Milk and Milk Products

11

Introduction

Milk is the first food of young mammals produced by the mammary glands of female mammals. It is a mixture of fat and high-quality protein in water and contains some carbohydrate (lactose), vitamins, and minerals. Milk and milk products may be obtained from different species, such as goats and sheep, although the focus of this chapter is on *cow's* milk and milk products.

While fluid milk contains a very large percentage of water, it may be concentrated to form evaporated milk and cheeses. Throughout the world, it is used in a variety of ways, such as a beverage, cheese, yogurt, or in soups and sauces.

By law, milk and milk products must contain a designated percent of ***total milk solids*** (all of the components of milk except water), and also, the ***milk solids***, ***not fat*** (***MSNF***) (all of the components of milk solids not including fat). The butterfat component of milk is the most expensive component of milk and its level determines if milk is offered for retail sale as whole milk or at some lesser percentage of fat, such as 2 % milk, 1 %, 1/2 %, or fat-free.

Milk may be cultured, dried, fortified, homogenized, or pasteurized and used to create products with different taste, texture, nutritive value, and shelf life. It may be processed into products such as buttermilk, cheese, cream, ice milk, ice cream, sour cream, and yogurt with different levels of fat content. Dried milk is added to a multitude of foods. It may be added to foods to increase the protein or calcium value.

The top eight milk-producing states produce 196.2 billions of pounds as follows:

California	21.1 %
Wisconsin	13.3
Idaho	6.8
New York	6.5
Pennsylvania	5.4
Texas	4.9
Minnesota	4.5
Michigan	4.3
All others	33.1 %
Source: USDA (2011)	

Total Milk Production has gone from 165.3 billions of pounds in 2001 to the 196.2 billion pounds in 2011 shown above.

High temperatures may curdle milk; therefore, care must be taken in the preparation of foods with milk. Milk requires safe handling and cold storage.

Milk is not well tolerated by a large portion of the population. The milk sugar, lactose, is not digested by persons lacking the enzyme lactase.

Definition of Milk

> Milk means the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows, which may be

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> clarified and may be adjusted by separating part of the fat there from; concentrated milk, reconstituted milk, and dry whole milk. Water, in a sufficient quantity to reconstitute concentrated and dry forms may be added. (FDA)

Further useful Food and Drug Administration (FDA) definitions, such as that for cheese, appear later in this chapter.

Composition of Milk

Milk varies in physical and chemical composition depending on such factors as age and breed of the cow, activity level, stage of lactation, use of medication, and interval between milking. It consists mainly of water and contains some serum solids or milk solids, nonfat (MSNF) such as lactose, caseins, whey proteins, and minerals. Milk also naturally contains fat.

Water

Water is the largest component of milk and is present at a level of approximately 87–88 %. If that water is removed, the shelf life of milk products is greatly extended.

Carbohydrate

Carbohydrate is water-soluble and present in the aqueous phase of milk, at levels of slightly less than 5 %. The disaccharide *lactose* is the main carbohydrate. It exhibits low solubility and may precipitate out of solution as a grainy textured substance. It is converted to lactic acid (1) upon souring due to bacterial fermentation and (2) in the process of aging cheese. Therefore, aged cheese may be digestible by lactose-intolerant individuals even in the absence of the enzyme lactase. (The lactose content of milk and some milk products appears in Table 11.2. See section "Lactose Intolerance.")

Fat

Fat has a low density and may *easily* be centrifuged or *skimmed off* of the milk yielding low-fat or *skim milk*. The fat, or butterfat, exists at levels of approximately 3.5 % in whole milk, at lesser levels in reduced-fat or nonfat milks, and at *significantly* higher percentages in cream. Fat is the expensive component of milk and the basis on which dairy farmers are paid for milk. When fat and its carotenoids are removed, milk is bluish in color.

Fat globules are less dense than the water in the aqueous phase of milk and, therefore, rise to the top of the container in the ***creaming*** process. When emulsified during *homogenization*, there is an increase in the number of fat cells and greater viscosity because the fat is distributed throughout the fluid, and creaming does *not* occur. Membranes of lipids and protein, including lecithin, from each fat globule remain in the milk as it is processed.

Fat content in milk varies greatly in calories. The completeness of milking determines richness of the fat content. Milk either carries or may be fortified to contain the fat-soluble vitamins, and it contains the pigments carotene and xanthophyll. Fat contains the sterol cholesterol and phospholipids, although it is primarily triglyceride (95 %) with saturated, polyunsaturated, and monounsaturated fatty acid components. These have varying melting points and susceptibility to oxidation. The fatty acid chains contain many short-chain fatty acids such as the saturated butyric acid (4 °C) and caproic, caprylic, and capric acids.

A number of the more than 400 individual fatty acids have been identified in milk fat. It is approximately 15–20 *fatty acids* that make up 90 % of the milk fat. *Phospholipids* (such as phosphatidylcholine and sphingomyelin) in cell membranes compose approximately 1 % of the fat in milk.

Protein

Protein represents 3–4 % of the composition of milk and components may be fractioned out of milk by *ultracentrifugation*. ***Casein** is the primary protein of milk*, comprising approximately 80 % of the milk protein. The caseins are actually a group of similar proteins, which can be separated from the other milk proteins by acidification to a pH of 4.6 (the isoelectric point). At this pH, the caseins aggregate, since they are hydrophobic, are poorly hydrated, and carry no net charge. The other milk proteins, being more hydrophilic, remain dispersed in the aqueous phase.

There are three main casein fractions, known as alpha$_s$-, beta-, and kappa-casein (α_s-, β-, and κ-casein). Alpha$_s$-casein actually comprises two fractions: α_{s1}-casein and α_{s2}-casein. However, these two fractions are difficult to separate from each other. The four fractions α_s-, β-, κ-, and α_{s2}-casein occur in the weight ratio 3:3:1:0.8. All four fractions are phosphoproteins containing phosphate groups esterified to the amino acid serine. The α_s- and β-casein fractions contain several phosphate groups and as a result are "calcium-sensitive" and may be coagulated by addition of calcium. Kappa-casein contains only one phosphate group and is not calcium-sensitive. The α_s- and β-casein fractions are very hydrophobic. However, κ-casein is a glycoprotein containing an acidic (charged) carbohydrate section, and so it is much more hydrophilic.

In milk, the casein fractions associate with each other and with colloidal calcium phosphate to form stable spherical structures known as ***casein micelles***. The more hydrophobic α_s- and β-casein fractions exist mainly in the interior of the micelles, whereas the more hydrophilic κ-casein exists mainly on the micelle surface. It is the κ-casein that gives the micelles their stability in milk under normal handling conditions.

This is due to the negative charge and hydration of the κ-casein, coupled with the fact that the charged hydrophilic carbohydrate section of the molecule tends to protrude from the micelle surface in hairlike structures, which confer steric (or spatial) stability on the micelles. Also, since κ-casein is not sensitive to calcium, it protects the other caseins from the ionic calcium in milk, thereby increasing the stability of the micelles.

There have been several different views of the structure of the casein micelles, and their structure is still debated. Two major structural models have been postulated. The submicelle model was developed first and was prominent for many years. That model consists of aggregates of casein submicelles linked by calcium phosphate. It is suggested that there are κ-casein-rich and κ-casein-poor micelles, with the former being present at the surface of the micelles. However, there is not sufficient evidence for the existence of discrete submicellar particles.

The most current view of casein micelle structure is a nanocluster model, which is an open structure involving calcium phosphate nanoclusters surrounded by casein phosphopeptides. The caseins bind to more calcium phosphate or to other caseins, thus forming the casein micelles. This could be considered an inversion of the submicelle model. The calcium phosphate nanoclusters vary in density and provide for a porous structure that is able to hold a large amount of water. In both models, the κ-casein is mainly present at the surface and has a stabilizing effect on the micelles.

There are many reviews of casein micelle structure for those who would like to dig deeper on this subject. A good starting place would be the recent review by Dalgleish and Corredig (2012).

The casein micelles are *coagulated by addition of acid* at a pH of 4.6–5.2. As the micelles approach their isoelectric point, the charge and extent of hydration is reduced, and the κ-casein hairlike structures flatten, reducing steric hindrance. Hence, the micelles are no longer stable, and so they aggregate. This is the basis for the formation of cottage cheese, which is an acid cheese containing casein curds.

Acid also causes some calcium to be removed from the micelles, and so cottage cheese is relatively low in calcium compared with some other dairy products. The casein micelles may also be *coagulated by addition of the enzyme* ***rennin***, which may be added to milk to prepare rennet custard or cheese. Rennin cleaves a specific bond in κ-casein and causes the charged, hydrophilic hairlike structures to be removed from the micelles.

Accordingly, the micelle surface is uncharged, hydrophobic, and unstable, and so the micelles aggregate to form curds. The curds may be separated from the whey and processed to form cheese (see section on "Cheese"). Coagulation by rennin does not cause calcium to be removed from the micelles.

Casein micelles are relatively heat stable and are not denatured by heat (at neutral pH) unless temperatures are very high and heating is prolonged. This is not a problem under most cooking conditions. However, it is a potential problem in heated concentrated milk products such as evaporated milk. The problem is avoided by addition of carrageenan to protect the protein.

Caseins contain both hydrophobic and hydrophilic sections; in addition, they contain a high proportion of the amino acid proline, and so they are flexible proteins containing little regular, ordered secondary structure (see Chap. 8). As a result, they readily adsorb at an oil–water interface, forming a stable film that prevents coalescence of emulsion droplets (see Chap. 13), and so they make excellent emulsifiers.

A *second protein fraction* of milk is the ***whey*** or serum. It makes up approximately 20 % of milk protein and includes the *lactalbumins* and *lactoglobulins*. Whey proteins are more hydrated than casein and are denatured and precipitated by heat, rather than by acid. (More information is contained in this chapter in the section entitled "Whey.")

Additional significant protein components of milk include enzymes such as lipase, protease, and *alkaline phosphatase*, which hydrolyze triglycerides, proteins, and phosphate esters, respectively. The average measures of protein quality, including biological value, digestibility, net protein utilization, protein efficiency, and chemical score, for milk and milk products appear in Table 11.1.

Vitamins and Minerals

Vitamins in milk are both the water-soluble and fat-soluble varieties. The nonfat portion of milk is especially plentiful in the B vitamin B_2—riboflavin, a greenish fluorescent colored vitamin. It acts as a photosynthesizer and is readily destroyed upon exposure to sunlight.

Additional *water-soluble B vitamins* in milk beside riboflavin include thiamin (vitamin B_1), niacin (vitamin B_3), pantothenic acid (vitamin B_5), vitamin B_6 (pyridoxine), vitamin B_{12} (cobalamin), vitamin C, and folate.

