

Milk for Liquid

Consumption

Liquid milk can be delivered to the consumer after various heat treatments: none (raw milk), pasteurized or sterilized, and either packaged or not (although sterilized milk is, of course, always packaged). The properties of liquid milk that require the most attention are safety to the consumer, shelf life, and flavor. Safety is, of course, essential and consumption of raw milk cannot be considered safe. Consequently, the delivery of raw milk is prohibited or severely curtailed in many countries. Likewise, delivering milk that is not packaged may involve health hazards. The relative importance of other quality marks depends on usage.

Milk can be consumed as a beverage, in which case flavor is of paramount importance. Most consumers tend to dislike a cooked flavor and, therefore, low-intensity pasteurization is generally preferred. Others use milk primarily in coffee or tea, in cooking, in baking, etc., where the absence of a cooked flavor is mostly not essential (if not too intense) and shelf life may be the most important quality mark. Consequently, sterilized milk is often favored.

One may even use milk preserves like evaporated milk, dried milk, or — for some uses — sweetened condensed milk.

Liquid milk may vary in composition. Often fat content is standardized to a value near that of average raw milk, but low-fat (semiskim) and skim milks are also sold. Fortification with solids-not-fat or with protein is occasionally applied. Standardization to a specified protein content by means of ultrafiltration is another possibility, but it may not be allowed. Most countries have legal requirements for a minimum solids-not-fat or protein content.

PASTEURIZED MILK

Pasteurized beverage milk must be safe for the consumer and have a shelf life of a week or longer when kept refrigerated. Flavor, nutritive value, and other properties should deviate only slightly from those of fresh raw milk.

The following contaminants can in principle be harmful to the consumer:

- Pathogenic microorganisms, which may already be in the milk while in the udder, or be incorporated during or after milking. Most of these do not survive pasteurization, but they may also enter the product by recontamination.
- Toxicants taken up by the cow (e.g., with the feed) and entering the milk during its synthesis.
- Antibiotics, used to treat (the udder of) the cow.
- Disinfectants used on the farm or in the plant.
- Bacterial toxins formed during keeping of the milk.
- Other toxicants entering the milk by contamination during and after milking.
- Radionuclides.

Pathogenic microorganisms can be killed by heat treatment. Most (chemical) contaminants cannot be eliminated in this way. Obviously, proper cattle management and adequate methods of collecting and handling the milk are necessary to prevent health hazards. Regular checks for the absence of contaminants are needed. With reference to the shelf life and safety of the milk, most countries have legal requirements for the maximum number of microorganisms (colony count) and coliforms, and for the absence of the enzyme alkaline phosphatase. To meet these requirements, the original milk should not contain too many heat-resistant bacteria, the

pasteurization step should be checked (recording thermometer and flow diversion valve), and contamination of pasteurized milk with microorganisms (or with raw milk) should be minimized. A cream layer is less desirable, especially when nontransparent packaging material is used. It can be prevented by homogenization, which implies that the pasteurizing intensity should be adapted to avoid lipolysis. The more intense the heat treatment, the more the flavor of the milk will differ from that of raw milk.

RECONSTITUTED MILKS

In several regions, there is a shortage of fresh (cows') milk. As an alternative, milk powder can be used to make a variety of liquid milk products. Some common types are the following:

Reconstituted milk: It is simply made by dissolving whole milk powder in water to obtain a liquid that is similar in composition to whole milk. Likewise, reconstituted skim milk can be made.

Recombined milk: It is made by dissolving skim milk powder in water, generally at 40 to 50°C, then adding liquid milk fat (preferably anhydrous milk fat of good quality; Subsection 18.5.1), making a coarse emulsion by vigorous stirring or with a static mixer, and then homogenizing the liquid. This product is similar to homogenized whole milk, except that it lacks most of the material of the natural fat globule membrane, such as phospholipids.

Other recombined milk products are made for recombined evaporated milk.

Filled milk: It is like recombined milk, except that instead of milk fat, a vegetable oil is used to provide the desired fat content.

