container and the contents may be examined carefully.

Color Evaporated milk should display a light, uniform cream color but may tend toward a light brown color. In case of brown discoloration, the exact shade of the color may be determined either instrumentally with a colorimeter or by visual comparison with color charts (using a numerical or graphical intensity scale) or by not-

ing and recording the relative intensity of darkening as follows: none, slight, distinct, and pronounced.

Uniformity Evaporated milk should be uniform or homogeneous as evidenced by the complete absence of a cream layer, curd formation, or destabilized milkfat. Product uniformity may be more readily determined with the assistance of a spatula. Results of the examination for product uniformity may be verified when the product is examined for body and texture. In the macroscopic examination of the product for uniformity, the evaluator should notice particularly the undersurface of the turned-back lid for possible adherence of cream or precipitated salts or sugars.

Study the Body and Texture The contents of the can should be poured slowly into a clean glass beaker; the judge should note the flow properties of the product. A smooth, relatively viscous evaporated milk should pour in a similar manner to a thin cream (without marked splashing action) without any apparent ropiness. The can is allowed to drain completely; when the container is empty, the evaluator should look for any possible types of deposits on the can's interior surfaces. If the bottom metal surface cannot be seen through the remaining film of evaporated milk, the can bottom should be scraped with a spatula to determine whether a firm, tenacious deposit is present. The can is set aside for later examination; the observer should proceed with an examination of the evaporated milk for viscosity and texture. This is done by spooning up some of the milk with a plastic or hard-rubber spatula and allowing it to drip back into the beaker. The evaluator needs to note the relative thickness and uniformity of the film that adheres to the spatula.

A test for examining the presence of particulate matter is achieved by examining a film of the milk through which a light source has been transmitted. By means of a 1.27–1.90 cm (1/2–3/4 in.) wire loop (or a cutaway spoon), the milk film is observed for surface evenness or uniformity. This is done by dipping the loop into the product and withdrawing it carefully to form a film across the face of the loop. Next, the milk film is held up to the light source, and the observer looks for curd particles of pinpoint size. The appearance of small grains throughout the film indicates protein destabilization or denaturation. If the milk appears rough, grainy, or lacks uniformity, these conditions may be associated with excessive viscosity and could also provoke the feathering defect in coffee.

Should evaporated milk lack uniformity of body/texture, the evaluator should try to determine the possible cause. Contributing factors may be destabilized milkfat or protein, the presence of precipitated salts, or foreign material. If destabilized milkfat is responsible, the defect generally will appear as a cream layer or as butter-like particles on the product surface. When denatured protein is the cause, the defect usually appears as either various-sized curds (distributed throughout) or as a form of gelation of different intensities. Salt deposits are responsible for formation of a hard, gritty precipitate that may have settled on the can bottom. Foreign material is the probable cause if the sediment is evident as a smudge-like discoloration on the can bottom; this is only evident when the last traces of the product contents are

decanted. Lactose crystals may also be formed in such products and are noticeable as a gritty precipitate with poor solubility.

Observe the Condition of the Container The observer should especially look for either spangling, blackening of the seams, or container corrosion (rustiness). Spangling refers to the appearance of alternate clean, bright and dark, overlapping blotches on the surface (as though the tin were attacked by acids). Typically, any such blotches are well distributed over the inner surfaces of the can. Next, the container should be rinsed and the inner surfaces observed for any evidence of chemical activity. Discoloration and rusting may occasionally be noted on any part of the can, but it tends to occur particularly at the milk–air interface.

Determine the Product Reaction in Coffee Though the use of evaporated milk as a coffee whitener has declined, there is still merit in checking its color reaction and miscibility in coffee. Evaporated milk should impart a rich, golden-brown color to coffee. The coloring power of evaporated milk may be readily determined by adding approximately 10 ml of the product to 100 ml of test coffee of typical strength and temperature. Occurrence of an iron contamination of the product may be indicated by the development of a greenish-dark, muddy, slate-like discoloration in coffee. Thus, this off-color in an evaporated milk–coffee mixture can often be associated with container rust formation. Feathering in coffee is the result of protein denaturation and typically manifests itself as finely divided, serrated curds shortly after a susceptible evaporated milk has been added to extremely hot coffee.

Determine the Flavor For flavor determination, evaporated milk should be mixed with distilled water in a 1:1 ratio. Sampling and flavor evaluation or flavoring are conducted by the same procedure employed in evaluating fluid milk. High-quality evaporated milk (made by a conventional process) tends to have a specific milk/cream flavor, which some individuals find reminiscent of a delicate, high-quality mushroom soup.

The evaluator should bear in mind that the source of added water might have an adverse effect on the flavor of evaporated milk. Some experienced judges of evaporated milk prefer direct tasting of the final sterile concentrate rather than evaluating a diluted product. This method of sensory evaluation requires keen perception, but it has the advantage of eliminating the flavor diluting effect of the water used for product reconstitution.

The declining demand in the USA for evaporated milk has served to discourage the development of product forms. As a result of improved concentration technologies, such as membrane processes, various forms of concentrated milk products have gained a larger share of milk markets in this country. The body characteristics of conventionally processed evaporated milks have been markedly improved through the use of stabilizers that prevent physical separation during storage and help keep the product smooth and creamy throughout typical distribution cycles (Graham et al., 1981).

The evaluator should be aware that evaporated milk is intended to be a shelf-stable product; any evidence of bacterial growth, spoilage, or loss of container integrity is unacceptable. The defects that will be subsequently discussed are the result of physical causes and/or chemical activity, which proceed in the absence of any viable microorganisms (Bodyfelt et al., 1988).

11.5 Specific Sensory Defects of Evaporated Milk

Flavor The flavor defects that usually occur in evaporated milk are unlike those commonly encountered in fresh beverage milk, due to concentration under vacuum (which removes volatile off-flavors) and the extent of the applied heat during sterilization.

Probably the most common storage defect of evaporated milk results from the progressive age-darkening or browning of the product. No single term seems to describe this off-flavor adequately. Such terms as old, strong, slightly acid, sour, and stale coffee may suggest the nature of the defect. The term caramel, which is probably suggested by the brownish milk color, is not appropriately descriptive in this instance; however, it does suggest the chemical origin of the off-flavor. A caramel flavor, as in certain confections, generally connotes a pleasant, appetizing taste sensation; however, this agreeable response is definitely lacking when this flavor occurs in evaporated milk. A caramel off-flavor is associated with the age-darkening of evaporated milk. When a caramelized sample is first placed into the mouth, the flavor sensation is not particularly different from that of normal evaporated milk, but soon a distinctly old or slightly acid off-flavor is evident. This flavor defect may persist for some time, even after the sample has been expectorated. This off-flavor may be accompanied by an odor that suggests staleness. The underlying taste reaction of age-darkened evaporated milk is acidic. The extent of staleness is primarily a function of product age and storage temperature.

A study by Sundararajan et al. (1966) determined flavor changes that occurred during the storage of evaporated milk produced by the (1) conventional (long-hold retort); (2) high-temperature, short-time (HTST) (short-hold retort); and (3) aseptic (ultrahigh temperature – UHT) methods of processing. These workers concluded that the type of heat processing had a significant effect on the initial flavor score. The aseptic process yielded the best-flavored product initially and remained the best when the product was stored at 10 °C (50 °F) or 27 °C (80.6 °F) for about 2 months. After storage for 1 year, flavor scores of the HTST and aseptically made products were similar, but the flavor of conventional evaporated milk was significantly lower in quality. Flavor ratings of the conventionally processed product scored the lowest of the three product forms throughout the storage study. These investigators employed a fluid milk scorecard with a 40-point scale for flavor. The evaporated milk samples were evaluated after appropriate dilution. The initial flavor of the conventionally manufactured product was described as cooked and caramel. The

off-flavors that developed during subsequent storage were variously described as acid, stale, storage, bitter, astringent, and puckery (mouthfeel).

Body and Texture Contemporary technologies applied to manufacture evaporated milk have resulted in improved quality control. This has resulted in improved product uniformity from batch to batch, as well as between processors. Currently, fresh evaporated milk is remarkably free of body and texture defects. However, when evaporated milk is held for extended time periods or under adverse conditions, some body and texture defects may be encountered, such as the following:

Buttery, fat separation
Curdy
Feathering
Gassy
Grainy
Low viscosity
Sediment

Buttery, Fat Separation The buttery defect appears as a 0.64–1.27 cm (1/4–1/2 in.) layer of heavy cream at the top of the can. The cream layer may be so dense and tenacious that it is not miscible with the remainder of the milk. Under such conditions, the shaken milk appears curdy, with floating masses of cream or butter particles within a liquid of relatively low viscosity. Several alleged causes of this defect are (1) inadequate homogenization; (2) high storage temperature; (3) extended storage period; and (4) improper handling while in storage, i.e., a combination of high temperature, excessive agitation, etc. The incorporation of stabilizing agents has helped to control this serious defect. Consumers object to this defect, since such milk fails to pour readily and thus creates the suspicion that the product may have spoiled. This body defect is not associated with any particular flavor defect. The occasionally noted thin film and/or surface streaks of cream are undesirable product features but do not dramatically alter the functionality of the product for the consumer relative to the more complete cream separation noted above.

Occasionally, discs of free fat, from 0.08 to 0.32 cm (1/32–1/8 in.) in diameter, may appear on the surface of evaporated milk; these rarely encountered droplets of hydrophobic milkfat in the product are referred to as “moon spots.” The fat appears yellowish, crystal clear, and as flattened spheres scattered sporadically on the surface. This defect seems to be associated with inadequate homogenization, destabilized protein, and low viscosity, which is probably accelerated by high-temperature storage. Such evaporated milk lacks the homogeneity of a high-quality product.

Curdy Curdy evaporated milk may be noted by the presence of coagulated protein particles interspersed throughout the milk or by a continuous mass of coagulum or soft gel. This condition differs from the buttery defect in that it is associated more with the formation of protein-based structure than with milkfat. With high milk quality, modern processing, and technical control, this defect is observed rarely in products consumed early in their shelf life. Nonetheless, a tendency toward age

gelation should be watched closely. The presence and activity of the endogenous milk enzyme plasmin have been indicated as a cause of age gelation in several milk products with long shelf life (<3 months, ambient storage temperature). Plasmin activity is more common in milks from animals with high somatic cell counts; the enzyme is surprisingly heat stable, allowing its activity to continue work to hydrolyze milk proteins, namely, casein, throughout storage.

Feathering The feathering of evaporated milk in hot coffee is difficult to predict by macroscopic examination; as such, it is more routinely ascertained by actually testing the milk sample in hot coffee. Such a test was proposed by Whitaker (1931), wherein he surmised that, upon examination of 52 cans of commercial evaporated milk, feathering in hot coffee was not a common defect. In addressing the coffee-whitening problem, Mojonnier and Troy (1925) found that curd formation (when evaporated milk was added to coffee) was due entirely to excessive viscosity of the product. A more recent method for the assessment of feathering was published by Anderson et al. (1977). Such feathering, as a defect, is distinctively different from a commonly encountered use of the term "feathering" of cream or milk by baristas in the coffee service industry. This latter feathering phenomenon refers to the generation and application of a delicate milk-based foam layered on the surface of coffee-based beverages in contrast to the appearance of a surface-based layer is relatively insoluble milk solids (Fig. 11.1).

Gassy Fortunately, gassy evaporated milk is uncommon. This defect is manifested by bulged cans and sometimes by a hissing sound of escaping gas when the can is punctured upon opening. This defect can be due occasionally to certain physical–chemical causes, but microbial fermentation is the most typical cause.

Grainy Graininess, like curdiness, is related to the relative heat stability of milk proteins. A grainy evaporated milk is one that lacks smoothness and uniformity throughout; such a product appears coarse. If this defect is present, a film across a loop or an open-bottom spoon will transmit light unevenly. Grainy evaporated milk

Fig. 11.1 Image of surface of cup of coffee with added creamer showing the feathering defect. Although the bulk of the creamer readily combines with the coffee, some remains on the surface; the material residing on the surface is an example of surface feathering of coffee creamer. (S. Rankin image)

is often associated with an excessively heavy, viscous body. The evaluator should recognize that grainy evaporated milk does not actually contain "grains" of sediment. The presence of curd particles of pinpoint size may be noted when a light source is transmitted through a film of the product; hence, the visible grain is indicative of protein break or denaturation.

Low Viscosity A low-viscosity evaporated milk may be noted by its more water-like consistency; such milk lacks creaminess and pours from the container as readily as fresh milk. The viscosity of evaporated milk is related to heat stability. Highly stable milk and technical efforts to achieve high heat stability tend to produce low viscosity; by contrast, low heat stability leads to high viscosity in the finished product. The viscosity attained immediately after sterilization may change, depending on several factors (storage temperatures, especially). Thinning or thickening (even to the point of gelation) may occur as a result of product aging; this depends on such factors as solid content, preheating temperatures, type of sterilization process, milk quality, and initial viscosity. In conventional evaporated milk, the addition of stabilizers has simplified the control of viscosity.