The *fat-soluble vitamins A*, *D*, *E*, *and K* are dependent upon the fat content of the milk. Vitamin A is *naturally* in the fat component of *whole* milk, and more may be added prior to sale. If the milk is reduced fat (2 % fat), or low-fat (1 % fat), or even skim milk (fat skimmed off), fortification with vitamin A must occur in order to be made nutritionally equivalent to whole milk.

Whole milk is generally (98 %) *fortified* with *vitamin D* because it is naturally present only in *small* amounts. Vitamin D is present in milk to *some* extent due to the synthesis of vitamin D by the cow as it is exposed to sunlight and because vitamin D may be present in animal feed. *Low-fat* and *nonfat* milk, containing reduced levels or no fat, may be fortified with *both* of these fat-soluble A and D vitamins. Fortification with vitamin D is voluntary. Vitamins E and K are minor constituents of milk.

Minerals such as calcium and phosphorus are present at levels of approximately 1 % of milk, with a third of calcium in solution, and two-thirds of it colloidally dispersed. Calcium is combined with the protein casein as calcium caseinate, with phosphorus as calcium phosphate and as calcium citrate. Other minerals present in milk are chloride, magnesium, potassium, sodium, and sulfur.

Classification of Milk

Whole milk may be classified as a solution, dispersion, or emulsion as follows:

Table 11.1 Average measures of protein quality for milk and milk products

	BV	Digestibility	NPU	PER[a]	Chemical score
Milk	84.5	96.9	81.6	3.09	60
Casein	79.7	96.3	72.1	2.86	58
Lactalbumin	82	97	79.5[b]	3.43	[c]
Nonfat dry milk	–	–	–	3.11	–

Source: Adapted from the National Dairy Council
Note: *Biological* value (BV) is the proportion of absorbed protein that is retained. *Digestibility* (*D*) is the proportion of food protein that is absorbed. *Net protein utilization* (NPU) is the proportion of food protein intake that is retained (calculated as BV $\times$ *D*). *Protein efficiency ratio* (PER) is the gain in body weight divided by weight of protein consumed. *Chemical score* is the content of the most limiting amino acid expressed as a percentage of the content of the same amino acid in egg protein
[a]Often, PER values are adjusted relative to casein which may be given a value of 2.5
[b]Calculated
[c]Denotes no value compiled in Food and Agriculture Organization of the United Nations (FAO) report

Table 11.2 Composition of milks from different species (100-g portions)

Nutrient	Cow	Human	Buffalo	Goat	Sheep
Water (g)	87.99	87.50	83.39	87.03	80.70
Calories	61	70	97	69	108
Protein ($N \times 6.38$) (g)	3.29	1.03	3.75	3.56	5.98
Fat (g)	3.34	4.38	6.89	4.14	7.00
Carbohydrate (g)	4.66	6.89	5.18	4.45	5.36
Fiber (g)	0	0	0	0	0
Cholesterol (mg)	14	14	19	11	–
Minerals					
Calcium (mg)	119	32	169	134	193
Iron (mg)	0.05	0.03	0.12	0.05	0.10
Magnesium (mg)	13	3	31	14	18
Phosphorus (mg)	93	14	117	111	158
Potassium (mg)	152	51	178	204	136
Sodium (mg)	49	17	52	50	44
Zinc (mg)	0.38	0.17	0.22	0.30	–
Vitamins					
Ascorbic acid (mg)	0.94	5.00	2.25	1.29	4.16
Thiamin (mg)	0.038	0.014	0.052	0.048	0.065
Riboflavin (mg)	0.162	0.036	0.135	0.138	0.355
Niacin (mg)	0.084	0.177	0.091	0.277	0.417
Pantothenic acid (mg)	0.314	0.223	0.192	0.310	0.407
B_6 (mg)	0.042	0.011	0.023	0.046	–
Folate (μg)	5	5	6	1	–
B_{12} (μg)	0.357	0.045	0.363	0.065	0.711
Vitamin A (RE)	31	64	53	56	42
Vitamin A (IU)	126	241	178	185	147

Source: National Dairy Council

- *Solution*—contains the sugar lactose, the water-soluble vitamins thiamin and riboflavin, and many mineral salts such calcium phosphate, citrates, and the minerals chloride, magnesium, potassium, and sodium.
- Colloidal *dispersion* (sol)—casein and whey proteins, calcium phosphate, magnesium phosphate, and citrates.
- *Emulsion*—fat globules suspended in the aqueous phase (serum) of milk. The fat globules are surrounded by a complex membrane, the milk fat globule membrane, which contains mainly protein and phospholipids (and a few carbohydrate side chains at the outer surface). This membrane prevents coalescence of the fat droplets.

Grading of Milk

Grades are based on bacterial counts. Milk is a *potentially hazardous food* that must be kept *out* of the temperature danger zone. With its high water content and plentiful protein, vitamins, and minerals, milk is an ideal medium for supporting bacterial growth. Production, processing, and distribution of milk must ensure that products are kept *free* from pathogenic bacteria and *low* in nonpathogens. *Healthy cows* and *sanitary* conditions of handling lead to *low* bacterial counts. *Proper handling* also contributes to satisfactory shelf life, as well as appearance, flavor, and nutritive value.

The *temperature* of raw milk should reach 40 °F (4 °C) or less within 2 h of being milked from the cow. It should be kept well chilled, as it is highly perishable and susceptible to bacterial growth. The shelf life for properly refrigerated milk is 14 days or up to 45 days for *ultra-pasteurized* milk products including cream and lactose-reduced milk (see section "Pasteurization").

Numerous factors may lead to the spread of diseases by milk or milk products. A contaminated cow, *cross-contamination* at the farm or from workers hands, and unsanitary equipment or utensils may all become problematic. Traditionally, the diseases of *diphtheria*, *salmonellosis*, *typhoid fever*, *tuberculosis*, and *undulant fever* were spread by consumption of unsafe milk. Today, the incidence of these diseases is *rarely* attributed to milk transmission, as milk is pasteurized to destroy pathogens. The control of insects and rodents, as well as separation of animal waste products from the milking area, is also necessary for safe milk production.

The *US* Department of Agriculture (USDA) and *state* Departments of Agriculture regulate milk and milk products in interstate and intrastate commerce. Grades are based on bacterial counts. Grade "A" milk is available to the consumer for sale as fluid milk, although grades "B" and "C," with higher bacterial counts, are also safe and wholesome. The grades of US Extra and US Standard are given to dried milk. USDA official grades are given to all inspected milk on a voluntary fee-for-service basis.

Enzymes such as lipase, oxidation, and light may induce deterioration of the fat.

Flavor of Milk

The flavor of milk is mild and slightly sweet. The characteristic mouthfeel is due to the presence of emulsified fat, colloidally dispersed proteins, the carbohydrate lactose, and milk salts. Fresh milk contains acetone, acetaldehyde, methyl ketones, and short-chain fatty acids that provide aroma.

Less desirable, "barny" or rancid flavors, or other "off-flavors," may be due to the following:

- Slightly "cooked" *flavor* from excessive pasteurization temperatures.
- *Animal feed*, including ragweed and other weeds, or wild onion from the field.
- *Lipase activity* causes rancidity of the fat, unless destroyed by the heat of pasteurization. (Or, the short-chain butyric acid may produce an off-odor or

off-flavor due to bacteria, rather than lipase in the emulsified water of milk.)

- *Oxidation* of fat or phospholipids in the fat globule membrane, especially in emulsified, homogenized milk. Adequate pasteurization temperatures are necessary to destroy the enzyme which oxidizes fat.
- *Light-induced* flavor changes in the proteins and riboflavin because riboflavin acts as a photosynthesizer.
- *Stage of lactation* of the cow.

Flavor treatment to standardize the odor and flavor typically follows *pasteurization*. In this treatment process, milk is instantly heated to 195 °F (91 °C) with live steam (injected directly into the product) and subsequently subjected to a vacuum that removes volatile off-flavors and evaporates excess water produced from the steam.

Milk Processing

Pasteurization

"Pasteurized, when used to describe a dairy ingredient means that every particle of such ingredient shall have been heated in properly operated equipment to one of the temperatures (specified in the table) and held continuously at or above that temperature for the specified time (or other time/temperature relationship which has been demonstrated to be equivalent thereto in microbial destruction)" (FDA). Fluid milk is *not routinely sterilized* (see below); *rather*, *it is pasteurized*. This assures destruction of the pathogenic bacteria, yeasts, and molds, as well as 95–99 % of nonpathogenic bacteria. ***Pasteurization*** minimizes the likelihood of disease and extends the storage life of milk.

Pasteurization temperatures do *not* change milk components to any great extent (see section "Nutritive Value"). Vitamin destruction and protein denaturation are minimal, and the result is that milk is made safe for consumption. Several acceptable methods of pasteurization including thermal processing according to the International Dairy Food Association (IDFA) are shown in the following chart:

- 145 °F (63 °C) for 30 or more minutes—the batch or holding method is Vat Pasteurization and is considered low-temperature longer time (LTLT) pasteurization.
- 161 °F (72 °C) for 15 s—the flash method for this temperature is the high-temperature short-time (HTST) method of pasteurization, the most common method.
- 191 °F (88 °C) for 1 s. Higher heat shorter time (HHST) at this temp and above.
- 194 °F (90 °C) for 0.5 s. HHST.
- 201 °F (94 °C) for 0.1 s. HHST.
- 204 °F (96 °C) for 0.05 s. HHST.
- 212 °F (100 °C) for 0.01 s. HHST.
  IDFA

"Another method, aseptic processing, which is also known as ultra high temperature (UHT), involves heating the milk using commercially sterile equipment and filling it under aseptic conditions into hermetically sealed packaging. The product is termed "shelf stable" and does not need refrigeration until opened. All aseptic operations are required to file their processes with the FDA's "Process Authority." There is no set time or temperature for aseptic processing; the Process Authority establishes and validates the proper time and temperature based on the equipment used and the products being processed."

"If the fat content of the milk product is 10 % or more, or if it contains added sweeteners, or if it is concentrated (condensed), the specified temperature shall be increased by 3 °C (5 °F). Provided that, eggnog shall be heated to at least the following temperature and time specifications:

Temperature Time Pasteurization Type
69 °C (155 °F) 30 min—vat pasteurization
80 °C (175 °F) 25 s—HTST pasteurization
83 °C (180 °F) 15 s—HTST"
(IDFA, http://www.idfa.org/files/249_Pasteurization Definition and Methods.pdf)

Pasteurization is required of all grade A fluid milk or milk products subject to interstate commerce for retail sale. Traditionally, prevention of tuberculosis (TB) was the primary concern in pasteurization; thus, temperatures of 143 °F (62 °C) were used to destroy *Mycobacterium tuberculosis*, the bacteria causing TB in humans. Actually, *Coxiella burnetii* that causes Q fever requires an even *higher* temperature for destruction; thus, the required 145 °F (63 °C) was set for pasteurization. The high pasteurization temperature, followed by rapid cooling, controls non-pathogenic growth.