Toned milk: It is a mixture of buffaloes' milk and reconstituted skim milk. The high fat content of buffaloes' milk (e.g., 7.5%) is thereby toned down.

Cream Products

Cream is sold in many varieties. The fat content may range from 10% (half-and half) to 48% (double cream). Although used for several purposes, it is primarily something of a luxury and, therefore, an excellent flavor is of paramount importance. Because of the high fat content, any off-flavor of the fat becomes concentrated. For instance, milk with a fat acidity of 1 mmol per 100 g fat will not be perceived to have a soapy, rancid flavor by most people, but a whipping cream made from it will definitely taste rancid. Therefore, the milk should be impeccable with regard to lipolysis and fat oxidation.

Sometimes anhydrous milk fat is used in cream products and recombination is applied. Such a fat may have an oxidation flavor, and even if impeccable in this respect, the taste of the product may be somewhat less rich because of the absence of components from the milk-fat-globule membrane. Besides plain cream, some derived products are made, such as sour cream and ice cream.

WHIPPING CREAM

This involves cream of, say, 35% fat. It is primarily designed to be beaten into a foam, often with sugar added. It is mostly available as a pasteurized product in small bottles, plastic cups, or large cans. It is also sold as in-can sterilized cream.

DESIRABLE PROPERTIES

The most important specific requirements are:

1. Flavor: The product is eaten for its flavor, which obviously must be perfect. Rancid and tallowy flavors in the original milk should be rigorously avoided; this requirement is even more essential than for coffee cream.

Not everybody appreciates a sterilization flavor or even a pronounced cooked flavor, and partly because of this, the cream usually is pasteurized.

2. Keeping quality: Many kinds of spoilage can occur, but it is often desirable to store the cream for a prolonged time. The original milk should contain not more than a few heat-resistant bacteria; above all, *Bacillus cereus* is a disastrous microorganism in whipping cream (it causes the fat emulsion to become unstable). Nor should growth of psychrotrophs occur in the original milk because they form heat-resistant lipases. To allow for a fairly long shelf life, the pasteurized cream should be packaged under strictly hygienic or even aseptic conditions. Recontamination by bacteria often raises complaints. Therefore, whipping cream is sometimes heated by in-can or in-bottle pasteurization.

Contamination by even minute amounts of copper causes autoxidation and hence off-flavor. Some coalescence of the fat globules during processing can readily lead to cream-plug formation during storage. The presence of a cream plug implies that the product can hardly be removed from the bottle; moreover, the cream will readily churn rather than whip during the beating in of air.

3. Whippability: In a few minutes the cream should easily whip up to form a firm and homogeneous product, containing 50 to 60% (v/v) of air, corresponding to 100 to 150% overrun (the overrun is the percentage increase in volume due to gas inclusion).

4. Stability after whipping: The whipped cream should be firm enough to retain its shape, remain stable during deformation (as in cake decoration), not exhibit coarsening of air cells, and show negligible leakage of liquid.

ICE CREAM

There are numerous types of edible ice, essentially mixtures of water, sugar, flavor substances, and other components, which are partly frozen and beaten to form a rigid foam. In most types, milk or cream is an important ingredient. Nowadays, a part of the milk solids not-fat is often substituted by whey constituents to lower ingredient costs. In some countries, the milk fat is often substituted by vegetable fat, for instance, partly hydrogenated palm kernel oil. Dairy ice cream is the product discussed here.

Furthermore, soft serve, ordinary, and hardened ice cream are distinguished. Soft ice is eaten while fresh. It is made on the spot, its temperature is usually -3 to -5°C, and, therefore, it still contains a fairly large amount of non frozen water; generally, its fat content and overrun are rather low. Hardened ice cream, usually packaged in small portions and sometimes supplied with an external chocolate coating, is much lower in temperature (say, -25°C). The solution remaining

is in a glassy state, and it has a shelf life of several months. Ordinary ice cream has a lower temperature than that of soft ice cream (-10 to -15°C), but is not so cold as to be entirely solid; it is stored for a few weeks at the most in cans, from which portions can be ladled out.