Sediment Sedimentation, as observed in evaporated milk, may be of two distinct kinds; each type of precipitation may arise from entirely different causes. The sediment resulting from the settling of somatic cells (leukocytes), denatured protein, and/or foreign material (of possible colloidal nature) is usually darker in color than the product itself. Since these forms of sediment are readily miscible, they may only be seen when an undisturbed can is emptied slowly. This infrequent defect is not readily experienced by the consumer, since evaporated milk is subject to some agitation, especially when decanted through small puncture holes in the can top.

The second type of sedimentation that may occur in evaporated milk results from the crystallization of specific calcium and magnesium salts such as tricalcium phosphate ($Ca_3(PO)_2$), magnesium phosphate ($Mg_3(PO_4)_2$), and tricalcium citrate ($Ca_3(C_6H_5O_7)_2$). These forms of gritty-like sedimentation frequently accompany the aging of evaporated milk. The rate at which crystals form seems to be influenced by the nature of the milk, conditions of manufacture, and storage temperature. Sato (1923), Mojonnier and Troy (1925), and Gould and Leininger (1947) found these white, gritty, sand-like particles to be chiefly lime salts of citric acid or tricalcium citrate ($Ca_3(C_6H_5O_7{\cdot}4\,H_2O)$). Their rather bland, chalky taste suggests a form of calcium salt. These crystals vary from the size of a pinpoint to the size of a wheat kernel. They are usually found on the container bottom and may be noted when the contents are emptied.

Color The principal color defect of evaporated milk is browning. This color defect results from the Maillard reaction involving chemical interactions between lactose and milk proteins (and their hydrolysis products) upon severe heat treatment and subsequent storage. Numerous flavor compounds, including those involving hydroxymethylfurfural, are also produced during the course of the browning reaction, which can lead to corresponding flavor defects. The degree or intensity of the brown discoloration is related to the intensity (time and temperature) of the steril-

ization process and the storage temperature. Aseptic and HTST sterilization systems generally yield a lighter-colored product than the conventional retort (long-hold) process. However, additional darkening may occur during storage in all cases, as a function of age and the storage temperature of the product.

11.6 Sweetened Condensed Milk

A description of sweetened condensed milk can be found in 21 CFR 131.120 (CFR, 2020):

(a) Description. Sweetened condensed milk is the food obtained by partial removal of water only from a mixture of milk and safe and suitable nutritive carbohydrate sweeteners (Fig. 11.2). The finished food contains not less than 8% by weight of milkfat and not less than 28% by weight of total milk solids. The quantity of nutritive carbohydrate sweetener used is sufficient to prevent spoilage. The food is pasteurized and may be homogenized.

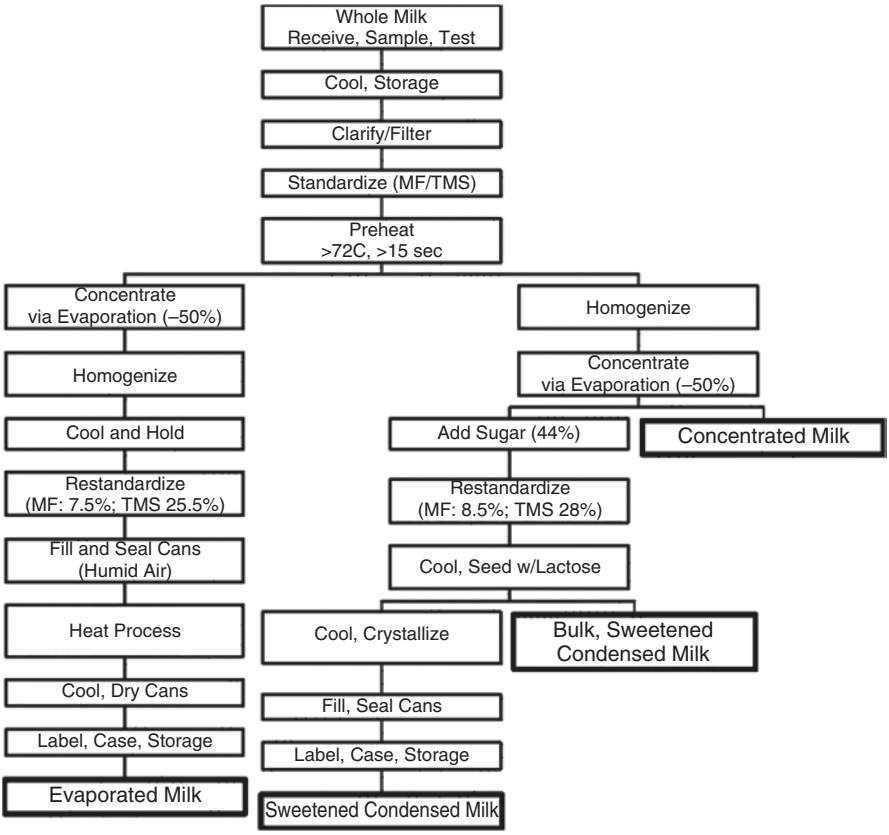

Fig. 11.2 Flow diagram for the manufacture of evaporated and condensed milks

(b) Optional ingredients. The following safe and suitable characterizing flavoring ingredients, with or without coloring and nutritive carbohydrate sweeteners, may be used:

1. Fruit and fruit juice, including concentrated fruit and fruit juice.
2. Natural and artificial food flavoring.

Sweetened condensed milk contains a sufficiently high percentage of sugar for preservation via mechanisms of high osmotic strength; thus, sterilization is not required for shelf stability. Additionally, the flavor sensation is predominantly (or overwhelmingly) sweet. However, beyond this intense sweetness, the flavor of this dairy product should be clean and pleasant, with a slight or trace aftertaste of milk caramel. The body of the product should be smooth and uniform; the color should be a light, translucent yellow (Fig. 11.1).

Whether sweetened condensed milk is used in the home kitchen or in a food processing plant, its primary function is as an ingredient in candy, cookies, pies, and ice cream and not as a beverage. Hence, its sensory properties are nearly exclusively evaluated in the research or quality control laboratories of processors or end users assessing ingredient performance. Careful consideration must be given to the functional properties of this product, but sensory characteristics are also important in the overall process of the quality evaluation of sweetened condensed milk before purchase or inclusion in manufacturing.

11.7 Examination Procedures for Sweetened Condensed Milk

The unique precautions and steps that were applicable in the evaluation of evaporated milk are not as germane to the examination of sweetened condensed milk (in consumer-size containers). However, a specified routine or protocol enables the evaluator to best utilize the available time with greater assurance that the examination is thorough and comparable to previous assessments. Hence, the following recommended procedure may be helpful (Bodyfelt et al., 1988).

The evaluator should place a representative container on a table for examination. The can should be in exactly the same (upright) position that it had assumed prior to examination. This readily enables the judge to open the container and make an initial examination of the top surface and product contents. Next, the evaluator should cut and turn back the container lid so that the condensed milk surface may be closely examined and the contents easily decanted from the container. The recommended order of visual examination is listed below.

Appearance of the Container The sweetened condensed milk container should appear to be in good condition. Since the container has not been subjected to high heat treatment, as in retorting (which dulls container surfaces), the can ends should

be as bright as new tin. It is advisable that the evaluator develops the habit of carefully scrutinizing or observing the relative condition of all containers.

Appearance of the Product Surface The product surface should have the same color intensity as various underlayers of the condensed milk. The product should be uniform in consistency with no indication of lumps, free fat, or film formation.

Color With a spatula, the judge should spoon up some of the product and note the relative translucency of a condensed milk layer. The color should be uniform throughout rather than have a lighter-colored layer at the container bottom. The evaluator should determine whether the sweetened condensed milk has a creamy or a less desirable brownish color.

Viscosity Next, the evaluator should tilt the container at an angle and then note the relative ease with which the product is able to flow within the can due to gravity. The product is poured into a beaker. The observed pouring characteristics (flow) should resemble those of a medium-heavy molasses. There definitely should be no indication of a gel or custard-like formation. Flow characteristics (viscosity) can also be determined objectively by physical measurement.

Sediment After the can has been emptied, the evaluator should scrape the bottom and note the presence or absence of a thickened layer (which may be a crystalline, granular material). The color of the granules should be compared with the bulk of the milk and the size of any precipitated crystals measured against any suspended in the liquid.

Flavor After the above macroscopic examination has been completed, the judge should note the flavor characteristics. With the sample at a typical room temperature (e.g., 25 °C), a small teaspoonful of the sweetened condensed milk should be placed into the mouth; the evaluator needs to observe the mouthfeel, taste, and aroma sensations. The relative smoothness of the product and the grain fineness can be noted by pressing some of the sample against the palate with the tongue. By this time, the evaluator may have experienced a secondary taste reaction – a perceived flavor other than sweetness. This delayed flavor note usually represents a blend of the sensory perception of the added sugar and dairy ingredients.

11.8 Defects of Sweetened Condensed Milk

Flavor Sweetened condensed milk, due to its concentration under vacuum, tends to have none of the volatile flavors that may occur in fresh milk. Since this product is preserved by sugar rather than by heat, it should not exhibit those off-flavors that result from the higher heat treatments applicable to evaporated milk and certain other milk products. Hence, when this product is properly manufactured, it is

remarkably free of flavor defects. However, several off-flavors in sweetened condensed milk have been noted to develop with increased storage time, as indicated below:

Metallic
Rancid
Strong
Tallowy

Metallic The metallic off-flavor of sweetened condensed milk is distinctly chemically induced; it is usually traceable to copper contamination. Hunziker (1949) stated that "sweetened condensed milk may have a pronounced, disagreeable metallic flavor – suggesting the puckery, copper-like taste of copper salts." Copper contamination should be encountered infrequently due to near ubiquitous use of stainless steel equipment in modern processing systems.

Rancid Fortunately, a rancid off-flavor occurs most infrequently in sweetened condensed milk. As discussed earlier in this book, rancidity results from milkfat hydrolysis due to enzymes secreted by spoilage bacteria or indigenous milk lipase, which may not have been heat inactivated or was active against the milkfat before the milk was pasteurized. If the milk source was rancid, the peculiar, offensive odor associated with hydrolytic rancidity may be readily noted when the can is first opened.

Strong The term strong or strong caramel is often used to describe the off-flavor that accompanies the progressive thickening and browning of condensed milk. While this particular flavor sensation must be classified as a defect, it is not usually a serious one. Unfortunately, a caked or gelled product, with its associated deep brown color, often suggests that the product may manifest extreme flavor impairment. However, such condensed milk occasionally may develop or display a rather pleasant caramel-like taste.

Tallowy Rice (1926) observed in the instance of tallowy condensed milk that on opening a tin, the sample may appear paler than normal. The aroma of the freshly opened product may be reminiscent of beef tallow and remains noticeable even after exposure to the air for several days. Tallowiness has become a rarely encountered oxidation defect in sweetened condensed milk. Elimination of copper contamination and prevention of exposure of milk to light and air are the most likely reasons why this off-flavor is practically extinct.

Off-Flavors Caused by Microorganisms Certain osmophilic and osmoduric microorganisms, including yeasts, molds, and bacteria, can tolerate high sugar concentrations and, under certain conditions, can grow and cause spoilage in sweetened condensed milk. The growth of these microorganisms or the activities of their enzymes may be accompanied by characteristic physical and appearance changes, gas production, off-flavors, and odors. Depending on the type of microorganism

involved, the resultant odor may be acidic, stale, cheesy, unclean, or yeasty. Any products that show evidence of microbial activity should be considered unsalable.

Body and Texture Due to the relatively high percentage of sugar required for preservation, sweetened condensed milk exhibits a relatively heavy body (somewhat like molasses). Also, this product usually has a fine-grained, smooth, and uniform texture. However, the following body and texture defects may be encountered:

Buttons
Lumpy
Fat separation
Gassy
Sandy (rough, grainy, granular)
Settled
Thickened

Buttons Although they generally change the consistency of a portion of the product, formed "buttons" are visually observed as round, firm, cheesy curds at the product surface. These buttons result from the proteolytic activity of certain molds. Product losses due to button formation can be eliminated by preventing contamination by osmophilic molds and other microorganisms.

Lumpy Occasionally, a product may exhibit pronounced differences in viscosity (lumpiness) within portions of the container contents. Sometimes, portions of the product may have actually gelled. It should be determined whether this problem is due to possible microbiological contamination or some other cause.

Fat Separation Fat separation in sweetened condensed milk seldom occurs. This defect may be noted by either an off-color, fatty film at the surface and/or floating droplets of free fat. Milkfat separation may be due to improper homogenization and elevated temperatures during the course of storage.