A large US foodborne illness outbreak in recent years, where many thousands of people became ill, was attributed to raw milk that inadvertently entered the wrong pipeline (not effectively prevented from entering) before packaging and subsequently contaminated the already pasteurized milk.

Many foods use enzyme tests in determining adequate pasteurization. *Adequate* pasteurization is demonstrated by the absence of the enzyme *alkaline phosphatase*. The phosphatases are highly effective in an alkaline environment. The term may be used synonymously as basic phosphatase. This enzyme is *naturally* present in milk and is *destroyed* (thus no longer present) at temperatures similar to those required for adequate pasteurization. A simple test determines its presence in milk. For example, *inadequate* pasteurization of raw milk reveals the presence of a *high* alkaline phosphatase activity. Inversely, *adequate* pasteurization shows its absence.

"Except for Michigan, not a single state law expressly prohibits the sale of raw milk for animal consumption. The variables are the states' willingness to grant licenses to producers of raw milk for animal feed and how strictly state agencies would monitor licensees to make sure that raw milk sales did only go for animal consumption" (http://www.realmilk.com).

Sterilization (ultra-pasteurization [UP])—pasteurization occurs at *higher* temperatures with a different time:

- 280–302 °F (138–150 °C) for 2–6 s

"Ultrapasteurized when used to describe a dairy ingredient means that such ingredient shall have been thermally processed at or above 280 °F for at least 2 s" (FDA). This UP process still requires that the milk be refrigerated afterward.

The use of *sterilization temperatures* in combination with the use of *presterilized containers*, under *sterile conditions*, creates ultrahigh-temperature (UHT) processing. It *does not* allow spoilage or pathogenic bacteria to enter the milk. If *packaging too* is sterilized, the package is referred to as being "*aseptically* packaged." Thus, milk treated in this manner may be safely stored up to 3 months or longer. An example of this is milk in packaging similar to "juice boxes."

The typical HTST pasteurization of fluid milk does not significantly affect the vitamin content. However, the high heat treatment of ultrahigh-temperature (UHT) pasteurization does cause losses of some water-soluble vitamins.

Regarding minerals, calcium phosphate will travel both in and out of the casein micelle with changes in temperature. Yet this process is reversible at *moderate* temperatures, although at very high temperatures the calcium phosphate may precipitate out of solution and subsequently cause irreversible changes in the casein micelle structure.

Exposure to light will cause a decrease in the levels of riboflavin and vitamin A in milk. Therefore, milk is stored in opaque plastic or paperboard containers that provide barriers to light to maximize vitamin retention. ***See*** http://www.milkfacts.info/Milk%20Composition/VitaminsMinerals.htm.

Homogenization

The primary *function* of ***homogenization*** is to *prevent creaming*, or the rising of fat to the top of the container of milk (whole or reduced-fat milks). The *result* is that milk maintains a more uniform composition with improved body and texture, a whiter appearance, richer flavor, and more digestible curd.

Homogenization *mechanically* increases the number and *reduces* the size of the fat globules. The size is reduced from 18 m to less than 2 m, or 1/10 of their original size. The process of homogenization permanently *emulsifies* the fine fat globules by a method that pumps milk under high pressure [2,000–2,500 lb/in.^{2} (psi)] through small mesh orifices of a homogenizer.

Homogenization offers a *permanent* emulsification because as the surfaces of many new fat globules are formed, each fat globule becomes coated with a part of the lipoprotein membrane and additional proteins from casein and whey. Thus, these proteins adsorb onto the freshly created oil surface *preventing* globules from reuniting or coalescing, and the fat remains homogeneously distributed throughout milk.

Milk may be homogenized *prior to* or *subsequent to* pasteurization. The homogenization process is completed at a *fast* rate to ensure the control of bacteria and loss of quality.

Various characteristics of homogenized milk include the following:

- *No creaming* or separation of cream to the top of the container.
- *Whiter* milk due to finer dispersions of fat. There is an increase in the absorption and reflection of light due to the smaller fat particles.
- *More viscous* and creamy milk due to a greater number of fat particles.
- *More bland* due to smaller fat particles.
- *Decreased fat stability* as fat globule membranes are broken.
- *Less stable to light* and may exhibit light-induced favor deterioration by sunlight or fluorescent light. Thus, paperboard cartons and clouded plastic bottles are used for milk.

Fortification

Fortification is defined as the addition of nutrients at levels beyond/different from the original food. The addition of fat-soluble vitamins A and D to *whole milk* is optional fortification. Low-fat milk, nonfat milk, and low-fat chocolate milk *must* be ***fortified*** (usually before pasteurization) to carry 2,000 International Units (IU) or 140 retinol equivalents (RE) *vitamin A* per quart. It is *required* for milk subjected to *interstate* commerce. *Vitamin D* addition to reach levels of 400 IU per quart is *optional*; however, it is routinely practiced. Evaporated milks must be fortified.

CULINARY ALERT! Vitamin A and D are fat-soluble vitamins, thus are not naturally in milk without fat. Low-/nonfat milk is fortified to contain these vitamins.

In order to add to the viscosity and appearance, as well as the nutritive value of low-fat milk, *nonfat milk solids* (*NFMS*) may be *added* to milk. This addition allows milk to reach a 10 % NFMS (versus 8.25 % usually present), and it will state "protein fortified" or "fortified with protein" on the label.

Bleaching

Bleaching carotenoid or chlorophyll pigments in milk may be desirable. The FDA allows benzoyl peroxide (BP) or a blend of it with potassium alum, calcium sulfate, or magnesium carbonate to be used as a bleaching agent in milk. The weight of BP must not exceed 0.002 % of the weight of the milk, and the potassium alum, calcium sulfate, and magnesium carbonate, individually or combined, must not be more than six times the weight of the BP. Vitamin A or its precursors *may be destroyed* in the bleaching process; therefore, sufficient vitamin A is added into the milk or in the case of cheesemaking to the curd.

The use of whey proteins in food and beverage applications is chiefly derived from annatto-colored cheddar cheese. Since not all of the annatto is removed from the whey, bleaching occurs.

Types of Milk

Fluid Milk

Fluid milk may come from goats (Mediterranean countries), sheep (southern Europe), reindeer (northern Europe), and other animal sources throughout the world. It is *Holstein* cows that typically produce the greatest quantity of milk and are, therefore, the *primary milk cow* in the United States. The Guernsey and Jersey breeds produce milk with the highest percentage of fat—approximately 5 % fat.

Milk appears *white* due to the reflection of light from colloidally dispersed casein protein and calcium phosphate particles in the milk dispersion; however, an *off-white* color may be due to carotenoid pigment in the animal feed. A *bluish* color may be observed in milk skimmed of fat and thus devoid of carotenoid pigments.

Both the fat content and percent of MSNF of fluid milk are subject to FDA regulations and new technological developments. The butterfat and caloric content of milk are as follows:

Type of milk	Fat percent	Calories
Whole	3.25	150 calories/ 8 ounce
Reduced fat	2	120 calories/ 8 ounce
Low fat or light	0.5, 1.0	100 calories/ 8 ounce (1 %)
Nonfat, fat-free/"skim" (fat skimmed off)	<0.5	90 calories/ 8 ounce

Flavored milk contains fat, protein, vitamin, and mineral contents similar to the type of milk to which the flavoring was added—whole, reduced fat, and so forth. It will vary in caloric and carbohydrate values according to added ingredients.

CULINARY ALERT! Substitutes for 1 cup whole milk:

- 1/2 cup evaporated milk + ½ cup water—reconstituted
- 1/3 cup NFMS in measuring cup + water to reach 1 cup mark of cup—reconstituted
- 1 cup buttermilk + ½ tsp. baking soda

Evaporated and Concentrated Milks

Evaporated and *condensed*, or *sweetened condensed*, coupled with packaging in cans, extends the shelf life of the milk. *Cans* of evaporated milk may be adequately stored for extended time periods, although due to the Maillard reaction (more later), undesirable tan or brownish color or flavor changes may occur after 1 year's time. Rehydration may then be made difficult.

CULINARY ALERT! Discoloration is not indicative of possible foodborne illness. Once the can has been opened, it should be refrigerated and can be held for up to 1 week.

Evaporated milk is concentrated through the process of evaporation [at 122–131 °F (50–55 °C)] in a vacuum chamber. Either *whole* or *nonfat* milk with 60 % of the water removed is then homogenized, fortified with vitamins A and D, canned, and sterilized in the can [240–245 °F (115–118 °C)] in a pressure canner.

Whole evaporated milk must contain not less than 25 % total milk solids and not less than 7.5 % milk fat. Evaporated nonfat milk must contain not less than 20 % milk solids and no more than 0.5 % milk fat. It must be fortified with 125 and 25 IU of vitamins A and D, respectively.

Milk is increasingly *less* stable with the progression of concentration and heat and it may coagulate, so the stabilization of milk proteins is better assured by preheating (forewarming) milk prior to sterilization at temperatures of 203 °F (95 °C) for 10–20 min. This *forewarming* is designed to denature colloidally dispersed serum proteins and to shift salt balance of calcium chloride and phosphates that are in solution. Disodium phosphate or *carrageenan* may be added to stabilize casein against precipitation (Chap. 5).

As mentioned previously (see section “Safety/Quality of Milk”), an undesirable browning may occur in canned milk. The high temperature used in processing evaporated milk or a long storage of the product may produce a *light tan* color due to the early stages of the ***Maillard reaction*** between the milk protein and the milk sugar, lactose. This color change is *not* a microbial threat.

CULINARY ALERT! Evaporated milk is reconstituted (rehydrated) at a 1:1 ratio of evaporated milk and water, adding slightly less water than was removed in the 60 % evaporation.

Sweetened condensed milk is concentrated whole or nonfat milk with approximately 60 % of the water removed, and sugar levels of 40–45 % in the finished product. There is a calorie difference in this milk processing, as whole sweetened condensed milk contains no less than 8 % milk fat and 28 % total milk solids, and nonfat contains no more than 0.5 % milk fat and 24 % total milk solids.

Sweetened condensed milk is *pasteurized*, although *not sterilized*, because the *high* sugar content (usually at least 60 % in the water phase) plays a role in preventing bacterial growth. This is due to the *osmotic* effect of the sugar that competes with the bacteria for water and, thus, controls bacterial growth.