Milk or cream of impeccable flavor is needed, especially with respect to rancidity and autoxidation. The latter defect may occur in hardened ice cream because it is stored for long periods, and its water activity is rather low; it contains a great deal of oxygen. Therefore, contamination by copper has to be rigorously avoided.

Butter

DESCRIPTION

Butter is generally made from cream by churning and working. It contains a good 80% fat, which is partly crystallized. The churning proceeds most easily at a temperature of around 15 to 20°C. Therefore, butter typically is a product originating from regions having a temperate climate. In addition to accumulated practical experience, a good deal of science has now been incorporated in butter making, enhancing the shelf life and quality of the product and the economy of manufacture.

Some variants occur: butter from cultured (soured) or from sweet cream and butter with or without added salt. Formerly, the salt was added as a preservative, but nowadays it is mainly added for the flavor; moreover, souring of the cream inevitably occurred (due to the duration of the gravity creaming), and now it is practiced intentionally. It enhances the keeping quality (although this hardly makes a difference when applying modern technology), and it greatly influences the flavor. The following are the most important specific requirements for the product and its manufacture:

1. Flavor: Off-flavors of the fat are to be avoided, especially those caused by lipolysis, but also those due to volatile contaminants. The latter mostly dissolve readily in fat; examples are off-flavors caused by feeds such as silage and Allium (onion) species. If the cream is heated too intensely, the butter gets a cooked flavor. Moreover, careful attention has to be paid to the souring (see the following text).

2. Shelf life: Spoilage by microorganisms may cause several off-flavors (putrid, volatile acid, yeasty, cheesy, and rancid). In cultured-cream butter, spoilage usually involves molds and yeasts, the pH of the moisture being too low (~4.6) for bacterial growth. Lipolysis causes a soapyrancid flavor; no lipases formed by psychrotrophs should be present in the milk. Furthermore, autoxidation of the fat can occur, especially at prolonged storage, even at a low temperature (-20°C), leading to a fatty or even a fishy flavor.

3. Consistency: Butter derives its firmness largely from fat crystals that are aggregated into a network. Butter should be sufficiently firm to retain its shape; likewise, oiling off (that is, separation of liquid fat) should not occur. On the other hand, the butter should be sufficiently soft so as to be easily spreadable on bread. The consistency can cause problems, because the firmness and the spreadability depend strongly on the composition of the fat and on the temperature.

4. Color and homogeneity: These rarely pose problems.

5. Yield: Some fat is lost in the skim milk and in the buttermilk. If the water content is below the legal limit (for example, 16%), this also means a loss of yield.

6. By-products: Buttermilk is sometimes desirable, but often it is not, owing to insufficient demand. Sour-cream buttermilk is only applicable as a beverage (or as animal feed), but it keeps

poorly due to rapid development of an oxidized flavor . Sweet-cream buttermilk can more readily be incorporated in certain products.

Concentrated Milks

Concentrated milks are liquid milk preserves with a considerably reduced water content. Water is removed by evaporation. Preservation is achieved either by sterilization, leading to a product called evaporated milk, or by creating conditions that do not allow growth of microorganisms. The latter is generally realized by addition of a large quantity of sucrose and exclusion of oxygen. The resulting product is called (sweetened) condensed milk. These products were initially meant for use in (usually tropical) regions where milk was hardly or not available. The milks were packaged in small cans. The contents were often diluted with water before consumption to resemble plain milk. Currently, alternative products are used more often, such as whole milk powder or recombined milk. For the concentrated milks, some alternative forms of use developed, and processing and packaging have been modified. The consumption of sweetened condensed milk has greatly declined.

Evaporated milk

Evaporated milk is sterilized, concentrated, homogenized milk. The product can be kept without refrigeration and has a long shelf life; it is completely safe for the user. After dilution, flavor and nutritive value of the product are not greatly different from that of fresh milk. A major problem with sterilization is the heat stability; the higher the concentration of the milk, the lower its stability. That is why concentrating cannot be by more than about 2.6 times, which corresponds to a level of about 22% solids-not-fat in the evaporated milk. Currently, bottled evaporated milk is often used in coffee in certain countries. It can be added while cold because a fairly small amount is involved as compared to nonevaporated milk. After the bottle has been opened, the milk can be kept in a refrigerator for up to 10 days because it initially contains no bacteria at all and because contaminating bacteria grow somewhat more slowly owing to the reduced water activity, which is about 0.98.