Gassy Condensed milk that has developed gassiness may be recognized by a bloated or huffed can. This defect results from contamination by and subsequent outgrowth of gas-producing microorganisms. Hammer (1919) studied the formation of gas in sweetened condensed milk and found the causative agent to be a yeast, which he named *Torula lactis condensi*. A yeasty odor was associated with this gaseous condition. Today, the defect is rarely noted.

Sandy (Rough, Grainy, Granular) All of these terms are used interchangeably to describe sweetened condensed milk that contains detectable or oversized lactose crystals. The solid lactose particles are sufficiently large enough to impart a distinct grittiness and general lack of product smoothness, which is readily noticeable as the sample is tasted. This defect can be readily detected by the consumer. The condition referred to as sandiness is due to the presence of relatively large lactose crystals (>50 μm). The so-called smooth condensed milk has minute-sized lactose crystals,

which seem to appear like a fine flour mixed into the condensed milk. If manufacturing conditions are not conducive to the formation of small lactose crystals (<50 μm), then large, coarse crystals are likely to form (sandiness). The sandy defect may also be caused by sucrose crystals, when the concentration of this sugar exceeds the saturation level.

Settled The term settled is used to describe a condensed milk in which a distinct settling of sugar crystals has occurred. The syrup that settles out forms a thick sugary layer on the container bottom. This sugar sediment consists primarily of lactose crystals, according to Hunziker (1949). Key measures for prevention of this defect include efforts to ensure small crystals and development of an adequate product viscosity to retard sedimentation.

Thickened Overly thickened condensed milk is one of the more common defects that can be encountered in sweetened condensed milk. The defect is manifested by an extensive gel formation, which leads to a product appearance more suggestive of a solid than a liquid. Excessively thickened condensed milk is usually associated with browning; both undesirable conditions become progressively more intense upon additional storage (especially at elevated temperatures). This defect varies markedly in intensity from a slight jelly to a firm custard consistency. As noted above, a high-quality sweetened condensed milk should pour like molasses. When the product is poured, it should gradually level out and leave no traces of folds on the surface. The formation of a gel, even a soft gel, is entirely undesirable. Both physical and chemical factors are commonly responsible for thickening of sweetened condensed milk, but certain microorganisms may also cause product thickening.

11.9 Other Concentrated Milk Products

The evaluation of other concentrated milk products differs little from that of the products previously described. Products such as milk protein concentrate, evaporated nonfat milk, and sweetened condensed nonfat milk should be evaluated in a similar manner to their water-containing counterparts. Obviously, one must allow for the absence of fat in evaluating both the flavor and tactile properties. Some products are produced to provide certain functional properties for specific applications. A good example is superheated condensed milk (or nonfat milk) for use as a milk ingredient in ice cream manufacture. This product should possess a desirable flavor and an appealing color as well as impart the desired body properties to ice cream. Instrumental measurements of viscosity should supplement sensory-derived assessments of product consistency. As a general principle, when a concentrated milk product is intended for beverage purposes, sensory evaluation should ascertain how closely the product quality approaches that of its unconcentrated, high-quality, fresh milk counterpart. When a concentrated milk is used as an ingredient, the primary

question becomes “Does the quality of this product as an ingredient reflect the target quality of the finished product?”

11.10 Dry Milk Products

Since its commercial origin, dry milk has been graded on the basis of bacteria, moisture, and certain physicochemical properties. More recently, flavor and other sensory properties have become important criteria in grading dry milk products. In addition to compliance with regulatory standards, dry milk must also have good flavor characteristics if it is to gain consumer or processor acceptance. The relative importance of flavor character is governed to a large extent by the intended use of the product. The evaluator of dry milk should be familiar not only with the product standards and the associated laboratory tests but also with the appropriate flavor standards and potential flavor defects.

11.11 Methods of Producing Milk Powder

There are two principal methods of producing milk powder from concentrated milk, namely, the roller process (nearly nonexistent in the USA) and the spray-drying process. Numerous technical developments in the removal of water from concentrated milk have vastly improved certain properties of dried milk and facilitated the drying of several milk product forms that would not have been possible otherwise. It should be noted that by convention, native milks are first concentrated through evaporation technologies to facilitate the final drying steps, namely, spray drying, to proceed with more efficiency. One development that has served to improve the rehydration of dried nonfat milk is the process known as agglomeration or instantizing. This process involves slightly humidifying and then redrying previously dried milk (referred to as rewet agglomeration) to attain a more soluble, porous particle form. In newer spray-drying facilities, this process is achieved during the actual spray-drying process (referred to as single-pass agglomeration). Other drying technologies include foam drying, freeze drying, and fluidized-bed drying, although these methods have had a greater impact on foods other than dairy products and/or are used in conjunction with standard spray-drying technologies.

The additional concentration of fluid milk that occurs at the instant of drying and the type of drying process substantially influence the physicochemical properties of the resultant dry milk. Thus, certain qualities of the finished product provide clues to the method of product manufacture. A descriptive outline of several milk-drying methods and some characteristic qualities of the respective dry products are given below.

Atmospheric Roller In this process, milk is dried in the open air on the surface of revolving, internally heated drums. The dried milk film is shaved from the drums and pulverized. The end product is characterized by a relatively heavy body, coarse texture, and comparative insolubility when it is initially added to water. Under the microscope, the solid particles appear angular, flaky, and irregular; seldom are spherical-shaped grains or particles noted.

Vacuum Drum This drying process is similar to the atmospheric roller process except that the drum rolls are enclosed within a vacuum chamber and thus permit drying at reduced temperatures. This is advantageous from a product quality standpoint in that lower temperatures and times are necessary for dehydration, thus limiting numerous thermal degradation reactions. Vacuum-drum-dried powder readily solubilizes when added to water (similar to spray-process powder), but it may be easily distinguished from the latter by its appearance under the microscope. Grains of spray-process powder are generally spherical, whereas particles from the vacuum drum process tend to be distinctly angular and fragmented.

Spray-Drying Process In this process, concentrated liquid milk is atomized (either by a high-pressure nozzle or by a spinning disc) into a current of hot, dry air in a high-volume vacuum chamber. The spray-drying process is much more efficient at heat transfer/water removal than roller or drum drying, in part due to the substantial increase in surface area – about 35 m^2/l of milk. As such, the resulting particle size of the powder is remarkably small and readily soluble. Under the microscope, the grains appear bead-like or spherical and are of relatively uniform size.

Instantizing Instantizing, or agglomeration, is a unique modification of the spray process of drying, which is generally applied to the drying of nonfat milk for home use in beverage applications. The process may also be adapted to whole or low-fat milk powders. The instantizing process substantially increases the particle size and porosity of the given milk powder, which significantly minimizes the tendency to ball up when dried milk is mixed with water. Agglomeration markedly improves the dispersibility and reliquefaction characteristics of dried milks. Since the introduction of instantized milk products in the 1950s, a number of patents have been issued that cover two basic processes, the two-step and one-step processes (Graham et al., 1981; Hall & Hedrick, 1971). The two-step process, which appears to be the most commonly employed method, consists of bringing previously spray-dried milk in contact with water or steam (under appropriate conditions). The moistened particles adhere to each other and form distinctly porous, agglomerated particles of larger size, which are then redried to the desired moisture content. In a typical one-step instantizing process, the drying is conducted in such a manner to enhance particle clustering. The larger agglomerates that are formed are subsequently separated, and the final drying step occurs in a secondary dryer. A wetting agent (generally lecithin) may or may not be added during the agglomeration process.

Foam Drying In "foam drying," the product is dried after a liquid slurry is converted to a foam state. Two basic processes can be applied: (1) foam drying and (2) foam-spray drying. In the former process, a nitrogen-gassed, whole milk concentrate (50% solids) is initially foamed and then applied to a continuous belt that leads into a vacuum-drying chamber. In the foam-spray drying method, compressed air is injected into concentrated milk through a mixing device that is located between a pressure pump and the spray nozzle. The gas-injected milk subsequently forms a foam upon sudden ejection into a heated air chamber. The thin air-cell films that are formed dry as fragile, eggshell-type particles.

Freeze Drying "Freeze drying" consists of removing moisture from a frozen product by sublimation under high vacuum. A food product dried by this method retains many of its initial, natural qualities due to the relative absence of heat-driven reaction conditions. However, freeze drying and some of the other drying processes have enjoyed only limited application to dairy products. This limitation is due primarily to rather substantial economic constraints related to energy inputs and the lack of flow-through or continuous freeze-drying technologies of appropriate scale as compared to more conventional processes for the large-scale production of dried milk products.

11.12 Types of Dry Milk Products

As denoted in 7CFR58, 21CFR184, with additional product descriptions/standards under specific USDA, Agricultural Marketing Service publications, some common dry milk products are listed below:

Dry buttermilk and dry buttermilk product
Dry cream
Dry whey (sweet and acid)
Dry whole milk
Dry ice cream
Edible dry casein (acid); caseinates
Instant nonfat dry milk
Low-fat dry milk
Malted milk
Modified dry milk products
Nonfat dry milk (roller and spray process)
Whey protein concentrate (WPC35, WPC80)
Whey protein isolate
Milk protein concentrate

Each of these products may have standards of identity promulgated by the Food and Drug Administration (CFR, 2020, with quality standards set and administered by the US Department of Agriculture). Occasionally, state or local regulations apply

to the manufacture and use of these dried milk products. In certain instances, a definition may not exist for the dry form of a product, but when it is reconstituted, the final product may have to comply with the definitions of its liquid counterpart. For example, dried ice cream mix has no definition (or standard of identity), but ice cream does. When dehydrated products are made into and sold as ice cream, the final product form must comply with the existing regulations that pertain to the respective type of frozen dairy dessert.

In the ensuing discussion, the major emphasis will be placed upon the sensory properties of dried milk products, although some details or other pertinent facts will also be provided. Some limited information from the CFR and several other documents related to dried milk will be cited. Since federal regulations may change from year to year, the reader is urged to consult the most recent edition of the CFR for current, authoritative information. Absolute compliance with USDA quality standards does not excuse failure to comply with certain rigorous provisions of the Federal Food, Drug and Cosmetic Act.

11.13 Dry Whole Milk

The Food and Drug Administration has defined dry whole milk in 21 CFR 131.147 (CFR, 2006) as follows:

> Description. Dry whole milk is the product obtained by removal of water only from pasteurized milk, as defined in Section 131.110(a), which may have been homogenized. Alternatively, dry whole milk may be obtained by blending fluid, condensed, or dried nonfat milk with liquid or dried cream or with fluid, condensed, or dried milk, as appropriate, provided the resulting dry whole milk is equivalent in composition to that obtained by the method described in the first sentence of this paragraph. It contains the lactose, milk proteins, milkfat, and milk minerals in the same relative proportions as the milk from which it was made. It contains not less than 26% but less than 40% by weight of milkfat on an as is basis. It contains not more than 5% by weight of moisture on a milk solids not fat basis.

Other provisions include the optional addition of vitamins A and D (when added, the content is regulated) and incorporation of the following safe and suitable optional ingredients: carriers for vitamins A and D, emulsifiers, stabilizers, anticaking agents, antioxidants, characterizing flavoring ingredients with or without coloring and nutritive carbohydrate sweeteners (including fruit, fruit juice, fruit juice concentrates, and natural and artificial food flavoring).

Grading standards of the USDA are published through the Agricultural Marketing Service in paragraphs 58.2701–58.2710 (Effective April 13, 2001). They pertain primarily to basic dry whole milk, which optionally may be fortified with vitamins A and D or both vitamins. Two USDA grades are recognized: (1) US extra grade and (2) US standard grade. The grades are determined on the combined basis of flavor, physical appearance, bacterial estimate, coliform count, milkfat content,

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

Flavor characteristics	US extra grade	US standard grade
Cooked	Definite	Definite
Feed	Slight	Definite
Bitter	NA	Slight
Oxidized	NA	Slight
Scorched	NA	Slight
Stale	NA	Slight
Storage	NA	Slight

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

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

Physical appearance characteristics	US extra grade	US standard grade
Dry product		
Unnatural color	None	Slight
Lumps	Slight pressure	Moderate pressure
Visible dark particles	Practically free	Reasonable free
Reconstituted product		
Grainy	Free	Reasonably free

[a]USDA, AMS US Standards for Grades of Dry Whole Milk (April 13, 2001)

moisture content, scorched particle content, solubility index, and titratable acidity. Tables 11.1, 11.2, and 11.3 summarize the requirements for the above two grades of dry whole milk. Definitions of the terms used in these tables are presented in a later segment of this chapter. Testing for certain other quality parameters may also be done at the option of the USDA or when examination is requested by an interested party. These optional requirements include vitamin addition (A and D), oxygen content (if gas packed), and protein content. Failure to meet "standard grade" or optional quality requirements (when the tests are performed), or a direct microscopic clump count in excess of 100 million/g, suffices to deny a given product the assignment of a USDA grade. Deficiencies in so-called good manufacturing practices by a processor may also disqualify products from eligibility for USDA grade assignment.