Dried Milk

Dried milk powder may be processed from either pasteurized *whole* or, more commonly, from *nonfat* milk. One method of drying involves *spray* drying. Milk is first condensed by removing two-thirds of the water and is typically sprayed into a heated vacuum chamber (spray drying) to dry to less than 5 % moisture levels. The drying process has *no* appreciable effect on the nutritive value of milk (National Dairy Council). Most nonfat dry milk is fortified with vitamins A and D.

Instant nonfat dry milk or *agglomerated* milk has some moisture added back to the spray-dried milk powder. As powder, it is easily pourable and dispersible in cold water. When reconstituted, the taste is best when the milk is prepared ahead and served well chilled.

CULINARY ALERT! Three and a half ounces (1–1/3 cups) of dried milk powder is needed to yield 1 quart of fluid milk. Nonfat dried milk (NFDM) may be added to foods to increase the protein or calcium content.

Dry whole milk is pasteurized whole milk with the water removed. It has limited retail distribution—mainly for use in infant feeding and for people without access to fresh milk, such as campers. Dry whole milk is usually sold to chocolate and candy manufacturers.

Tips on Dry Whole Milk: An opened package should be tightly sealed and stored in a cool, dry place. Dry whole milk develops off-flavors if not used soon after opening. (USDA)

In addition to whole or nonfat milk, *buttermilk* and *whey* may also be dried. Whey is of high biological value containing lactalbumins and lactoglobulins, with *one-half* of the protein and slightly *more* lactose than NFDM.

In particular, dried milk is an economical form of milk for shipping. It has an extended shelf life and is useful as an ingredient for addition to numerous other foods.

Cultured Milk/Fermentation

Cultured products are ***fermented*** by the addition of bacterial cultures, such as *Lactobacilli* and *Streptococci*, to fluid dairy products. These harmless bacteria (or bacterial enzymes) induce a chemical change in the organic substrates of milk solids. Lactose is fermented to lactic acid creating a low pH in the process, which

(1) controls both spoilage and pathogenic bacterial growth and (2) causes the casein to coagulate.

In earlier days, warm milk from various animals (cows, sheep, goats, camels) was preserved for several days or weeks, with no need for refrigeration. This was achieved by the addition of a small milk culture from a preceding batch.

Acidified products are produced by *souring* milk with an acid such as lactic, citric, phosphoric, or tartaric acid with or without microorganisms. The addition of lactic acid-producing bacteria is optional, and because cultured and acidified products contain different amounts of lactic acid, they differ in flavor.

The following milk products are examples of some commonly *cultured* milk products:

- ***Buttermilk***
  Traditionally, buttermilk was the liquid that *remained* when cream was churned to form butter. It was a by-product. *Today*, this is *not* the case commercially, because low-fat or skim milk, *not* cream, begins the process. Although its name (*buttermilk*) may mistakenly signify a high-fat content, the opposite is true! It is more correctly named "cultured low-fat milk" or "cultured nonfat milk."

  Buttermilk differs from nonfat milk in that it contains phospholipids and protein from the fat globule membrane, whereas nonfat milk does not. The texture is different as well.
- **Cultured buttermilk**
  Cultured buttermilk is the pasteurized low-fat, nonfat, or whole milk to which a starter culture of *Lactobacilli* and *Streptococci* (*S. lactis*) is added after the mix has been heated and then cooled. These bacteria ferment lactose, producing lactic acid, which clots the milk. Butter flakes or liquid butter, or low levels (0.01–0.15 %) of salt, may be added. *Leuconostoc citrovorum* and *L. destranicum* bacteria, 0.2 % citric acid, or sodium citrate may be added for flavor.
- **Sour cream**
  Traditionally, sour cream was made from heavy (whipping) cream that was soured. *Today*, it is made from pasteurized, homogenized, fresh, *light cream* (approximately 18 % fat) that is coagulated by a method similar to buttermilk (recall that while *buttermilk* starts *with low-fat or skim milk*, *sour cream* production begins with *18 % fat*, *or perhaps cream*). While inoculation and fermentation steps are *similar* to buttermilk production, fermentation is shortened.

  S. lactis and *Leuconostoc* bacteria may be added for flavor, and stabilizers such as gelatin or gums may be present. *Nonfat milk solids* may be *added* to thicken the cream. A bitter taste in sour cream that is stored more than 3–4 weeks may form due to proteolytic bacterial enzyme activity.
- **Yogurt**
  Yogurt is the food produced by culturing one or more of the pasteurized fluid dairy ingredients such as cream, milk, partially skimmed milk, or skim milk (used alone or in combination depending on the desired fat content) with a bacteria culture. In industrialized regions of the world, yogurt is made with cow's milk.

Treatment of the milk is that it is both pasteurized and homogenized *before* the addition of a starter which contains the lactic acid-producing bacteria, *L. bulgaricus* and *S. thermophilus*. The process used to make yogurt is similar to buttermilk and sour cream, although the incubation temperature and types of bacteria are different.

Denaturing proteins (unfolding the native chains or globular shape) becomes important for digestion and for yogurt production wherein the whey proteins bind water and provide a characteristic yogurt texture.

Yogurt may be made using whole, low-fat, or skim milk. The formulation may include nonfat dry milk (NFDM) or condensed skim milk to boost its solids. It contains not less than 8.5 % MSNF and not less than 3.25 % milk fat. Or it may be prepared to be a reduced- or low-fat yogurt and have levels of 0.5–2.0 % milk fat or less. Other optional ingredients include buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals to increase the nonfat solid contents of the food. New research and development continues to explore additional optional ingredients.

Microorganisms in yogurt exist in a *friendly* form, known as *probiotic flora*. Such probiotic yogurt, with *Lactobacillus* and *Bifidobacterium*, is able to survive destruction during gastrointestinal (GI) passage and offer health benefits such as immune stimulation and positive balance to the GI microflora (Hollingsworth 2001). The Food and Agriculture Organization of the United Nations (FAO) defines probiotics as "live microorganisms administered in adequate amounts which confer a beneficial health effect on the host" (FAO). Most probiotics are bacteria, one is a yeast—*Saccharomyces boulardii* (Hollingsworth 2001).

The National Yogurt Association's "live and active cultures" seal indicates that the yogurt contains at least 100 million *L. acidophilus* bacteria per gram at the time it is manufactured, although this number diminishes with time and the microbial enzyme lactase.

Frozen yogurt may contain stabilizers for freezer stability, sugar, and added milk solids. The different types of yogurt, including sundae-style or, the blended, Swiss yogurt, are cultured and stored in different manners. Nutritive or nonnutritive sweeteners may be added, as well as flavoring agents, color additives, and stabilizers such as gelatin, gums, and pectin (Chap. 17).

- **Acidophilus milk**
  Acidophilus milk is a cultured product made from pasteurized low-fat, nonfat, or whole milk. *Lactobacillus acidophilus* is added and incubated at 99 °F (37 °C). Although *not* proven yet, a possible *benefit* of consumption is that ingestion can produce a number of B vitamins, thereby replacing what may have been destroyed during antibiotic treatment. A variation of this is sweet acidophilus milk. This sweet version has culture added, however is not incubated. It is thought to be therapeutic without the characteristic high acidity and flavor.

  Acidophilus produces the enzyme lactase and helps correct the symptoms of lactose intolerance. It is thought that lactase in combination with *L. acidophilus* is enabled to pass successfully through the stomach acids and reach the small intestine where it functions in lactose digestion, preventing the discomfort experienced by those individuals who are lactose intolerant and unable to digest lactose (National Dairy Council).
- **Kefir**
  Kefir is another, less well-known, fermented, probiotic milk product. It contains numerous bacteria including *Lactobacillus caucasicus* and the yeasts *Saccharomyces kefir* and *Torula kefir*. As well, it is slightly bubbly due to the fermentation process, and it may therefore contain a small amount—approximately 1 %—of alcohol.

  Fermented dairy products have been and *are* used routinely throughout the world—it is a way of life and there is nothing novel about it. Yogurts, smoothies, and a plethora of flavors may be created using kefir. Each introduces live bacteria for good gut health. "... kefir in particular ... adding excitement to the drinkable yogurt shelf." The lumps in kefir "grains" are not grains, but, rather, are "little clumps of bacteria, yeasts, sugars, proteins and lipids" (Decker 2012).

  "<u>Prebiotics</u> are nondigestible carbohydrates that act as food for probiotics. When probiotics and prebiotics are combined, they form a synbiotic [the term 'synbiotic' should be used only if the net health benefit is synergistic—the United Nations Food & Agriculture Organization (FAO)]. Fermented dairy products, such as yogurt and kefir, are considered synbiotic because they contain live bacteria and the fuel they need to thrive.

  <u>Probiotics</u> are found in foods such as yogurt, while prebiotics are found in whole grains, bananas, onions, garlic, honey and artichokes. In addition, probiotics and

prebiotics are added to some foods and available as dietary supplements" (http://www.mayoclinic.com).

Additional specialty types of milk include low-sodium, lactose-reduced milk, calcium-fortified, as well as flavored milks, and shakes. Non-milks such as rice and soy "milk" are also consumed. The latter are especially useful to persons who are lactose intolerant.

Other Milk Products

Butter

Butter is a concentrated form of fluid milk, produced through churning of pasteurized cream. ***Churning*** involves agitation that breaks fat globule membranes so the emulsion breaks, fat coalesces, and water (buttermilk) escapes. Emulsions may be of two types. The original 20/80 *oil-in-water* type of emulsion of milk becomes a 20/80 *water-in-oil* emulsion. Milk is churned to form butter and the watery buttermilk. Butter may have a yellow color due to the fat-soluble animal pigment, carotene, or an additive.

> Butter is made by churning pasteurized cream. Federal law requires that it contain at least 80 percent milkfat. Salt and coloring may be added. Nutritionally, butter is a fat; one tablespoon contains 12 grams total fat, 7 grams saturated fatty acids, 31 milligrams cholesterol, and 100 calories. Whipped butter is regular butter whipped for easier spreading. Whipping increases the amount of air in butter and increases the volume of butter per pound. The USDA grade shield on butter packages means that butter has been tested and graded by experienced government graders. In addition to checking the quality of the butter, the graders also test its keeping ability. (USDA)

Today, there are various blends of butter and margarine in the market. The fat composition and taste differ from the original. Margarine, or oleomargarine, is the food in plastic form or liquid emulsion containing not less than 80 % fat. It may be produced from water and/or milk and/or milk product, unsalted, or lactose-free. It contains vitamin A and may contain vitamin D.

Sweet cream butter is made by the addition of *S. diacetylactis*, which ferments the citrate in milk to acetaldehyde, acetic acid, and diacetyl, the last being the major flavor compound of butter. Commercially, it may contain salt, yet is known as "sweet cream" butter, because today, the butter is prepared from sweet, not the traditional soured cream. The USDA grade AA is of superior quality, USDA grade A is very good, and grade B is standard.