Sweetened condensed milk

Sweetened condensed milk is milk that is concentrated by evaporation, to which sucrose is added to form an almost saturated sugar solution, after which it is canned. The high sugar concentration is primarily responsible for the keeping quality of the product and for its fairly long shelf life, even after the can has been opened, although it then will eventually become moldy.

There are compositions of two kinds of sweetened condensed milk.

Sweetened condensed skim milk is also made. The milk is highly concentrated: the mass concentration ratio, Q , ranges from 4.6 to 5, and the increase in concentration relative to water, Q^* , is 7.3 to 8.5. Because of this and the high sugar content, the product is highly viscous, i.e., η_a is approximately 2 Pa·sec, about 1000 times the viscosity of milk. The product is somewhat glassy in appearance because the fat globules show little light scattering as the refractive index of the continuous phase is almost equal to that of fat. The turbidity of the product is largely due to lactose crystals. Most of the lactose crystallizes because of its supersaturation.

Milk Powder

This chapter discusses spray-dried powders made from whole milk, skim milk, and, to a lesser extent, whey.

Objectives

We may distinguish the following objectives:

1. The main purpose of the manufacture of milk powder is to convert the liquid perishable raw material to a product that can be stored without substantial loss of quality, preferably for some years. Decrease in quality mainly concerns formation of gluey and tallowy flavors (due to Maillard reactions and autoxidation, respectively) and decreasing nutritive value (especially decrease in available lysine). If the water content becomes very high and the storage temperature is high, caking (due to lactose crystallization) and enzymic and even microbial deterioration can occur; however, such problems are avoidable.
2. The powder should be easy to handle. It should not dust too much or be overly voluminous. It should be free-flowing, i.e., flow readily from an opening, and not stick to the walls of vessels and machinery. The latter requirement is especially important for powder used in coffee machines, etc.
3. After adding water the powder should be reconstituted completely and readily to a homogeneous mixture, similar in composition to the original product. Complete reconstitution means that no undissolved pieces or flakes are left and that neither butter grains nor oil droplets appear on top of the solution. 'Readily reconstituted' means that during mixing of powder and water no lumps are formed, because these are hard to dissolve. In the ideal situation the powder will disperse rapidly when scattered on cold water; this is called instant powder. Special processing steps are needed to achieve this property. The importance of instant properties closely depends on the kind of application.
4. According to its intended use the reconstituted product should meet specific requirements. If the use is beverage milk, the absence of a cooked flavor is of importance. If the powder is to be used for cheese making, the milk should have good clotting properties. If used to make recombined evaporated milk, satisfactory heat stability is necessary.

Hygienic Aspects

The requirements for the bacteriological quality of milk powder partly depend on its intended use and, in connection with this, also on the manufacturing process. For example, whether the powder is meant for direct consumption or whether it is subjected to a heat treatment after reconstitution (e.g., for recombined milk) is important. The heat treatment during the manufacture of (skim) milk powder, classified as 'low heat', usually is not more intense than the heat treatment during low pasteurization (say, 72°C for 20 s); consequently, many bacteria may survive the manufacturing process.

The causes for milk powder to be bacteriologically unacceptable or even unsafe can be of three kinds:

1. In the fresh milk, bacteria are present that are not killed by the heat treatments to which the milk is subjected before and during drying.
2. Conditions during the various process steps until the product is dry do allow growth of some bacterial species.

3. During manufacture, incidental contamination may occur. The level of contamination is generally low and remains low if the bacteria involved cannot grow.

In establishing the bacteriological quality of the powder, the species of bacteria involved should be considered. Then the cause of the contamination may be deduced, as may the measures that must be taken to improve the quality.