Specific details for conducting each of these tests or assays are included and described, as follows:

(a) Scorched particle content and solubility index shall be determined by the methods contained in the latest revision of 918-RL, Laboratory Methods and Procedures, USDA/AMS/Dairy Programs, Dairy Grading Branch, Room 2746-S, 14th and Independence Ave. S.W. Washington, DC 20250-0230.
(b) All other tests shall be performed by the methods contained in the latest edition of the "Official Methods of Analysis," published by AOAC International, 2275 Research Blvd, Ste. 300, Rockville, MD 20850; by the methods provided in the latest edition of the "Standard Methods for the Examination of Dairy Products,"

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

Laboratory tests	US extra grade	US standard grade
Bacterial estimate (SPC/gram) (max)	10,000	50,000
Coliform count (per gram) (max)	10	10
Milkfat content (percent)	Not less than 26.0, but less than 40.0	Not less than 26.0, but less than 40.0
Moisture content (percent)[b] (max)	4.5	5.0
Scorched particle content (mg) (max)		
Spray process	15.0	22.5
Roller process	22.5	32.5
Solubility index (ml) (max)		
Spray process	1.0	1.5
Roller process	15.0	15.0
Titratable acidity (lactic acid) (percent) (max)	Not more than 0.15	Not more than 0.17

[a]USDA, AMS US Standards for Grades of Dry Whole Milk (April 13, 2001)
[b]Mild solids not fat basis

available from the American Public Health Association, 800 I Street NW, Washington, DC 20001, or by methods published by the International Dairy Federation, available from the International Dairy Federation AISBL, 70/B, Boulevard Auguste Reyers, 1030 Brussels, Belgium.

11.14 Flavor Properties of Dry Whole Milk

Upon rehydration, ideal dry whole milk or whole milk powder (WMP) should have flavor characteristics that are clean, rich, sweet, fresh, and pleasant, not unlike that of fine pastry. Sensory defects may be due to either poor-quality raw material, handling, and processing of the fluid milk; the drying method; or extended or abusive storage conditions. The development of storage-based defects in dry whole milk is most difficult to control or eliminate. Carunchia-Whetstine and Drake (2007) highlighted the application of descriptive sensory analysis to document the flavor and flavor stability of WMP. This work denoted the relatively rapid onset of off-flavors (as early as 3–6 months) in WMP as primarily a function of the generation of lipid oxidation products. Descriptive terms used in their study to differentiate WMP over the course of a 24-month storage period include fishy, astringent, fatty/fryer oil, grassy/hay, and painty. Some additional common quality defects/terms encountered in dry whole milk are scorched, stale, and oxidized.

Scorched A scorched off-flavor is likely to occur in those products that have been subjected to excessive heat (during the drying stage) or have remained in the drying chamber too long. This product defect is usually accompanied by numerous

scorched particles; sometimes dark discoloration occurs. Terms used to describe this defect include scorched, burnt, and burnt feathers.

Stale A "stale" off-flavor develops during storage, even in products that have been packed in modified atmosphere and/or contain an extremely low oxygen concentration in the headspace of the container. Dry whole milks stored with a moderately high level of oxygen in the headspace can develop this off-flavor. Effective preventive measures against the development of a stale off-flavor have been pursued by researchers for decades. Specific aids in inhibiting the development of stale odors may include the use of light and oxygen barrier packaging, storage of product at lower temperatures, and the exclusive use of only the highest quality raw milk. This defect is characterized as having stale, wet dog, and brothy flavor characteristics.

Oxidized, Tallowy The oxidized, tallowy off-flavor is an especially troublesome sensory defect of WMP. This off-flavor, suggestive of old tallow, renders WMP unpalatable. Frequently, various stages of oxidation may be noted. Numerous factors seem to affect the development and rate of oxidation, notably (1) storage and processing temperatures; (2) light exposure; (3) product acidity; (4) metallic salts; (5) water activity; (6) headspace oxygen content; and (7) the type of packaging. Differentiated from stale as being considered to involve more lipid-based precursors, typical flavor descriptors for this defect may include wet cardboard, tallowy, and painty.

11.15 Other Properties of Whole Milk Powder (WMP)

Tactile properties of WMP vary with the method of manufacture, the degree of concentration prior to drying, and the particle size and porosity after drying (Hall & Hedrick, 1971; Hunziker, 1949). Dry whole milk manufactured by the spray process may be extremely fine and uniform throughout, but two powder defects may occasionally be noted: lumpy and caked.

Lumpy Lumpy powder lacks definite homogeneity in appearance. Hard lumps the size of wheat grains or larger may be present in the powdered mass. This defect is found more frequently in spray-process forms of WMP. The lumps can result from insufficient drying, dripping spray nozzles, or particle exposure to moisture-laden air. Dry whole milk, because of its relatively high fat content, may contain so-called soft lumps. This condition is particularly characteristic of cold-stored products. It stems from the unintentional agglomeration of powder particles. This defect should not be confused with a "hard lumpy" product, wherein the formed particles (lumps) feel firm and sometimes even sticky when they are pressed between the fingers.

Caked Usually, the caked defect is not encountered in WMP. However, when it does occur, WMP loses it powdery consistency and becomes "solid as a rock."

When this solid mass is broken up, the product remains as chunks and thus fails to regain the original powdery state. This defect is considered most serious, since such an altered WMP has lost sales value for human use.

Color Dry whole milk is typically light yellow in color, but it can vary seasonally with the amount of pigmentation present in the milkfat. The color can range from a creamy white to a deep yellow. The possible defects of color in dry whole milk are *browned* or *darkened*, *scorched*, and *lack of uniformity*.

Browned or Darkened This color defect of WMP is associated with product age. When this defect occurs, the typical creamy color has been replaced by a distinct brown shade. Furthermore, this color defect is usually associated with a distinctive stale off-flavor. This defect is potentiated by conditions that favor general Maillard browning reactions, including water activity, high storage temperatures, extended storage times, and pH extremes.

Scorched Discoloration due to burning (scorching) of milk solids is more commonly associated with roller-processed powders than spray-processed products. Sections of large spraying systems, where even minor masses of product can accumulate, can also result in this defect. The powder color may vary from light to dark brown; rarely will burnt particles be so dark as to appear black. Milk powders that exhibit discolored particles or foreign sediment are severely discriminated and downgraded against the grading standards.

Lack of Uniformity This defect may be due to either partial discoloration (browning) that may develop after product packaging or the result of partial scorching during the manufacturing process.

11.16 Nonfat Dry Milk (NDM)

The Food and Drug Administration has two definitions for nonfat dry milk, as noted in 21 CFR 131.125 and 131.127 (2020). The only difference in the second definition is that the product is fortified with vitamins A and D. Nonfat dry milk (NDM) is defined as follows:

Description. Nonfat dry milk is the product obtained by removal of water only from pasteurized skim milk. It contains not more than 5% by weight of moisture and not more than 1 and 1/2% by weight of milkfat unless otherwise indicated.

Optional ingredients. Safe and suitable characterizing flavoring ingredients (with or without coloring and nutritive carbohydrate sweetener) as follows: fruit and fruit juice (including concentrated fruit and fruit juice) and natural and artificial food flavorings.

The following is the additional language for nonfat dry milk fortified with vitamins A and D:

Description. Nonfat dry milk fortified with vitamins A and D conforms to the standard of identity for nonfat dry milk, except that vitamins A and D are added as prescribed by paragraph (b) of this section.

(b) Vitamin addition.

(1) Vitamin A is added in such quantity that, when prepared according to label directions, each quart of the reconstituted product contains 2000 International Units thereof.

(2) Vitamin D is added in such quantity that, when prepared according to label directions, each quart of the reconstituted product contains 400 International Units thereof.

(3) The requirements of this paragraph will be deemed to have been met if reasonable overages, within limits of good manufacturing practice, are present to ensure that the required levels of vitamins are maintained throughout the expected shelf life of the food under customary conditions of distribution.

The USDA has quality standards for three types of NDM, namely, spray process, roller process, and instant. The details of these standards may be found by accessing the USDA, Agricultural Marketing Service (http://www.ams.usda.gov). A summary of the requirements is given in Tables 11.4, 11.5, and 11.6. The products covered by these standards must not contain buttermilk or any added preservative, neutralizing agent, or other chemicals. Conditions under which a "U.S. Grade" is not assignable vary for the different types of NDM. Only the "Extra Grade" is recognized for use as instant nonfat milk. For spray- and roller-process nonfat milk, failure to meet the requirements for US standard grade and/or a direct microscopic clump count in excess of 100 million/g results in nonassignment of a grade.

Table 11.4 US grade classifications of nonfat dry milk (reliquified basis) based on flavor and odor[a]

Flavor characteristics	US extra grade[b]	US standard grade[b]
Bitter	NA	Slight
Chalky	Slight	Definite
Cooked (spray and instant)	Slight	Definite
Feed	Slight	Definite
Flat	Slight	Definite
Oxidized	NA	Slight
Scorched	NA	Slight
Stale	NA	Slight
Storage	NA	Slight
Utensil	NA	Slight

"NA" means not allowed at any level

[a]USDA, AMS US Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant)

[b]Instant nonfat dry milk is allowed only as US extra grade

Table 11.5 US grade classifications of nonfat dry milk based on physical appearance characteristics[a]

Physical appearance characteristics	US extra grade	US standard grade[b]
Dry product		
Lumpy	Slight	Moderate
Unnatural color	NA	Slight
Visible dark particles	Practically free	Reasonably free
Reconstituted product		
Grainy	NA	Reasonably free

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

Table 11.6 US Grade Classifications of Nonfat Dry Milk according to laboratory analyses[a]

Laboratory tests (or parameters)	U.S. extra grade[b]	U.S. standard grade
Bacterial estimate, standard plate count/g (max)	10,000	75,000
Milkfat content, % (max)	1.25	1.5
Moisture content, % (max)	4.0 (4.5 instant)	5.0
Scorched particle content, mg (max)	15.0	22.5
Solubility index, ml (max)		
Spray	1.2	2.0
US high heat[c]	2.0	2.5
Roller	15.0	15.0
Instant	1.0	
Titratable acidity, % (max)	0.15	0.17
Coliform count/g instant (max)	10	
Dispersibility, instant (max%)	85	

[a]USDA, AMS US Standards for Grades of Nonfat Dry Milk (Spray, Roller and Instant)
[b]Instant nonfat dry milk may be assigned only one grade, "U.S. Extra"
[c]Heat classification is as follows:
Low heat ≥6.0 mg undenatured whey protein nitrogen/g dry product
Medium heat 1.51–5.99 mg undenatured whey protein nitrogen/g dry product
High heat ≤1.5 mg undenatured whey protein nitrogen/g dry product

When NDM (especially the instantized form) is used as a beverage, a sensory comparison with fresh fluid nonfat milk is inevitable. Under ideal conditions, the sensory difference may not be that significant; even expert evaluators may find little to criticize in reconstituted NDM of high quality. However, there are several points to keep in mind. Fresh, liquid nonfat milk (or another liquid product) is not guaranteed to be free of flavor defects; in some instances, fresh nonfat milk may be inferior to the dehydrated and rehydrated product. Generally, there is no logical basis for comparing a good-quality fluid product with a poor-quality dry product or vice versa. Each product form should be evaluated for its own merits and defects (Fig. 11.3).