Spreads contain a higher percentage of water and may not be suitable for some baking and cooking applications.

Cream

> Cream means cream, reconstituted cream, dry cream, and plastic cream. Water, in a sufficient quantity to reconstitute concentrated and dry forms, may be added. (FDA)

Cream is the high-fat component separated from whole milk as a result of the creaming process. It has a higher proportion of fat droplets to milk than regular fluid milk, and according to federal standards of identity, cream must contain *18 % milk fat* or more. Due to this high-fat content of cream compared to milk, some yellow, fat-soluble pigments may be apparent. Some fats are naturally small and do not coalesce.

Various liquid creams available for use in foods include the following:

- Light (coffee) cream—18–30 % butterfat
- Light whipping cream—30–36 % butterfat
- Heavy cream—36 % butterfat, minimum
- "Half-and-Half" cream diluted with nonfat milk—10.5 % butterfat
- Whipping cream packaged under pressure in aerosol cans—may be nonfat or contain various levels of fat, sugar, flavoring, emulsifiers, and a stabilizer

Ice Cream

Ice cream is sometimes referred to as an "indulgent" food, meaning that while fat is reduced elsewhere in the diet, ice cream consumption may not decrease! While ice mixes were enjoyed for centuries prior to this, the first commercial, wholesale ice cream was manufactured in 1851, in Baltimore, MD.

Ice cream is a food produced by freezing, while stirring a pasteurized mix containing *dairy* product. The mix consists of one or more dairy ingredients such as cream, milk, skim milk, sweet cream buttermilk or sweetened condensed milk, and optional caseinates. *In addition* to the dairy ingredient, sherbet, low-fat ice cream, and ice creams contain other ingredients. Typically, sugar (sucrose, dextrose, which flavors and depresses the freezing point), cookies, eggs, fruit, nuts, and other ingredients such as coloring or flavoring agents, emulsifiers [such as egg yolks, polysorbate 80 (a sorbitol ester consisting of a glucose molecule bound to the fatty acid, oleic acid), or mono- and diglycerides], stabilizers (gelatin, vegetable gum), and water are added.

The ice cream mix is subject to pasteurization, homogenization, holding (for aging), and quick freezing. Slow freezing creates larger ice crystals. Air is naturally incorporated into an ice cream mixture by agitation, although excessive air may *not* be whipped into a mix as specified by federal and state standards. The increase in volume due to air is ***overrun*** and is calculated as

$$
\begin{aligned}
\%\ \text{Overrun} = (&\text{Volume of ice cream} \\
&- \text{Volume of mix}) \times 100 \\
&= \text{Volume of mix}
\end{aligned}
$$

For instance, if a 1-gallon container of ice cream contains an equal measure of ice cream mix and air, it has 100 % overrun. Overrun in ice creams may range from 60 % to greater than 100 %.

Ice cream contains not less than 10 % milk fat, nor less than 10 % MSNF, except when it contains milk fat at 1 % increments above the 10 % minimum.

Low-fat ice cream (formerly ice milk) contains less fat and more MSNF, and deluxe ice cream contains more milk fat and less MSNF. Other frozen desserts may include milk and varying percentages of milk fat or perhaps a fat substitute.

Blended milk products are fruit juices and milk, which may contain added lactic acid, or caffeine, plus other ingredients, and may be prepared using herb teas and additional sugars.

Sherbet contains 1–2 % milk fat and 2–5 % total milk solids. A greater amount of sugar and less air (hence 30–40 % overrun) than ice cream are standard.

Percent milk fat	Minimum percent MSNF
10	10
11	9
12	8
13	7
14	6

Whey

Whey has previously been discussed as the aqueous (serum) protein in milk, yet it warrants further discussion due to its *increasing* use in consumer products. Research is ongoing to target separating milk serum proteins from liquid milk prior to cheesemaking. Some cheese such as ricotta cheese may be made *partially* of whey.

Whey comprises approximately *20 %* of the protein in milk. It contains the albumins and globulins, the majority of *lactose*, and the water-soluble nutrients, such as riboflavin. Whey is the *by-product* of cheesemaking, the liquid that remains after curds are formed and drained (recall the nursery rhyme Little Miss Muffet—eating her curds and whey!). A tremendous quantity of cheese is manufactured, and, currently, more satisfactory ways of using whey are being explored.

Whey is a nutritious product. It may also be used in beverages, frozen dairy desserts, and baked goods. In a dried form, it may have useful applications as an emulsifier and in providing extra protein to foods. Whey also has foaming and gelling applications. Yet, because it contains lactose, which the majority of the world cannot digest (see section "Lactose Intolerance"), it *cannot* be used in worldwide feeding.

Whey begins to precipitate at temperatures below the coagulation temperature of casein, yet is not precipitated at a pH of 4.6 or by rennin, as is casein. Evidence of whey precipitation is seen when the lactalbumin coagulum (as well as calcium phosphate) sticks to the bottom of the pan and scorches.

In addition to some uses previously listed, whey is concentrated by ultrafiltration to yield *whey protein concentrates* (WPCs). WPC/whey protein isolate (WPI) is also used in sports supplements and bars due to their high nutritional value; WPCs are frequently added to yogurt and dried for use in such items as coffee whitener, whipped toppings, meringue, fruit beverages, chocolate drinks, and processed meats.

Further purification steps may be added to yield WPIs. For example, WPIs are used in infant formulas, and whey refinery may yield proteins used to fortify clear bottled drinks, including sodas. Fractionation in the whey refining process could lead to products without phenylalanine and thus to products with useful ingredients to people with phenylketonuria (PKU) (Food Eng 2000a).

Cooking Applications

Cooking applications subsequent to the mild denaturation or change in molecular structure of proteins may form cross-links and coagulate milk. ***Coagulation*** and precipitation of clumps or aggregates may occur with heat or when acid, enzymes, or salts are in a formulation. In more severe heat, acid, enzyme, or salt treatment, unwelcome curdling may be expected to occur. Some of these effects are as follows:

- **Heat**: Heat, especially direct or high heat, may *denature*, *coagulate*, *or curdle* milk. Slow, *low*, or moderate heat such as indirect heating over a water bath should be used for milk-based products. Increasing temperatures and length of heating may break the fat emulsion if the protein film around the fat globules breaks. Thus, the fat will coalesce. *High* heat also forms greater amounts of coagulum at the bottom of the pan than low heat.
  The *same* calcium phosphate compound that forms at the bottom of the pan by scorching also forms a skin (scum or film) at the surface of the food as water evaporates. This surface skin may "hold in" heat and lead to a boilover of the milk product subjected to heat. Prevention includes use of a pan lid or surface application of an agent such as fat.

CULINARY ALERT! Cooking with a cover is recommended in order to prevent skin formation. Stirring constantly also helps avoid protein precipitation on the sides of the cooking vessel.

- **Acid**: Acid may come from a variety of sources. It be *added* to food or be a *part* of a food, or it may be produced by bacteria. It coagulates milk mixtures by forming unstable *casein* proteins. Casein precipitates at a pH of approximately 4.6 (recall that *whey* proteins are not precipitated by acid). Use of a white sauce may control precipitation.
- **Enzyme coagulation**: As will be discussed in the chapter section on "Cheese," *several* sources of enzymes are responsible for coagulation and curd formation—animal, plant, or microbial enzymes. However, the *primary* enzyme used to coagulate milk in cheese or ice cream is rennin (commercially known as rennet).
  Rennin requires a slightly acidic environment and functions best at temperatures of 104–108 °F (40–42 °C), rather than high temperatures. Calcium is retained if the coagulation of milk is achieved by rennin rather than acid (e.g., some custard-like desserts and cottage cheese).
- **Polyphenolic compound coagulation**: *Phenolic* compounds (formerly called tannins) are in some plant materials including fruits and vegetables (e.g., potatoes, tomatoes), tea, and coffee, and they coagulate milk. Although baking soda (alkali) may be added to milk

combinations to shift the pH and control curdling, it is not recommended, as it destroys vitamin C in the product. Low heat and a gelatinized starch buffer (white sauce) may be used for controlling this undesirable coagulation.

- **Salt coagulation**: *Calcium* and *phosphorus salts* present in milk are less soluble with heat and may coagulate milk protein. Salty foods such as ham as well as some vegetables and salt flavorings that are added to milk frequently may cause the milk to curdle. As with acid-cause coagulation, a gelatinized starch buffer is used to prevent undesirable precipitation.

Fig. 11.1 Cheeses (courtesy of SYSCO® Incorporated)

Cheese

Cheese as defined by the FDA is "a product made from curd obtained from the whole, partly skimmed, or skimmed milk of cows, or from milk of other animals, with or without added cream, by coagulating with rennet, lactic acid, or other suitable enzyme or acid, and with or without further treatment of the separated curd by heat or pressure, or by means of ripening ferments, special molds, or seasoning" (FDA).

With a look at an amount of US cheese consumption over 25 years, beginning in 1985, the per capita cheese rose steadily from 22.5 lb in 1985 to a projected 34.9 lb (Wisconsin Milk Marketing Board).

Cheese (Fig. 11.1) is a concentrated form of milk that contains casein; various percentages of fat, primarily saturated fat; mineral salts; and a small portion of milk serum (whey proteins, lactose, and water-soluble vitamins). It is the curd that forms as a result of casein coagulation by the enzyme rennin (also known as chymosin) or lactic acid. It requires approximately 10 lb of milk to make a pound of cheese.

"Chymosin, known also as rennin, is a proteolytic enzyme synthesized by chief cells in the stomach. Its role in digestion is to curdle or coagulate milk in the stomach, a process of considerable importance in the very young animal. If milk were not coagulated, it would rapidly flow through the stomach and miss the opportunity for initial digestion of its proteins.

"Chymosin efficiently converts liquid milk to a semisolid like cottage cheese, allowing it to be retained for longer periods in the stomach. Chymosin secretion is maximal during the first few days after birth, and declines thereafter, replaced in effect by secretion of pepsin as the major gastric protease.

In days gone by, chymosin was extracted from dried calf stomachs for this purpose. Presently, the cheesemaking industry has expanded beyond the supply of available young calves. Many proteases are able to coagulate milk by converting casein to paracasein; and alternatives to chymosin are readily available. "Rennet" is the name given to any enzymatic preparation that clots milk."

Animal (calf, bovine pepsin), plant (papain), and microbial protease *enzymes* clot milk to form curds. Genetic engineering of bacteria has produced new options. Cheesemaking typically uses rennin and pepsin. Rennin produces clots that are rich in calcium (although slightly tougher curds form with rennin than lactic acid).