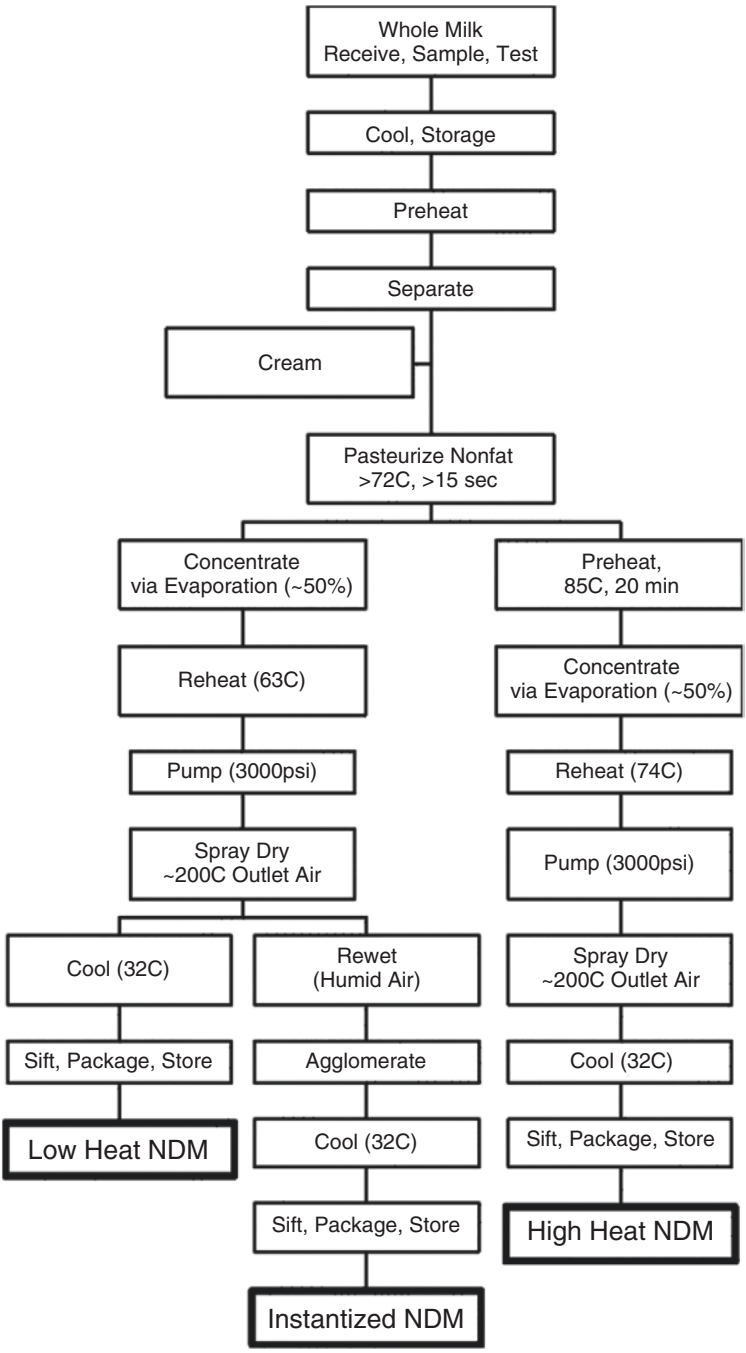

Fig. 11.3 Flow diagram for the manufacture of three forms of nonfat dry milk: low heat, instantized, and high heat

Fresh, fluid nonfat milk deteriorates with age (as do other highly perishable milk products), generally due to microbial activity. On the other hand, flavor deterioration in a dry product is most commonly due to chemical mechanisms such as the browning reaction, oxidation, and the process of staling. Also, since dry products may be in storage for months or years (as opposed to a maximum of several weeks for conventionally pasteurized fluid products), certain gradual chemical reactions generally have adequate time to manifest themselves. Thus, a sample of 1-year-old NDM may exhibit flavor characteristics inferior to that of fresh, fluid nonfat milk. However, a year-old NDM may be substantially more acceptable in flavor than a 3-week-old fluid nonfat milk.

A noteworthy supplement to the NDM (spray process) grading standard is the inclusion of criteria to distinguish the product based on heat treatment. Such details are not a grade requirement, with the exception of when the higher solubility index for high-heat powder is permitted. The nomenclature of the US Heat Treatment Classification with definition is as follows:

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

US Medium-Heat
The finished product shall exceed 1.50 mg undenatured whey protein nitrogen per gram of nonfat dry milk and shall be less than 6.00 mg undenatured whey protein nitrogen per gram of nonfat dry milk.

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

The abovementioned assay for whey protein nitrogen, in essence, is intended to measure the degree to which heat-labile whey proteins are affected as a function of the thermal treatment of the whey. Manufacturers will produce powders differentiated as such for specific food applications where the presence of undenatured whey proteins may be desirable or, conversely, undesirable relative to their functionality, e.g., high-heat powder as an ingredient in bread dough, low-heat powder used to fortify cheesemilk. Methods for the conduct of this assay are described as follows:

The whey protein nitrogen test shall be performed in accordance with DA Instruction 918-RL, "Instruction for Resident Grading Quality Control Service Programs and Laboratory Analysis," Dairy Grading Branch, Dairy Division, Agricultural Marketing Service, U.S. Department of Agriculture, Washington, DC, 20090-6456, or the latest edition of "Standard Methods for the Examination of Dairy Products," as referenced earlier in this chapter.

Medium-heat powder is considered a type of globally available standard in the manufacturing industry. Low-heat powder is used and available primarily in the USA for use in the manufacture of cheese, and high-heat powder is used primarily in the baking industry.

Whereas US labeling regulations have prohibited the use of the term "skim" when referring to any dairy product, the term "skimmed milk powder" or SMP is recognized internationally by codex nomenclature standards. SMP has a higher allowable milkfat content (1.5% max) as well as a higher allowable moisture content (5%). The criterion for protein content is also different, requiring a 34% milk protein in milk solids nonfat of 34%. Specific additives are allowed to be used in the manufacture of SMP including stabilizers, firming agents, acid regulators, emulsifiers, anticaking agents, and antioxidants.

11.17 Sensory Properties of NDM

Flavor The flavor of high-quality NDM should be similar, when reconstituted, to that of fresh fluid nonfat milk. Due to the extremely low milkfat content, NDM does not possess the rich pastry flavor of products of higher fat content. The flavor should be clean, sweet, and pleasant, but NDM may possess a slight cooked or heated flavor. Likewise, the off-flavors found in reconstituted NDM have much in common with those of WMP but differ in their relative importance. Caudle et al. (2005) demonstrated a reduction in consumer acceptance toward products formulated with off-flavored NDM powders. Interestingly, Lloyd et al. (2004) demonstrated that even extremely aged samples of NDM were acceptable to consumers for use in an emergency. Some common flavor defects of NDM include scorched, stale, storage, old, and oxidized/tallowy.

Scorched As in the instance of WMP, a scorched off-flavor is also developed in NDMs that have been subjected to abnormally high heat during processing. This defect is usually accompanied by an excessive number of scorched particles in the product; a darker, slightly brown color may be observed.

Stale, Storage, Old This flavor defect is frequently encountered in NDM. This particular off-flavor is even more quick to occur and distinct in NDM than in WMP. Usually, this flavor defect is accompanied by a slight to definite darkening of the powder color. However, some staleness may frequently be detected before any change in color is noted. As pointed out elsewhere in this chapter, there are some reasons for considering stale and storage off-flavors as separate entities. Many graders of milk powders do not attempt or even make the effort to distinguish between these two off-flavors. In old, darkened products, a sharp, slightly sour taste may be detected after the first sensation of staleness has completely disappeared. This slightly sour taste is quite similar to that noted in darkened evaporated milk, which may have resulted from storage at a high temperature for an extended time. Lea et al. (1943) variously described this off-flavor as burnt, stale, or glue-like. They reported that the so-called burnt flavor may have stemmed from a blend of the toffee flavor (derived from milkfat) and slight lactose caramelization and that quite possibly the stale off-flavor was derived from protein deterioration. Recent work (Caudle

et al., 2005) has described the storage-based flavor of NDM with such terms as animal-like, wet dog, and fryer oil. Additional recent references include Karagul-Yuceer et al. (2001), Drake et al. (2003), Karagul-Yuceer et al. (2004), and Drake et al. (2006).

Oxidized, Tallowy This off-flavor is less frequently encountered in NDMs than in WMPs. Since tallowiness is a fat-associated off-flavor, it develops when appreciable fat constituents are present. Nonfat dry milk contains a negligible amount of milkfat available to undergo autoxidation; nonetheless, under certain conditions, an objectionable oxidized or tallowy off-flavor can develop. Studies have indicated that lipid oxidation products are present in stored NDM (Karagul-Yuceer et al., 2001, 2002). Of particular note for the dried milk products judge is that a tallowy product tends to have a pronounced odor, whereas a stale powder does not exhibit an intense odor.

11.18 Physical Characteristics of NDM

Fineness and Homogeneity The grain fineness of high-quality NDM is dependent upon the characteristics of spray nozzle(s) or atomization device, the extent of concentration prior to spray drying, the extent of deficiency of pulverization, and the mesh of the bolting when the product is roller-dried. Nonfat dry milk manufactured by the spray process usually exhibits a fine, uniform particle size (Fig. 11.4). The dried product made by the roller process is much more coarse and less homogeneous, unless it is extensively pulverized after drying.

Instant NDM is usually quite granular; the product should pour as readily as corn meal, hence the name, and should readily hydrate when added to water. In contrast, non-instantized spray-dried NDM is light, dusty (nearly airborne) and has flow characteristics similar to flour (see Fig. 11.3). Upon addition to water,

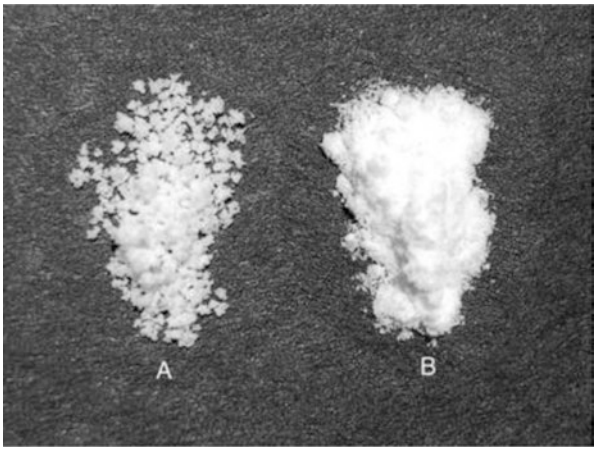

Fig. 11.4 Samples of instantized (**a**) and non-instantized (**b**) nonfat dry milk powders; note the large, porous structures of the instantized product allowing for improved wettability properties as compared to the fine structure in sample B where clumping can readily occur during rehydration

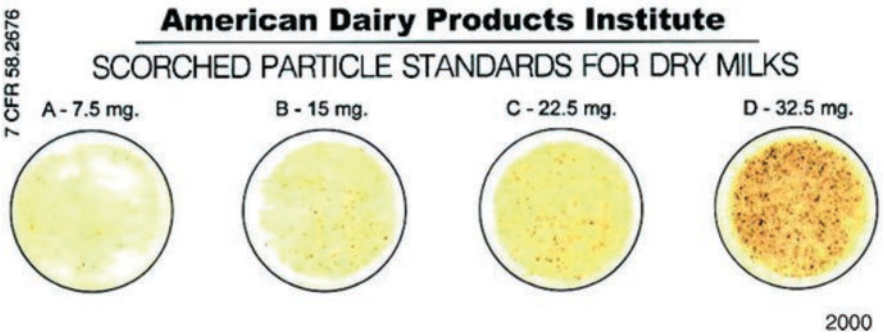

Fig. 11.5 A scorecard depicting standards or grades of dry milk relative to the appearance/mass of scorched particles. (ADPI, 2002)

non-instantized product, while easily hydrated, readily forms clumps or small nodules that can hinder further processing steps or is at least visually unappealing to consumers.

Color Nonfat dry milk, like dry whole milk, should be uniform in color and be free of foreign specks and burnt particles (see Fig. 11.5). NDM should exhibit a creamy white or light yellow color, though it may vary slightly in intensity with season of the year. Under certain conditions, NDM tends to darken in color with aging; the light yellow color darkens to a distinct brown. This appearance defect is usually associated with a stale off-flavor. For reasons not well understood, spray-process products seem to be more susceptible to age darkening (and to a greater intensity) than roller-process powders. However, dry powders made by both processes are susceptible to this defect.

11.19 Dry Buttermilk

The definitions and standards (USDA, Agricultural Marketing Service (effective February 2, 2001 for dry buttermilk (protein ≥30%) and dry buttermilk product (protein <30%) are defined as follows:

(a) Dry buttermilk (made by the spray process or the atmospheric roller process) is the product resulting from drying liquid buttermilk that was derived from the churning of butter and pasteurized prior to condensing at a temperature of 161 °F for 15 s or its equivalent in bacterial destruction. Dry buttermilk shall have a protein content of not less than 30.0%. Dry buttermilk shall not contain nor be derived from nonfat dry milk, dry whey, or products other than buttermilk and shall not contain any added preservative, neutralizing agent, or other chemicals.

(b) Dry buttermilk product (made by the spray process or the atmospheric roller process) is the product resulting from drying liquid buttermilk that was derived from the churning of butter and was pasteurized prior to condensing at a temperature of 161 °F for 15 s or its equivalent in bacterial destruction. Dry buttermilk product has a protein content less than 30.0%. Dry buttermilk product shall not contain nor be derived from nonfat dry milk, dry whey, or products other than buttermilk and shall not contain any added preservative, neutralizing agent, or other chemicals.

The two US grades of dry buttermilk and dry buttermilk product, "US Extra" and "US Standard," are determined on the basis of "flavor, physical appearance, bacterial estimate on the basis of standard plate count, milkfat, moisture, scorched particles, solubility index, titratable acidity, and protein content." The US grade requirements for dry buttermilk are summarized in Table 11.7.