- ***Rennin*** is from the stomach of milk-fed *calves*. Although rennin is active at neutral pH, the enzyme clots milk much faster in acidic conditions, such as when lactic acid is used.

Biotechnology has enabled the *specific gene* that produces rennin to be reproduced in *bacteria without* extracts from the calves' stomach. Rennet (the commercial name for rennin) is then produced through fermentation. In fact, half of rennet in cheese production is produced through fermentation (IFIC).

- *Pepsin* is from the stomach of *pigs* (swine).
- *Proteases* from fungi.
- *Plant enzymes* such as *papain* (from papaya) and *ficin* (from figs) may be used by industry to clot milk casein and form some cheeses.

In general, cheese is classified according to (1) the moisture content, producing either very hard, hard, semisoft, or soft cheeses, and (2) the kind and extent of ripening. A brief explanation appears below.

Moisture content

- *Very hard cheese*—e.g., Parmesan and Romano.
- *Hard cheese contains 30–40 % water. It has very tiny fat globules and is a near-perfect emulsion.* For example, cheddar, Colby, Gouda, and Swiss cheese.
- *Semisoft cheese*—blue, feta, Monterey Jack, mozzarella, Muenster cheese, and provolone cheese.
- *Soft cheese* contains 40–75 % water and has large fat globules. It is only slightly emulsified. For example, Brie, Camembert, ricotta, and cottage cheese.

Ripening

Ripening may require 2–12 months. In that time, the changes involve the following:

- *Carbohydrate* lactose is fermented by lactase to lactic acid.
- *Fat* is hydrolyzed by lipase.
- *Protein* undergoes mild proteolysis to amino acids by rennin.

Ripening refers to the *chemical and physical changes* that occur in the cheese in the time between curd precipitation and satisfactory completion of texture, flavor, aroma, and color development. Ripening modifies the characteristics mentioned, as well as continuing to ferment residual lactose.

First, milk proteins are coagulated with enzymes (rennet) and acids. Then, aging or ripening by bacteria or mold occurs. It may be due to bacteria, bacterial enzymes (chiefly rennin), or the fungus mold and yeast. Some example follows:

- Cheeses, such as cottage cheese or cream cheese, are *not* ripened. Other popular unripened cheeses include feta cheese and ricotta.
- Cheeses may be *ripened with bacteria*. Examples include cheddar cheese, Colby, Parmesan, and Swiss cheese. For example, the holes or eye formation in Swiss cheese is evidence of gas-producing bacteria that exist throughout the interior of the cheese.
- Camembert and Brie, for example, are *ripened by mold* that is sprayed onto the surface of the cheese, or mold may be introduced internally as in the *ripening* of blue cheese that is inoculated with *Penicillium roqueforti*.

According to USDA preliminary 2011 statistics, the average personal consumption rose from 29.8 lb per capita in 2000 to 34.9 lb in 2011 (USDA). In descending order, American, cheddar, and mozzarella cheese are by far the leaders in sales, followed by a distant Monterey Jack, Swiss, and Colby cheese. Many American kitchens also contain Parmesan and perhaps blue cheese.

> Cheese production and markets have emerged as important elements of the dairy industry over the past three decades. Supply-and-use analysis shows an upward trend in total cheese consumption over the past three decades. Nielsen 2005 retail Homescan data were used to analyze cheese consumption by location as well as by income, age, and racial/ethnic groups. . . .To the extent that increases in consumers' food expenditure translate into more cheese purchases, it is expected that total cheese consumption will continue to rise. However, changes in the demographic profile of the U.S. population may somewhat slow future growth. USDA Outlook No. (LDPM-193-01) 19 pp, August 2010 (Davis et al. 2010)

In the United States, the FDA has requirements for specific standardized cheese that must be followed by manufacturers, packers, and distributors. For some cheese varieties, a starter culture is used.

Curd development begins as a starter culture is added to milk. Once a curd has formed, it is cut, cooked to shrink the curd, and drained of any remaining whey (syneresis). Next, it is salted to provide flavor, draw whey from the curd, and retard microbial growth. The curd is then pressed and fermented with various microorganisms at 40–55 °F (4–13 °C).

Cottage cheese is an example of a cheese that may be made without bacteria or yeast, however with lactic acid. The origins were not in industry, yet rather individual "cottages." Thus, the name! Cottage cheese is a no/low-fat, soft, acid cheese formed by coagulation of casein with lactic acid. It is made from pasteurized skim milk, to which is added *either* lactic acid or a bacterial culture that produces lactic acid to reduce the pH to 4.6.

Cheese is cut and packaged under hundreds of names worldwide. Despite the abundance of names given to various cheeses throughout the world, there are only approximately 18 types that differ in flavor and texture (Potter and Hotchkiss 1998). These types are listed as follows:

- Brick (USA)—semisoft, ripened primarily by bacteria
- Camembert (France)—soft, mold externally applied (*Oidium lactis* and then *P. camemberti*); thin edible crust
- Cheddar (England)—hard, bacteria ripened (*S. lactis and S. cremoris*); most common cheese used for cooking in the United States, colored by annatto (a seed pod extract)
- Cottage cheese—soft, unripened; creamed, low-fat, nonfat, or dry curd
- Cream cheese (USA)—soft, unripened; may be flavored
- Edam (the Netherlands)—hard, ripened; ball shaped with a red paraffin coating
- Gouda (the Netherlands)—semisoft to hard, ripened; similar to Edam
- Hand—soft
- Limburger (Belgium)—soft, surface bacteria ripened (Bacterium linens)
- Neufchatel (France)—soft, unripened in the United States; ripened in France
- Parmesan (Italy)—hard, bacteria ripened
- Provolone (Italy)—hard, ripened
- Romano (Italy)—very hard, ripened
- Roquefort (France)—semisoft, internally mold ripened (*P. roqueforti*)
- Sapsago (Switzerland)—very hard, ripened by bacteria
- Swiss, Emmentaler (Switzerland)—hard, ripened by gas-forming bacteria (*S. lactis* or *S. cremoris* and *S. thermophilus*, *S. bulgaricus*, and *P. shermani*)
- Trappist—semisoft, ripened by bacteria and surface microorganisms
- Whey cheeses, such as ricotta (Italy), which may be a combination of whole and low-fat milk or whey; coagulated by heating, not rennin (Potter and Hotchkiss 1998; some definition in fourth and fifth edn.)

More details of the types of cheese available to the consumer are listed and explained below:

- *Natural cheese* is the curd of precipitated casein—either ripened or unripened. It may be overcoagulated and allow water to be squeezed out, or the fat emulsion to break when exposed to *high* heat, in which case it shows a separated appearance and stringy texture. Therefore, *low* heat should be used when cooking with natural cheese.

- *Pasteurized process*(*ed*) *cheese* is the most common cheese produced in the United States. By FDA ruling, it is "prepared by comminuting and mixing, with the aid of heat, one or more cheeses of the same, or two or more varieties, except cream cheese, neufchatel cheese, cottage cheese, low-fat cottage cheese, cottage cheese dry curd, cook cheese, hard grating cheese, semisoft, part-skim cheese, part-skim spiced cheese, and skim milk cheese for manufacturing with an emulsifying agent . . . into a homogeneous plastic mass" (CFR 21).

  The mixture is pasteurized (which halts ripening and its flavor development) for 3 min at 150 °F (66 °C), and salt is added. An emulsifier such as disodium phosphate or sodium citrate is incorporated to bind the calcium and produce a more soluble, homogeneous, and smooth cheese that can withstand higher heat than natural cheese, without coagulating. The melted cheese is placed in jars or molds such as foil-lined cardboard boxes or single-slice plastic wrap.

  This cheese may also contain an optional mold-inhibiting ingredient consisting of not more than 0.2 % by weight of sorbic acid, potassium sorbate, sodium sorbate, or any combination of two or more of these or consisting of not more than 0.3 % by weight of sodium propionate, calcium propionate, or a combination of sodium and calcium propionate. It may contain pimentos, fruits, vegetables, or meats.

  The moisture content of a process cheese made from a *single variety* of cheese is not more than 1 % greater than the maximum moisture content prescribed by the definition and standard of identity, for the variety of cheese used, if there is one. In no case is the moisture more than 43 % (except 40 % for process washed curd and process Colby cheese and 44 % process Swiss and Gruyere). The moisture content of a process cheese made from *two or more* varieties of cheese, as opposed to the aforementioned one is not more than 1 % greater than the arithmetical average of the maximum moisture contents prescribed by the definitions and standards of identity, if there is one, for the cheeses used. In no case is the moisture content more than 43 % (40 % cheddar, Colby, 44 % Swiss and Gruyere).

  The fat content of process cheese made from a single variety of cheese is not less than the minimum prescribed by the definition and standard of identity for the variety of cheese used, and in no case is less than 47 % (except process Swiss 43 % and process Gruyere 45 %). The fat content of process cheese made from two or more varieties of cheese is not less than the arithmetical average of the two cheeses, as described above, and in no case is less than 47 % (except the mixture of Swiss and Gruyere 45 %).

- *Pasteurized process*(*ed*) *cheese food* is comminuted and mixed and contains not less than 51 % cheese by weight. The moisture is not more than 44 %, and the fat content is not less than 23 %. Thus, it contains less cheese and more moisture than process cheese. It may contain cream, milk, nonfat milk, NDM, whey, and other color or flavoring agents. It has a soft texture and melts easily.

  An emulsifying agent may be added in such quantity that the weight of the solids of such an emulsifying agent is not more than 3 % of the weight of the pasteurized process cheese food (FDA).

- *Pasteurized process cheese spread* is comminuted and mixed. It has a moisture content of 44–60 % and a milk fat level of not less than 20 %. Therefore, it has more moisture and less fat than processed cheese food and can be spread. Gelatin and gums such as carob bean, cellulose gum (carboxymethylcellulose), guar, tragacanth, and xanthan, as well as carrageenan, may be added if such substances are not more than 0.8 % of the weight of the finished product

(FDA). Sodium may be added to retain moisture, and sugar or corn syrup may be added for sweetness.

- *Cold-pack cheese* preparation involves grinding and mixing natural cheese without heat. The moisture content of a cold-pack cheese made from a single variety of cheese is not more than the maximum prescribed for the variety of cheese used (if there is a standard of identity), and the fat content is not less than the minimum prescribed for that cheese, yet is not less than 47 % (except 43 % cold-pack Swiss and 45 % Gruyere).

Although cold-pack cheeses may contain various flavor combinations, manufacturers have/have used the technology to create custom-colored and custom-flavored specialty cheeses as needed (Food Eng 2000b). When made from two or more varieties of cheese, the moisture content should be the arithmetical average of the maximum of the two cheeses, as prescribed by the definition or standard of identity, yet in no case more than 42 %. The fat content is not less than the arithmetical average of the minimum percent of fat prescribed for the cheeses, if there is a standard of identity or definition, but in no case less than 47 % (cold-pack Swiss and Gruyere 45 %).