The flavor of dry sweet cream buttermilk should be clean, sweet, and pleasant; it should have a somewhat richer flavor than NDM. Whereas NDM contains less than 1.5% of milkfat, dry buttermilk is allowed not less than 4.5%. With this much milkfat present in sweet cream buttermilk, the product can possess a richer, fuller flavor than NDM. On the other hand, the evaluator should remember that buttermilk is rich

Table 11.7 US grade classifications of dry buttermilk based on flavor, physical appearance, and laboratory analyses[a]

Quality attributes (or laboratory tests)	US extra grade	US standard grade
Flavor		
Unnatural	NA	Slight
Offensive	NA	NA
Physical appearance		
Lumpy	Slight	Moderate
Visible dark particles	Practically free	Reasonably free
Bacterial estimate per g (max)	20,000	75,000
Butterfat content, % (min)	4.5	4.5
Moisture content, % (max)	4.0	5.0
Scorched particles, mg (max)		
Spray	15	22.5
Roller	22.5	32.5
Solubility index, ml (max)		
Spray	1.25	2.0
Roller	15.0	15.0
Titratable acidity, %	≥0.10 to ≤0.18	≥0.10 to ≤0.20
Protein		
Dry buttermilk (min)	30.0	30.0
Dry buttermilk product	<30.0	<30

"NA" means not allowed at any level

[a]USDA, AMS US Standards for Grades of Dry Buttermilk and Dry Buttermilk Product (February 2, 2001)

in lipid constituents that are quite susceptible to oxidation. Thus, dried buttermilk powders are frequently quite vulnerable to rapid flavor deterioration and may have unpredictably high flavor variability, even lot to lot from a specific manufacturer. Off-flavors noted in dry buttermilk (stored under adverse conditions) in a study by Davis (1939) included various intensities of stale, old, musty, sharp, bitter, soapy, coarse, cheesy, rubbery, acid, fruity, tallowy, and putrid. A wider range of off-flavors will probably be noted in evaluating buttermilk than when judging NDM for flavor. The USDA standards with respect to flavor of dry buttermilk products evaluated as reconstituted products are as follows:

For US Extra Grade: "Shall be sweet and pleasing, and has no unnatural or offensive flavors."
For US Standard Grade: "Should possess a fairly pleasing flavor, but may possess slight unnatural flavors and has no offensive flavors."

Although a great deal of research on buttermilk has not been published recently, some work detailing the compositional and functional characteristics (Sodini et al., 2006) as well as the possible nutritional value of buttermilk fractions (Rombaut et al., 2006) is available in the current literature.

11.20 Dry Whey

The US standards for dry whey are available through USDA, AMS (effective December 14, 2000). Whey and dry whey are therein defined as follows:

"Whey" is the fluid obtained by separating the coagulum from milk, cream, and/or skim milk in cheesemaking. It shall conform to the applicable provisions of 21 CFR 184.1979. The acidity of the whey may be adjusted by the addition of safe and suitable pH adjusting ingredients. Moisture removed from cheese curd as a result of salting may be collected for further processing as whey if the collection of the moisture and the removal of the salt from the moisture are conducted in accordance with procedures approved by the Administrator.
"Dry Whey" is the product resulting from drying fresh whey which has been pasteurized and to which nothing has been added as a preservative. It shall conform to the applicable provisions of 21 CFR 184.1979. It contains all constituents, except moisture, in the same relative proportions as in the whey.

Only a single grade of dry whey, "US Extra Grade," is recognized; compliance is determined on the basis of flavor, physical appearance, bacterial estimate, coliform count, milkfat content, moisture, and scorched particle content (see Table 11.8). Acidity is not a component of the US grading requirement; however, acidity may be assigned as sweet (<0.16% TA), as a stated percentage %TA (>0.16 to <0.35) or as acid whey (>0.35%TA).

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

Table 11.8 US grade classifications of dry whey based on flavor, physical appearance, and laboratory analyses[a]

Category	US extra grade standard
Flavor	
Bitter	Slight
Feed	Definite
Fermented	Slight
Storage	Slight
Utensil	Slight
Weedy	Definite
Physical appearance	
Color	Uniform
Free flowing	Reasonably
Lumpy	Slight pressure
Visible dark particles	Practically free
Bacterial estimate/g (max)	30,000
Coliform	10
Milkfat content % (max)	1.5
Moisture content % (max)	5.0
Scorched particles, mg (max)	15.0

[a]USDA, AMS US Standards for Dry Whey (December 14, 2000)

with a subtle or slightly subdued acid aftertaste. Such assessments can be made by rehydrating (10 g sample to 100 g distilled water tempered to 24 °C; see ADPI, 2002). The flavor may change markedly during storage toward a stale, slightly sour flavor, accompanied by a definite browning of the product. Bodyfelt et al. (1979) studied the quality impact of dried wheys of various degrees of age and flavor quality on vanilla ice cream mix. Gas–liquid chromatography analyses indicated several pyrazines and 2-furfural to be partially responsible for mix off-flavors, variously described by the investigators as lacks freshness, stale, and whey flavor. More recent work on whey powders denotes additional detail on composition and function (Banavara et al., 2003), flavor (Mahajan et al., 2004), and browning chemistry (Dattatreya & Rankin, 2006) as well as shelf life estimation (Dattatreya et al., 2007) relative to the development of brown discoloration. One approach to the attenuation of whey color development involves the use of bleaching agents focused on denaturing water-soluble, annatto-based pigments (see Croissant et al., 2009).

The initial flavor quality of whey depends on such factors as (1) the quality of milk from which the cheese was made; (2) the type of cheese manufactured; (3) the method of whey handling immediately after curd draining; (4) the elapsed time between draining and pasteurization; and (5) the extent of adherence to good manufacturing practices. The manufacture of cheese requires the combined activity of microorganisms and enzymes, but these biochemical activities must be suddenly terminated in the whey to prevent off-flavor(s) development (Carunchia-Whetstine et al., 2003).

Acid whey, the by-product of cottage cheese and other acid-set cheese types and other dairy foods that recover low pH whey, e.g., Greek yogurt manufacturing,

represents a significant challenge to dairy plants due to decreased functionality and lower levels of valuable constituents. Although specific details are not readily available, many plants continue to dispose of rather than further refine acid whey for value-added opportunities.

Another major category of dried dairy ingredients involves the use of membrane separation and fractionation technologies and includes such products as whey protein concentrate and whey protein isolate. By subjecting either a native milk or whey stream to a membrane separation system, specific fractions of these original streams can be recovered, concentrated, and dried into powders with specific uses (Kotsanopoulos & Arvanitoyannis, 2015). Literature detailing the manufacturing and composition (Kumar et al., 2013) and sensory properties (Russell et al., 2006; Carunchia-Whetstine et al., 2005) is available. Because of the increased value and functionality of such products, continued work has focused on the application of these novel ingredients in model and authentic food systems. Advancements in separation technologies coupled with other unit operations such as hydrolysis or catalysis have resulted in increases in market opportunities and a modest proliferation of ingredients that are permutations of the general fractionation and concentration technologies. A complete listing of the collection of such ingredients is beyond the scope of this work but includes such ingredients as whey protein concentrate and isolate of various compositions, demineralized whey, individual whey protein fractions, glycomacropeptide, lactose, and mineral concentrates.

11.21 Edible Dry Casein and Caseinates

The USDA, AMS definition (effective July 20, 1968) of edible dry casein (acid) is cited as follows:

1. For the purposes of these standards, edible dry casein (acid) is the pulverized or unpulverized product resulting from washing, drying, or otherwise processing the coagulum resulting from acid precipitation of skim milk which has been pasteurized before or during the process of manufacture in a manner approved by the Administrator.
2. The product shall have been produced in a plant under conditions suitable for the manufacture of human food and packaged in a container which will prevent contamination, deterioration, and/or development of a public health hazard under normal conditions of storage and transportation.

Two grades of edible dry casein are recognized, "U.S. Extra" and "U.S. Standard," which are assigned on the basis of flavor and odor, physical appearance, bacterial estimate on the basis of standard plate count and coliform count, protein content, moisture content, milkfat content, extraneous materials, and free acid. Additional optional tests include *Salmonella* or *Staphylococcus*, percent metals (Cu), yeast, ash, and mold (as listed in Section 58.2805) and particle size. The requirements and recommended criteria for edible dry casein are summarized in Table 11.9.

Table 11.9 US grade classifications of edible dry casein (acid) based on flavor and odor, physical appearance, and laboratory analyses[a]

Category	US extra grade	US standard grade
Flavor and odor	Bland natural flavor and odor and free from offensive flavors and odors such as sour and cheesy	Not more than slight unnatural flavors or odors and free from offensive flavors and odors such as sour or cheesy
Physical appearance	White to cream colored physical appearance; if pulverized, free from lumps that do not break up under slight pressure	White to cream colored physical appearance; if pulverized, free from lumps that do not break up under moderate pressure
Bacterial estimates:		
Standard plate count/g	≤30,000	≤100,000
Coliform count/0.1 g	Negative	≤2
Protein content, $N \times 6.38$, dry basis, %	≥95	≥90
Moisture content, %	≤10	≤12
Milkfat content, %	≤1.5	≤2
Extraneous materials	Scorched particles not more than 15 mg and free from foreign materials in 25 g	Scorched particles not more than 22.5 mg and free from foreign materials in 25 g
Free acid	Titrated to not more than 0.20 ml of 0.1 N NaOH per g	Titrated to not more than 0.27 ml of 0.1 N NaOH per g
Optional tests (recommended criteria):		
Ash (phosphorus fixed) %	≤2.2	
Copper, ppm	≤5.0	
Lead, ppm	≤5.0	
Iron, ppm	≤20.0	
Yeast and mold, per 0.1 g	≤5.0	
Thermophiles, per g	≤5000	
Reducing sugars (as lactose) %	≤1.0	
Staphylococcus (coagulase positive)	Negative	
Salmonella in 100 g	Negative	
Particle size – 30, 60, 80 or other specified mesh		
30 mesh	100% must pass 30 ASTM screen, 10% may pass 60 ASTM screen	
60 mesh	99% must pass 50 ASTM screen, 10% may pass 80 ASTM screen	
80 mesh	100% must pass 60 ASTM screen, 85% may pass 80 ASTM screen	

[a]USDA, AMS US Standards for Grades of Edible Dry Casein (Acid) (July 20, 1968)

Caseinates Acid casein is commonly recovered as a more usable form such as sodium, potassium, or calcium caseinate. In the salt form, caseinates have found wide application as food ingredients, principally in nondairy foods such as bakery products, dairy product analogs, processed meats, and coffee whiteners, due to their increased solubility relative to the acid or rennet forms. A blend of caseinate and whey solids may be made to emulate the composition and functional properties of nonfat dry milk. In various food applications, caseinates perform specific functions. How adequately a given lot or source of caseinate performs the various food ingredient functions should be a primary criterion of the quality evaluation process for these milk-derived products. Hydrolyzed sodium caseinates are also available as highly functional protein-based food ingredients.

Casein (rennet) and caseinates are subject to variations in sensory quality either during the manufacturing process or as a result of deteriorative changes that occur during storage. The USDA standards specify freedom from offensive flavors and odors; off-flavors such as sour and cheesy are identified. A stale off-flavor may develop during storage, which may be related to a similar off-flavor that occurs in stored dry milk, sterile milk, and evaporated milk. More research is needed to better chemically characterize this off-flavor and to learn the mechanism(s) of the stale flavor formation.

In the process of manufacturing casein, the curd is washed to remove impurities and residual milk components. Lactose is one of several compounds that may be retained in excessive concentration if the casein curd is not adequately washed. The USDA standards establish 1% as the upper limit for lactose in casein. The presence of lactose in casein products unfortunately potentiates the Maillard (browning) reaction, especially when casein has been converted to a more alkaline caseinate. A brown pigment need not appear for off-flavors to manifest themselves, because pigment formation occurs in latter stages of the nonenzymatic browning, after numerous flavor compounds and precursors have been formed. Thus, low residual lactose levels should be sought in dry casein products.

A frequent and serious flavor defect in caseinates is referred to as gluey. As the term implies, this off-flavor is suggestive of protein degradation. Under alkaline conditions (as with caseinates), protein degradation occurs at an accelerated rate. Work to determine the chemical cause of off-odors in rennet casein identified such compounds as guaiacol, indole, and ρ-cresol was conducted by Karagul-Yuceer et al. (2003).

11.22 Dry Milk, Other Milkfat Levels

With the introduction of the Nutrition Labeling and Education Act of 1990, some traditional dairy product nomenclature was revised to comply with this cross-commodity standard, e.g., skim milk was renamed as nonfat milk. One dry product, low-fat dry milk and its accompanying descriptions, definitions, and standards was

also affected in this regulatory shift. What was once present as "Lowfat Dry Milk" in 21 CFR 131.123 no longer exists as a discrete product under the new labeling laws. Products that are intermediate to nonfat and whole dry milks now come under the labeling/nomenclature and compositional requirements of 21 CFR 101.62, Nutritional Content Claims For Fat, Fatty Acid, and Cholesterol Content of Foods.