The lactose content of ripened cheese *decreases* during ripening and is virtually *absent* in several weeks. It is the whey that contains lactose, which some individuals cannot consume (lactose intolerance). The majority of vitamins and minerals remain after ripening, some protein is hydrolyzed by rennin or proteases, and some fat is digested. Grades of US grade AA and A are assigned to some commonly consumed cheeses such as cheddar and Swiss cheese.

CULINARY ALERT! Tips for lengthening shelf life of cheese involve cold storage and lowering the pH. This is achieved by refrigeration and wrapping in a vinegar-soaked cheesecloth.

If mold forms on the cheese, it may not be acceptable to the would-be consumer. Yet, the rule of thumb is not necessarily to discard the entire piece of cheese. Rather, any apparent mold should be cut off deeper than what is seen in order to cut out the roots. The mold may produce a toxin. (Keep in mind that mold is acceptable in certain cheeses such as blue cheese.)

CULINARY ALERT! Blue cheese is made from cow's milk; Roquefort cheese is made from sheep milk. If other cheeses show mold, they can be consumed if mold is cut away deeper than what can be seen. It is recommended to cut off ¼ to 1 in. of this moldy product.

According to a research study by Oregon State University, "Imitation cheese is made from vegetable oil: it is less expensive, but also has less flavor and doesn't melt well. For the record, *Velveeta*® is pasteurized process cheese spread and *Velveeta Light*® is pasteurized process cheese product. *Cheez Whiz*® is labeled as pasteurized process cheese sauce, although that type isn't noted in the *Code of Federal Regulations*" (OSU).

Milk Substitutes Imitation Milk Products

Milk substitute and imitation milk products were officially defined in 1973. At that time, the FDA differentiated between *substitute* and *imitation* products by establishing regulations regarding the use of the two names. More details follow each introduction:

A milk ***substitute*** product is one that resembles the traditional product and is nutritionally equal. A substitute is pasteurized, homogenized, and packaged like milk. It is more economical than real dairy products because it does not contain the costly butterfat.

Filled Milk

Filled milk is an example of milk ***substitute*** and *does not contain milk fat*. It consists of a *vegetable* fat or oil, and nonfat milk solids, so it is a not a substitute for persons with milk allergies. The vegetable fat has *traditionally* been coconut oil, although it may be partially hydrogenated corn, cottonseed, palm, or soy oil. Oil, water, an emulsifier such as monoglycerides or diglycerides, color such as carotene, and flavoring may be added. Filled milk contains no cholesterol.

An ***imitation milk*** product may look and taste like the traditional product, yet is nutritionally inferior. Specifying the term "imitation" on labels is no longer a legal requirement.

Imitation Milk

Imitation milk usually contains *no* milk products at all—*no* milk fat or milk solids. It is composed of water, vegetable oil, corn syrup, sugar, sodium caseinate, or soy, and stabilizers and emulsifiers. Vitamins and minerals may be added to the product to improve the nutritional value. Again, the term "imitation" on labels is no longer a legal requirement.

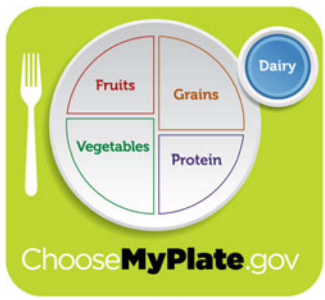
Food items that are available in the marketplace, including nondairy dry and liquid creamer, may fit into these above categories.

CULINARY ALERT! Milk and milk products with the "Real" symbol on the package indicate that the product is made from real dairy products, not substitutes or imitations.

CULINARY ALERT! Flavored "milk," "butter," "cream cheese," whipped "cream," and other imitation products are readily available in the marketplace. Nondairy "creamers" or whiteners are prevalent in fluid and dehydrated form.

Nutritive Value of Milk and Milk Products

The 1996 FDA ruling for nutritive value of milk and milk products *revoked* the "standard of identity" (prescribed formulation or recipe that the manufacturer needed to follow). The nutrient claims such as "fat-free" and others similar to those carried by other products became the *rule* for dairy labels.



Open to some discussion and further research on fats, the current American Heart Association recommendation states that "We recommend that adults and children age 2 and older use milk that's *low* in dairy fats. This includes fortified fat-free (skim or nonfat) milk, fortified nonfat milk powder, and 1/2 and 1 % low-fat milk. The label on the container should show that the milk has been fortified with *vitamins A and D*. We also recommend buttermilk made from skim milk and canned evaporated skim milk.

10 tips
Nutrition Education Series

got your dairy today?

10 tips to help you eat and drink more fat-free or low-fat dairy foods

The Dairy Group includes milk, yogurt, cheese, and fortified soymilk. They provide calcium, vitamin D, potassium, protein, and other nutrients needed for good health throughout life. Choices should be low-fat or fat-free—to cut calories and saturated fat. How much is needed? Older children, teens, and adults need 3 cups* a day, while children 4 to 8 years old need 2½ cups, and children 2 to 3 years old need 2 cups.

1 "skim" the fat
Drink fat-free (skim) or low-fat (1%) milk. If you currently drink whole milk, gradually switch to lower fat versions. This change cuts calories but doesn't reduce calcium or other essential nutrients.

2 boost potassium and vitamin D, and cut sodium

Choose fat-free or low-fat milk or yogurt more often than cheese. Milk and yogurt have more potassium and less sodium than most cheeses. Also, almost all milk and many yogurts are fortified with vitamin D.

3 top off your meals

Use fat-free or low-fat milk on cereal and oatmeal. Top fruit salads and baked potatoes with low-fat yogurt instead of higher fat toppings such as sour cream.

4 choose cheeses with less fat
Many cheeses are high in saturated fat. Look for "reduced-fat" or "low-fat" on the label. Try different brands or types to find the one that you like.

5 what about cream cheese?
Regular cream cheese, cream, and butter ***are not*** part of the dairy food group. They are high in saturated fat and have little or no calcium.

* What counts as a cup in the Dairy Group? 1 cup of milk or yogurt, 1½ ounces of natural cheese, or 2 ounces of processed cheese.

6 ingredient switches
When recipes such as dips call for sour cream, substitute plain yogurt. Use fat-free evaporated milk instead of cream, and try ricotta cheese as a substitute for cream cheese.

7 choose sweet dairy foods with care
Flavored milks, fruit yogurts, frozen yogurt, and puddings can contain a lot of added sugars. These added sugars are empty calories. You need the nutrients in dairy foods—not these empty calories.

8 caffeinating?
If so, get your calcium along with your morning caffeine boost. Make or order coffee, a latte, or cappuccino with fat-free or low-fat milk.

9 can't drink milk?
If you are lactose intolerant, try lactose-free milk, drink smaller amounts of milk at a time, or try soymilk (soy beverage). Check the Nutrition Facts label to be sure your soymilk has about 300 mg of calcium. Calcium in some leafy greens is well absorbed, but eating several cups each day to meet calcium needs may be unrealistic.

10 take care of yourself and your family

Parents who drink milk and eat dairy foods show their kids that it is important. Dairy foods are especially important to build the growing bones of kids and teens. Routinely include low-fat or fat-free dairy foods with meals and snacks—for everyone's benefit.

United States Department of Agriculture
Center for Nutrition Policy and Promotion

Go to www.ChooseMyPlate.gov for more information.

DG TipSheet No. 5
June 2011
USDA is an equal opportunity provider and employer.

Avoid substitutes that contain *coconut oil*, *palm oil or palm kernel oil*. These oils are very high in *saturated* fats. Saturated fats tend to raise the level of cholesterol in the blood. High blood cholesterol is one of the six major risk factors for heart disease that can be changed, treated or modified. It can also lead to developing other heart and blood vessel diseases (AHA)."

Proteins

High-quality proteins are in milk—casein and whey. According to the American Diabetes Association (ADA) Exchange List, an 8-ounce serving of fluid milk contains 8 g of protein, regardless of fat content.

Several milklike substitutes are available on the market—rice milk, soy milk, and others may be found at the grocery store and specialty stores. Such products meet special allergy and nutrition needs.

Fats and Cholesterol

Labeling changes have served both to benefit processors' creativity, such as in developing "light" milk, and to better assist consumers in lowering their fat and saturated fat intake. As shown above (Types of Milk), a label may state whole milk, reduced fat, or fat-free. The calorie levels differ according to the fat content. For example, whole milk contains 150 calories per 8 ounce and skim milk contains 90 calories per 8 ounce. Cholesterol levels range from 4 to 33 mg per cup.

According to the USDA, milk sales have indicated an increase in the sales of reduced-fat and skim milk, while there has been a decrease in sales of full-fat, whole milk.

Carbohydrates

The carbohydrate content of 8 ounces of milk is 12 g regardless of the level of fat. A discussion of lactose intolerance follows.

Vitamins and Minerals

The fat-soluble vitamins A, D, E, and K are present in whole and some reduced-fat milk. Fortification beyond vitamin A and D is not allowed in current standards of identity. Milk is a major source of riboflavin (B_2) in the diet of many populations. Losses of B_2 may occur due to exposure to sunlight as riboflavin is a photosynthesizer. Milk also contains the amino acid tryptophan, a precursor to niacin. Milk is a good source of the mineral calcium.

No apparent undesirable effect on protein, fat, carbohydrates, minerals, and vitamins B_6, A, D, and E is observed with pasteurization. Vitamin K is slightly diminished, and there is less than 10 % loss of thiamin and vitamin B_{12}.

One 8-ounce cup (240 mL) of whole fluid cow's milk contains the following minerals: potassium, calcium, chlorine, phosphorus, sodium, sulfur, and magnesium. Milk does not contain iron. The composition of milks from different species appears in Table 11.2.

Low-sodium milk may be included in diets with sodium restrictions. Sodium may be reduced from a normal amount of 49 mg to about 2.5 mg/100 g of milk by replacing the sodium with potassium in an ion exchange.

Flavored milks are an alternative to such beverages and may assist in consuming calcium (Johnson et al. 2002).

CULINARY ALERT! There is no appreciable effect on the availability of calcium or protein to humans when normal quantities of *chocolate* are added to milk (National Dairy Council).

FDA Report Summary

The Food and Drug Administration (FDA) is announcing that the International Dairy Foods Association (IDFA) and the National Milk Producers Federation (NMPF) have filed a petition requesting that the Agency amend the standard of identity for milk and 17 other dairy

> products to provide for the use of any safe and suitable sweetener as an optional ingredient. FDA is issuing this notice to request comments, data, and information about the issues presented in the petition. (FDA 2013)

Last modified on December 26, 2012 is An Overview of U.S. State Milk Laws—http://www.realmilk.com.