11.23 Dry Cream

The FDA standard of identity for dry cream may be found in 21 CFR 131.149 (2020). The following is the description and list of optional ingredients for dry cream:

Description
Dry cream is the product obtained by removal of water only from pasteurized milk or cream or a mixture thereof, which may have been homogenized. Alternatively, dry cream may be obtained by blending dry milks as defined in Section 131.125(a) and 131.147(a) with dry cream as appropriate, provided that the resulting product is equivalent in composition to that obtained by the method described in the first sentence of this paragraph. It contains not less than 40% but less than 75% by weight of milkfat on an as is basis. It contains not more than 5% by weight of moisture on a milk solids not fat basis.

Optional Ingredients
The following safe and suitable optional ingredients may be used: emulsifiers, stabilizers, anticaking agents, antioxidants, and nutritive carbohydrate sweeteners. Characterizing flavoring ingredients, with or without coloring, is as follows: fruit and fruit juice, including concentrated fruit and fruit juice; natural and artificial food flavoring.

No specific classification for grades of dry cream has been issued by the USDA. Off-flavors in dry cream products parallel those that develop in dry whole milk (i.e., stem from oxidation of lipid components during storage). In addition to lipid oxidation, browning reactions and staling are significant quality problems of dry cream. Dry creams have many applications as food ingredients, especially in the formulation and manufacture of finished products in regions where a consistent source of fresh cream is difficult to secure.

11.24 Dry Ice Cream Mix

Dry ice cream mix products differ from the other dry products in that mere reconstitution with water does not yield the finished product, in this case, frozen ice cream or low-fat ice cream. The reconstituted mix generally requires added flavoring, and this mixture is then frozen. Thus, evaluation of the dry mix following reconstitution may not be adequate, since the sensory properties of the resultant frozen product are

of paramount interest. As a rule, a mix that has inferior flavor characteristics can be expected to yield an ice cream of poor flavor quality. Freezing characteristics, body and texture, and color/appearance are additional quality considerations for the product.

Dry ice cream or low-fat ice cream mix may be made by spray drying the liquid mix, although a portion of the sweetener may be withheld prior to drying to avoid excessive browning. The remaining required sugar can be subsequently dry-blended with the dry mix. Alternatively, the entire dry mix may be assembled by dry-blending all of the various ingredients, such as nonfat dry milk, dry cream, sugars, and any stabilizer/emulsifier. A concern would exist as to whether the reconstituted mix can then be frozen without re-pasteurization (assuming the initial mix was pasteurized). Dry ice cream (and low-fat ice cream) mixes are subject to the development of exactly the same defects as dry whole milk and dry cream. These defects result from heat treatment, browning reactions, staling, and oxidation processes.

11.25 Miscellaneous Dry Products

A partial list of miscellaneous dry milk products includes milk protein concentrates and isolates, instant chocolate drink, instant hot cocoa mix, instant breakfast drinks, dry cheese, casein/whey blends, malted milk, nondairy coffee whiteners, and other, novel dairy fractions such as whey protein phospholipid concentrate and de-lactosed permeate. Products of this type are generally formulated according to proprietary specifications; some are covered by specific patents. Sensory quality control of dry-milk-based foods depends on maintaining a high level of consumer acceptability; this embraces flavor, physical appearance, rehydration characteristics, and product functionality. Some of these products are manufactured by drying from a high-concentration liquid slurry state, while other dry products may be assembled as the result of dry-blending various ingredients.

11.26 Scoring and Grading Dry Milk

Several sensory terms have been adopted in an attempt to classify flavor defects of various dry milk products. Unfortunately, these particular descriptors have not been used that consistently between technologists or researchers involved with dry milk products. As early as 1957, a committee of the American Dairy Science Association (Thomas, 1958) proposed definitions for the flavor and appearance characteristics as well as for the packaging of dry milks. A suggested dry milk products scorecard is presented in Fig. 11.5, and a suggested scoring guide for flavor is offered in Table 11.10. A typical recommendation for the evaluation of dry milk products involves rehydrating the product to a reasonable concentration (e.g., 10% w/w

Table 11.10 A suggested scoring guide for the flavor of dry milk (reliquified basis)

	Scores for a given intensity				
Defect	Slight	Moderate	Definite	Strong	Pronounced
Acid	2	1	0	0	0
Astringent	8	7	6	5	0–4
Bitter	6	5	4	3	0–2
Chalky	8	7	6	5	0–4
Cooked	9	8	7	6	5
Feed	8	7	6	5	0–4
Fermented	6	5	4	3	0–2
Flat	9	8	7	6	5
Foreign[a]	2	1	0	0	0
Gluey	2	1	0	0	0
Metallic	4	3	2	1	0
Neutralizer[b]	0	0	0	0	0
Oxidized/tallow[c]y	4	3	2	1	0
Rancid (lipolysis)	5	4	3	2	0–1
Salty	7	6	5	4	0–3
Scorched	4	3	2	1	0
Stale	4	3	2	1	0
Storage	7	6	5	4	0–3
Unclean/utensil	5	4	3	2	0–1
Weedy	3	2	1	0	0

"No criticism" is assigned a score of "10." Normal range is 1–10 for a salable product where 10 represents a product of ideal flavor character. A sample may be assigned a score of "0" (zero) if the defect makes the product unsalable

[a]Due to the variety of foreign off-flavor sources, a fixed scoring range is not appropriate. Some foreign off-flavors warrant a score of "0" (zero) even if the intensity is slight (i.e., gasoline, pesticides, lubricating oil)

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

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

solution), allowing the product to fully rehydrate (Lloyd et al., 2004) and sampling the product at the appropriate temperature. Higher sampling temperatures (e.g., 45 °C) tend to make volatile aroma compounds more apparent to the imbiber. While such a practice may yield an overly sensitive assessment, it may be appropriate when the powder will be used in a food that requires a concentration step (i.e., cheese manufacture) or that has an extremely sensitive flavor profile. The lists below contain terms and brief definitions that have traditionally been used for the quality evaluation of most dry dairy ingredients. A more complete analysis of the sensory attributes of dried dairy ingredients requires descriptive sensory analysis. Both this technique and sensory attributes specific and descriptive of dried dairy ingredients are addressed elsewhere in this book (Fig. 11.6).

Product ID		Date	Sample #							
Flavor		Criticism/Score ---------->								
No Criticism	10	Acid								
Normal Range	4 to 8	Astringent								
Unsalable	0 to 3	Bitter								
		Chalky								
		Cooked								
		Feed								
		Fermented								
		Flat Foreign								
		Gluey								
		Metallic								
		Neutralizer								
		Oxidized/Tallowy								
		Rancid (Lipolysis)								
		Salty								
		Scorched								
		Stale								
		Storage								
		Unclear/Utensil								
		Weedy								
Physical Appearance		Criticism/Score ---------->								
No Criticism	5	***Dry Product***								
Normal Range	2 to 4	Caked								
Unsalable	0 to 1	Lumpy								
		Unnatural Color								
		Reconstituted Product								
		Charred Particle								
		Dark Particle								
		Grainy								
		Undispersed Lumps								
Packaging		Criticism/Score ---------->								
No Criticism	5	Ruptured Vapor Barrier								
Normal Range	2 to 4	Soiled								
Unsalable	0 to 1	Unsealed								
Laboratory Tests		Criticism/Score ---------->								
No Criticism	5	***Chemistry***								
Normal Range	2 to 4	Alkalinity of Ash (mL/100g)								
Unsalable	0 to 1	Alkaline Phosphatase (U/L)								
		Ash Phosphorous Fixed (%)								
		Copper (ppm)								
		Fat (%)								
		Iron (ppm)								
		Lead (ppm)								
		Moisture (%)								
		Oxygen Content (%)								
		Protein (%)								
		Reducing Sugars (as Lactose %)								
		Undenatured Whey Protein Nitrogen (mg/gram)								
		Vitamin A (IU)								
		Vitamin D (IU)								
		Functionality								
		Dispersibility (Modified Moats-Dabbah method (%))								
		Mesh (Screen %)								
		Scorched particles (mg)								
		Solubility Index (mL)								
		Titratable Acidity (% Lactic acid)								
		Microbiology								
		Coliform Count (per gram)								
		Direct Microscopic Count (per gram)								
		Salmonella Count (per 100 gram)								
		Staphylococcus Count (Coagulase+) per gram								
		Thermophilic Count (per gram)								
		Total Plate Count (per gram)								
		Yeast and Mold Count (per 0.1 gram)								

Signatures: _____

_____

_____

Fig. 11.6 A suggested dry milk product scorecard

11.27 Flavor Descriptors of Dry Milks

As a preface for purposes of providing definitions for the intensities of specific sensory attributes, the USDA has defined the following terms:

Slight
Detected only upon critical examination.

Definite
Not intense but detectable.

Acid The term acid is used to describe the odor and taste (primarily) that result from the action of lactose-fermenting bacteria in milk and milk products to produce lactic acid that typically exhibits a clean, distinct sour taste.

Astringent Astringent refers to a puckery type of mouthfeel sensation similar to that produced by a chemical such as aluminum ammonium sulfate and tannic acid; unripe bananas may also be used as a standard. There is an associated tactile sensation to the astringent off-flavor; the mucous membranes of the palate and/or tongue tend to shrink (Sano et al., 2005).

Bitter The bitter defect resembles the taste sensation imparted by bitter substances, such as quinine, caffeine, and certain milk-protein-derived peptides. This defect is often associated with the growth of proteolytic microorganisms in milk (certain psychrotrophs and some spore-forming bacteria).

The USDA employs comparable definitions of bitter for several dry milk products. For instance, in describing bitterness in dry whole milk, the USDA states "Similar to taste of quinine and produces a puckery sensation." The USDA Explanation of Terms sections for graded dairy products states "Distasteful, similar to taste of quinine." A direct statement such as "resembles the taste of quinine or caffeine" seems to be an adequate definition of bitterness.

Chalky This descriptor of a common off-flavor in concentrated milk products suggests the inclusion of fine, insoluble, chalk (powder) particles. The USDA definition for chalky is "A tactual type of flavor lacking in characteristic milk flavor." The chalky off-flavor is more of an objectionable mouthfeel sensation than it is an off-taste. The chalky defect frequently tends to manifest itself as a delayed mouthfeel – an aftertaste response of the evaluator.

Cooked Cooked has an odor and flavor resembling that of milk that has been heated to 73.8 °C (164.8 °F) or higher. The USDA definition for cooked flavor in dry milk products is "Similar to a custard flavor and imparts a smooth aftertaste."

Feed A milk off-flavor that is usually characteristic of the roughage (feeds) consumed by milk cows is simply referred to as a feed defect. Several USDA definitions

state “Feed flavors (such as alfalfa, sweet clover, silage, or similar feed) in milk carried through into the nonfat dry milk.”

Flat The descriptor flat implies a lack of fullness of flavor; this flavor defect is suggestive of added water. It is not detectable by odor perception. The listed USDA definition for flat is “Insipid, practically devoid of any characteristic reconstituted nonfat dry milk flavor.”

Fermented The following definition for fermented is taken from the USDA standards for dry whey: “Flavors, such as fruity or yeasty, produced through unwanted chemical changes brought about by microorganisms or their enzyme systems.”

Foreign Foreign refers to any atypical or objectionable off-flavor that is not ordinarily associated with good-quality milk; sometimes a chemical- or medicinal-like off-flavor may have occurred. This flavor defect usually stems from the fluid milk used as a raw material to produce the dry milk and may relate to the presence of residual sanitizer and/or cleaning agents in the product.

Metallic The off-flavor, metallic, is quite suggestive of the presence of copper or iron in the raw material used to produce the dried product. Metallic is usually regarded as a phase of oxidized (metal-induced) off-flavor.

Neutralizer The neutralizer off-flavor is an alkaline taste generally derived from alkaline substances used to neutralize any developed acidity in milk. The USDA has made provisions for the pH adjustment of dry whey using “safe and suitable pH adjusting ingredients,” but acid neutralization of most other dry products is not permitted.

Oxidized Milkfat oxidation is the cause of the defect described by the term oxidized in many dairy foods, including dry milk products. The perceived sensation in an oxidized off-flavor resembles wet cardboard, oily substances, or aged beef tallow, depending on the defect intensity. The USDA definition also includes the term cappy, which refers to the bygone days when paperboard “caps” were placed on milk containers, imparting a type of “wet cardboard” aroma.

Rancid Rancidity in dry milk products usually exhibits a strong, pungent odor that may be accompanied by a soapy aftertaste. These sensory properties are primarily due to the generation of small, short-chain fatty acids resulting from the hydrolysis of milk triglyceride.

Salty A salty taste defect in dry milk products is simply a perceived primary taste of salt or a salt solution; it resembles a milk product that contains excessive amounts of salt. Perception of a salty taste on the front tip and sides of the tongue is relatively rapid, compared to other experienced taste sensations.

Scorched This flavor defect is produced when milk powder has been subjected to excessive heat in the drier or other heat-exchange processes; it is generally suggestive of burnt protein. The USDA definition for scorched is "A more intensified flavor than cooked," plus an additional statement that this flavor defect is generally characterized by having a burnt aftertaste.