Lactose Intolerance

Lactose intolerance is an inability to digest the principal milk sugar, lactose. Many individuals demonstrate a permanent loss of the enzyme used to digest lactose. It may be due to the absence of, or insufficient amount of, lactase, a birth deficit, or physical impairment. Caucasians are among the *few* population groups who can digest lactose.

A reminder: Lactose is a disaccharide of glucose and galactose and represents the slightly less than 5 % carbohydrate that is in milk.

If lactose remains undigested by lactase in the intestine, it is fermented by microflora to form short-chain fatty acids and gases such as carbon dioxide, hydrogen, and, in some individuals, methane. Symptoms of lactose intolerance include flatulence, abdominal pain, and diarrhea due to the high solute concentration of undigested lactose. A correct understanding of tolerable doses may be more liberal than expected. Both the lactose-intolerant individual and the food industry may benefit. Also, acidophilus milk contains the needed enzyme lactase and is readily available at many grocery markets.

Lactose assists in the absorption of calcium, phosphorus, magnesium, zinc, and other minerals from the small intestine brush border. Nondairy "milk" such as rice or soy milk or other imitation milk contains no lactose and may be consumed by individuals with milk allergies and by those who would otherwise not drink milk.

The loss of lactase activity in the intestine affects, to some extent, approximately 75 % of the world's population. Individuals with lactose intolerance may compensate by consuming lactase-treated milk (which reduces lactose by 70 %) or purchase the lactase enzyme and administer it directly to milk prior to consumption. It has been shown that small servings (120 mL = 6 g of lactose) of milk and hard cheeses (less than 2 g of lactose) may be consumed without an increase in intolerance symptoms. Hard cheeses contain less lactose than soft cheeses. Up to 12 g of lactose are tolerated, especially if the individual consumes other foods with the source of lactose.

A quantity of fermented products, such as cheese, is tolerated if lactose has sufficiently been converted to lactic acid. Aged cheese is an example of such food. The lactose content of some milk and milk products is given in Table 11.3.

Safety/Quality of Milk

Safe handling was previously discussed in this chapter.

Milk is a highly perishable substance, high in water, with significant amount of protein and a near-neutral pH (6.6)—the qualities that *support bacteria growth*. Details of sanitation are previously mentioned, but it is important to know about the care and safety of milk. Depending on the ingredients, even nondairy imitation "milks" *may* require refrigeration or freezing comparable to the dairy product that they resemble.

Packaging contains a date on the carton that should be followed for a retail sale. Milk may remain fresh and usable for several days past this "sell-by date" if the following directions, suggested by the Dairy Council, are observed:

Table 11.3 Lactose content of milk and milk products

Type of milk	Weight 1 cup (g)	Average percentage	Grams/cup
Whole milk	244	4.7	11.5
Reduced-fat milk (2 %)	245	4.7	11.5
Low-fat milk (1 %)	245	5	12.3
Nonfat milk	245	5	12.5
Chocolate milk	250	4.5	11.3
Evaporated milk	252	10.3	26.0
Sweetened condensed milk	306	12.9	39.5
Nonfat dry milk (unreconstituted)	120	51.3	61.6
Whole dry milk (unreconstituted)	128	37.5	47.9
Acidophilus milk (nonfat)	245	4.4	10.8
Buttermilk	244	4.3	10.5
Sour cream	230	3.9	8.9
Yogurt (plain)	277	4.4	10.0
Half-and-Half	242	4.2	10.0
Light cream	240	3.9	9.3
Whipping cream	239	2.9	6.9

Source: National Dairy Council

- Use proper containers to protect milk from exposure to sunlight, bright daylight, and strong fluorescent light to prevent the development of off-flavor and a reduction in riboflavin, ascorbic acid, and vitamin B_6 content.
- Store milk at refrigerated temperatures [45 °F (7 °C)] or below as soon as possible after purchase.
- Keep milk containers closed to prevent absorption of other food flavors in the refrigerator. An absorbed flavor alters the taste but the milk is still safe.
- Use milk in the order purchased.
- Serve milk cold.
- Return milk container to the refrigerator immediately to prevent bacterial growth. Temperatures above 45 °F (7 °C) for fluid and cultured milk products for even a few minutes reduce shelf life. Never return unused milk to the original container.
- Keep canned milk in a cool, dry place. Once opened, it should be transferred to a clean opaque container and refrigerated.
- Store dry milk in a cool, dry place and reseal the container after opening. Humidity causes dry milk to lump and may affect flavor and color changes. If such changes occur, the milk should not be consumed. Once reconstituted, dry milk should be treated like any other fluid milk: covered and stored in the refrigerator.
- Serve UHT milk cold and store in the refrigerator after opening.

"In 1924, the United States Public Health Service (USPHS), a branch of the FDA, developed the Standard Milk Ordinance, known today as the Pasteurized Milk Ordinance (PMO). This is a model regulation helping states and municipalities have an effective program to prevent milk borne disease. The PMO contains provisions governing the production, processing, packaging and sale of Grade "A" milk and milk products. It is the basic standard used in the, a program all 50 states, the District of Columbia and U.S. Territories participate in.

Forty-six of the 50 have adopted most or all of the PMO for their own milk safety laws with those states not adopting it passing laws that are similar. California, Pennsylvania, New York and Maryland have not adopted the PMO.

Section 9 of the PMO states in part that, "only Grade 'A' pasteurized, ultra-pasteurized or aseptically processed milk and milk products shall be sold to the final consumer, to restaurants, soda fountains, grocery stores or similar establishments" (http://www.realmilk.com).

How USDA's Dairy Grading Program Works

The **US grade AA or grade A** shield is most commonly found on butter and sometimes on cheddar cheese.

US Extra Grade is the grade name for instant nonfat dry milk of high quality. Processors who use USDA's grading and inspection service may use the official grade name or shield on the package.

The "**Quality Approved**" shield may be used on other dairy products (e.g., cottage cheese) or other cheeses for which no official US grade standards exist if the products have been inspected for quality under USDA's grading and inspection program. USDA

. . . the composition or milkfat content given for each product (except for butter) is required under FDA regulations. State laws or regulations may differ somewhat from FDA's. The milkfat content of butter is set by a Federal law. FDA has established a regulation that allows a product to deviate from the standard composition in order to qualify for a nutrient content claim. Products such as nonfat sour cream, light eggnog, reduced fat butter, and nonfat cottage cheese fall into this category. (USDA)

Carbohydrate browning reactions with their color and flavor changes are observed in canned or dry milk that has been subject to either long or high-temperature storage. It should be mentioned here that the browning does not indicate contamination or spoilage. Rather, it is the nonenzymatic ***Maillard browning*** or "carbonyl-amine browning" reaction between the free carbonyl group of a reducing sugar and the free amino group of protein.

Marketing Milk

Marketing milk has made use of the National Milk Mustache "got milk?" Campaign. See the Milk Processor Education Program at http://www.milknewsroom.com/index.htm. This site is designed to be a resource for the media to access information about milk research, milk programs, and the National Milk Mustache "got milk?" Campaign.

Conclusion

Milk is the first food of mammals. It contains major nutrients, carbohydrate, fat, and protein, with water being predominant (88 %). The two major proteins in milk are casein and whey, with additional protein found in enzymes. The fat content of milk is designated by law according to the specific product and jurisdiction.

Milk is pasteurized to destroy pathogens and is homogenized to emulsify fat and prevent creaming. Grade A milk must be treated in this manner if subjected to interstate commerce. Milk may be fluid, evaporated, condensed, dried, or cultured and made into butter, cheese, cream, ice cream, or a variety of other products. It is a potentially hazardous food due to its high protein, water activity, and neutral pH and must be kept cold.

Notes

CULINARY ALERT!

Glossary

Buttermilk, cultured Pasteurized low-fat or nonfat milk to which bacteria are added to ferment lactose to the more acidic lactic acid that clots the casein in milk.

Casein Primary protein of milk, colloidally dispersed.

Casein micelles Stable spherical particles in milk containing α_s-, β-, and κ-casein, and also colloidal calcium phosphate. The micelles are stabilized by κ-casein, which exists mainly at the surface; the α_s- and β-casein fractions are located mainly in the interior of the micelles.

Cheese Coagulated product formed from the coagulation of casein by lactic acid or rennin; may be unripened or bacteria ripened; made from concentrated milk.

Churning Agitation breaks fat globule membranes so the emulsion breaks, fat coalesces, and water escapes.

Coagulate The formation of new cross-links subsequent to the denaturation of a protein. This forms a clot, gel, or semisolid material as macromolecules of protein aggregate.

Creaming Fat globules coalesce (less dense than the aqueous phase of milk) and rise to the surface of unhomogenized, whole, and some low-fat milk.

Cultured See fermented.

Evaporated milk Concentrated to remove 60 % of the water of ordinary fluid milk; canned.

Fermented (Cultured) enzymes from microorganisms or acid that reduce the pH and clot milk by breaking down the organic substrates to smaller molecules.

Fortified Increasing the vitamin content of fresh milk to contain vitamins A and D to levels not ordinarily found in milk.

Homogenization Dispersion of an increased number and smaller fat globules to prevent creaming.

Imitation milk Resembles (looks, tastes like) the traditional product but is nutritionally inferior—contains no butterfat or milk products.

Lactose intolerance Inability to digest lactose due to the absence or insufficient level of intestinal lactase enzyme.

Maillard reaction The first step of browning that occurs due to a reaction between the free amino group of an amino acid and a reducing sugar; nonenzymatic browning.

Milk solids nonfat (MSNF) All of the components of milk solids except fat.

Milk substitute Resembles (looks, tastes like) traditional product and is nutritionally equal; contains no butterfat (e.g., filled milk).

Overrun The increase in volume of ice cream over the volume of ice cream mix due to the incorporation of air.

Pasteurization Heat treatment to destroy pathogenic bacteria, fungi (mold and yeast), and most nonpathogenic bacteria.

Rennin Enzyme from the stomach of milk-fed calves used to clot milk and form many cheeses.

Ripening The time between curd precipitation and completion of texture, flavor, and color development in cheese. Lactose is fermented, fat is hydrolyzed, and protein goes through some hydrolysis to amino acids.

Sterilization Temperature higher than that required for pasteurization, which leaves the product free from all bacteria.

Sweetened, condensed milk Concentrated to remove 60 % of the water, contains 40–45 % sugar.

Total milk solids All of the components of milk except for water.

Whey Secondary protein of milk, contained in serum or aqueous solution; contains lactalbumins and lactoglobulins.

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Model FDA Food Code

National Dairy Council. Rosemont, IL

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USDA ChooseMyPlate.gov