Stale Stale generally implies a lack of product freshness. This flavor sensation in dried milk products is ordinarily associated with deterioration of milk protein rather than milkfat. Some dairy product evaluators tend to use the descriptor "lacks freshness" in lieu of the term "stale," while other evaluators use both of the aforementioned descriptors interchangeably. The terms "stale" or "lacks freshness" are commonly applied when the flavor is not as refreshing as expected by the evaluator.

There is an apparent anomaly in use of the terms "stale" and "storage" as flavor descriptors. The USDA provides guidelines for various intensities of both stale and storage off-flavors, but their singular definition treats them as one and introduces some element of confusion for product evaluators (i.e., "Stale, storage. Lacking in freshness and imparting a 'rough' aftertaste"). Such discrepancies suggest that more mainstream sensory techniques should be applied to develop a more accurate terminology.

The author notes that a logical argument can be made for the acceptance of separate meanings of the terms "stale" and "storage." It is true that a stale off-flavor in dry milk can develop during storage but so can the oxidized off-flavor. Analogous to the oxidized off-flavor, stale is a distinctively recognizable off-flavor that typically develops over the course of storage. Unfortunately, thus far, research has not conclusively pinpointed the chemical precursor or the actual chemical entity that is responsible for the stale off-flavor. The precursor could be any of the following: (1) a protein, (2) a product of the Maillard reaction, or (3) some compound(s) derived from milkfat. The chemical compound(s) produced from potential precursor(s) may require that the substance(s) undergo oxidation to eventually produce the stale off-flavor. The salient point is that the stale off-flavor is a distinct entity, whereas the designation "storage off-flavor" is somewhat more generic. Hence, the descriptor "storage" more appropriately encompasses a range of off-flavors that dry milk products may acquire during a period of storage. These shortcomings may range from absorbed off-flavors (from the storage environment) to flavor defects that develop from slow, gradual chemical reactions in the product, which can be appropriately designated as a "lacks freshness" and/or "storage" off-flavor.

Unclean (Utensil) Typically, the unclean flavor defect in dry milks refers to an unpleasant odor and lingering aftertaste that is suggestive of organic decomposition products. The sensation of "uncleanliness" may vary from an odor that resembles barny or barnyard-like, to that of spoiled feed or the decay of organic matter. These objectionable sensory characteristics are usually due to proteolytic or lipolytic activity by spoilage bacteria in milk. The unpleasant aftertaste is often dirty-like, persistent, and generally objectionable, if not obnoxious.

The USDA definition is somewhat more general and only relies on the antiquated term "utensil." Hence, unclean (utensil) is described by USDA terminology thus, "A flavor that is suggestive of improper or inadequate washing and sanitation of milking machines, utensils, or manufacturing equipment." Due to its questionable relevance, the term utensil should probably no longer be used in describing this off-flavor, yet it still exists in the standards. The activity of spoilage microorganisms (e.g., psychrotrophs) in residual milk soils that remain on the equipment is responsible for the defect, not the equipment and/or utensils themselves.

Undesirable The USDA uses the term undesirable to describe certain off-flavors that are in excess of the permitted intensity in specific grades of dried milk products or for those miscellaneous off-flavors that are not otherwise listed.

Weedy Weedy is a flavor characteristic of certain weeds that may be consumed by cows that produced some of the raw material used for manufacture of the dried product. See the dry whey grading standard (USDA, AMS, 2001).

11.28 Terms Describing the Appearance of Dry Products

The reader is advised to review Table 11.11 for a suggested scoring scheme for physical appearance characteristics of dry milks. USDA grading literature also provides the following intensity definitions:

Practically Free
Present only upon very critical examination.

Reasonably Free
Present only upon critical examination.

Table 11.11 Suggested scoring guide for the physical appearance characteristics of dry milk

	Scores for a given intensity				
Defect	Slight	Moderate	Definite	Strong	Pronounced
Dry:					
Caked	2	1	0	0	0
Dark particles	3	2	1	0	0
Lumpy	4	3	2	1	0
Unnatural color	4	3	2	1	0
Color not uniform	4	3	2	1	0
Reconstituted:					
Churned particles	3	2	1	0	0
Dark particles	3	2	1	0	0
Grainy	3	2	1	0	0
Undispersed lumps	3	2	1	0	0

"No criticism" is assigned a score of "5." Normal range is 1–5 for a salable product where 5 represents a product of ideal appearance character. A score of "0" (zero) is assigned if the product is determined to be unsalable

Moderately Free
Discernible upon careful examination.

Caked Caked means a hardened mass of powder that results from lactose crystallization. It usually disintegrates into small hard chunks, which are practically undispersible in water.

Lumpy Lumpy refers to a nonhomogeneous appearance of dry milk, which is due to sizeable lumps of agglomerated powder particles. The USDA definition for lumpy is "Loss of powdery consistency but not caked into hard chunks."

Reasonably Free Flowing This refers to the ability of the product to flow, in powder form. USDA language is as follows: "Pours in a fairly constant, uniform stream from the open end of a tilted container or scoop."

Unnatural/Natural Color Unnatural color refers to an abnormal or atypical color of the product due to either caramelization of lactose, nonenzymatic browning, or added color. The USDA defines unnatural color for dry whole milk and nonfat dry milk as follows: "A color that is more intense than light cream and is brownish, dull or grey-like." Conversely, *natural color* is defined as "A color that is white to light cream."

Visible Dark Particles Scorched powder particles or visible extraneous matter is termed "visible dark particles." A similar definition is offered by the USDA: "The presence of scorched or discolored specks." The American Dairy Products Institute (see https://www.adpi.org/DairyProducts/tabid/62/Default.aspx) provides publicly available standards for such particles for a variety of common dried dairy ingredients.

11.29 Terms Describing the Appearance of Reconstituted Product

Churned Particles Masses of coalesced fat and/or coagulated protein that may float to the surface (and eventually adhere to the side wall of the container) are generally called "churned particles."

Grainy Grainy refers to visible insoluble particles in reconstituted milk products that distinctly appear granular. This is the only appearance term defined by the USDA for reconstituted dry products. The USDA definition reads "Minute particles of undissolved powder appearing in a thin film on the surface of a glass or tumbler."

Pressure This term refers to the dissolution of lumps as the product is rehydrated and blended, similar to what will occur during manufacture, and is defined as follows: "*Very slight pressure*. Lumps fall apart with only light touch," "*Slight pres-*

sure. Only sufficient pressure to disintegrate the lumps readily," and "*Moderate pressure*. Only sufficient pressure to disintegrate the lumps easily." Intuitively, the term "undispersed lumps" refers to masses of caked or lumpy powder that do not readily dissolve in water.

11.30 Terms to Describe Packaging Defects

The product package is not a defined criterion in the USDA grading system. Documents included in 7 CFR 42 provide general requirements for the condition of food-grade packaging. The US Dairy Export Council provides some description and convention regarding adequate packaging design and application for dried dairy ingredients in their publication, "Reference Manual for U.S. Milk Powders, 2005 revision." A suggested guide for scoring the package integrity of dry milk products is illustrated in Table 11.12.

Ruptured Vapor Barrier Any visible mechanical opening in the product package is referred to as a "ruptured vapor barrier."

Soiled The unsightly appearance of the package exterior due to adherence of dried product or any foreign substance is simply called "soiled."

Unsealed Unsealed refers to a closure that is not secured in such a manner to guarantee that access to the product is impossible without breaking or tearing a visible seal on the product container.

11.31 Laboratory Tests of Dry Dairy Products

Certain laboratory tests are indispensable in helping to assess the quality parameters of dry dairy products. Analyses provide objective, quantitative measures of hygienic quality, product composition, rehydration characteristics, possible acidity development (as well as evidence of neutralization of excessive acidity), compliance with minimum pasteurization requirements, and potential keeping-quality

Table 11.12 A suggested scoring guide for the packaging of dry milk

Parameter	Score range
Soiled package, graded and scored proportional to the nature and quantity of soil	0–5
Unsealed package and/or ruptured or defective vapor barrier	0
Any packaging that fails to meet the requirements of regulatory agencies	0

A score of zero ("0") is assigned if the defect is so serious (or pronounced in intensity) as to render the product unsalable

characteristics. Descriptions and procedures used for conducting such assays are included in several well-recognized resources, listed below for reference.

AOAC, International. (2019) Official Methods of Analysis 21st Ed. Revision 1. AOAC International, Arlington VA. See www.aoac.org

Standard Methods for the Examination of Dairy Products 17th Ed. (2004) H. M. Wehr and J.F. Frank eds. American Public Health Association, Inc., Washington D.C. See www.apha.org

From the U.S. Dairy Export Council (See www.usdec.org).

Reference Manual for U.S. Milk Powders
Reference Manual for U.S. Whey and Lactose Products

From the American Dairy Products institute (See www.adpi.org).

Dry Milks
Concentrated milk
Whey products

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

11.32 Methods of Reconstituting Dry Dairy Products for Flavor Examinations

Limited quantities of reconstituted dry milk and whey products are used as beverage products in the USA. However, even if they are used only as ingredients in dairy products or other foods, the sensory properties of reconstituted dry dairy ingredients must meet desired standards and favorably contribute to the desired quality criteria of finished product(s). Therefore, a standardized procedure should be devised by each user for evaluating dry dairy products for determining their suitability as a food product ingredient. For example, if a poor-quality (off-flavored) NDM is used in ice cream manufacture, the off-flavor(s) will most likely carry through into the ice cream. On the other hand, a slightly off-flavor NDM may sometimes be incorporated into highly flavored products with little negative impact.

Two types of test situations may arise with dry dairy products to be consumed as a beverage. In acceptability testing using a consumer panel, the product should be reconstituted in exactly the same manner as the consumer is instructed to do by the user directions on the container. The temperature at which the reconstituted product is served in the test should be the typical consumption temperature for the product. In grading or quality evaluation (discrimination) by trained evaluators or panelists, conditions are chosen and defined in order to optimize detection of off-flavors but not exaggerate their intensity; such assessments may include the incorporation of the ingredient into an authentic dairy food (Lloyd et al., 2004; Caudle et al., 2005; Drake et al., 2003). Since the perceived intensity of flavor characteristics varies with temperature, comparative judgments should be made with reconstituted samples at the same temperature. In most instances, USDA dairy product grading standards

require that products be evaluated within a specific temperature range. However, a study using trained evaluators and Cheddar cheeses showed that serving temperature had no impact on panelist or panel performance (Drake et al., 2005).

Normally, grading or quality evaluation should be performed on dry dairy products that are intended as ingredients for other foods. The odor perceived immediately after the containers are opened should be carefully noted, since it provides an immediate clue to a possible flavor problem. Precautions should be taken to avoid inhaling powder. The powder should be reconstituted and evaluated under standardized conditions, including a specified ratio of powder to water, source of water, manner of mixing, temperatures and time interval between reconstitution, and actual testing. The re-liquefied product should be evaluated in practically the same manner as its fluid counterpart. The evaluators should know, learn, and "fix-in-mind" the desirable flavor characteristics of whey, sweet cream, buttermilk, nonfat milk, etc., to which they must mentally compare the flavor of the reconstituted product.

Distilled water is commonly used for reconstituting dry dairy ingredients for flavor evaluation, even though tap water is more likely to be used in the home, as well as in the plant. Since tap water varies in hardness and flavor in different locations, there is a rationale for specifying distilled water. However, since distilled water may also vary in sensory properties (depending on residual impurities), a good precaution is to ensure that the water is relatively tasteless and odorless.

Directions for determining the taste and odor of products derived from reconstituted milk were prescribed by the USDA as follows:

> Reconstitute with an electric mixer 6.5 g of whey, 10 g of nonfat dry milk, or 13 g of dry whole milk in 100 ml of distilled water. Allow samples to stand 1 hour, stir thoroughly, and taste at room temperature. Observe odor and taste in a room free of disturbance and off-odors. Report the flavor as satisfactory or report the off-flavor in accordance with the appropriate US grade standards.

A directory of Codex Standards for the evaluation of dairy ingredients in found in the document Codex Stan 234-1999 wherein the sampling method allows an adjustment based on milkfat content (see IDF 50C and 113A).

11.33 Conclusion

With the ability to provide high nutrition, quality, and functionality, dry dairy ingredients continue to be a strong component of the dairy foods industry, growing in both volume and diversity. Coupled with the advent of improved manufacturing technologies as well as novel technologies such as membrane separation systems, dry dairy ingredients see applications as novel ingredients in a growing number of food systems. In almost every case, however, dried dairy ingredients remain complex both physically and chemically, requiring a sound, science-based understanding of their properties to maintain the value of these ingredients in an increasingly competitive market. Sensory assessments continue to provide a frontline of

information detailing the chemical, microbial, and physical properties of dry dairy ingredients. Routine grading practices as well as formally defined consumer and trained descriptive methods each have roles in the maintenance and understanding of manufacturing dry dairy ingredients with desirable flavor and functional properties.

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