Paper No. 7 Technology of Milk and Milk Products

Module No. 5 Pretreatments to milk for product manufacture

Introduction

Milk is a very wholesome food having an array of nutrients. However, it is highly perishable and needs to be treated adequately to prevent it from spoilage (souring, curdling). Chilling of raw milk is the most common treatment meted out to preserve the quality of raw milk till it is processed at the dairy plant. Moreover, treating the milk prior to product making or even marketing of milk, value can be added into it (i.e. lactose hydrolysis of milk/whey) or enables obtaining resultant product of desired (superior) quality, without incurring much losses of milk solids (i.e. *chhana* or *paneer* making).

Pre-treatment meted out to milk

The treatments meted out to milk at the dairy plant are discussed under separate headings as under.

I. Filtration or Clarification of raw milk

Most of the plants employ mechanical processes for removing the foreign materials from milk as it is received from the producer. The two types of equipment used for such purpose are the filter and the clarifier. The examples of undesired constituents in raw milk are particles of dirt, blood residues, udder cells and several bacteria. The principle of centrifuge would be to remove matter whose specific gravity is greater than that of milk. The filter relies on enmeshing the solid particles in the fleecy surface of the filter cloth or wire mesh filter. Pore width should not exceed 0.2 mm. There is more reduction in the somatic cell count (SCC) (especially from diseased udder of animal) in case of clarification (especially at 110^{o}F) compared to filtration.

The clarifier is more efficient than filter in removal of sediment from milk. The filtration does not influence the keeping quality of raw milk. A temperature either between 8°C and 15°C (46°F and 59°F) which is typical for storage or between 52°C and 58°C (126°F and 136°F) is recommended. Warm clarification of milk, e. g. at 50 to 55°C (122 to 131°F), is preferable to cold clarification. Product is lost as a result of spun-off solids being discharged from the separator bowl. Protein losses to the extent of 0.12 % are considered feasible.

II. Chilling of raw milk

Chilling of milk means rapid cooling of raw milk to sufficiently low temperature so that the growth of micro-organisms present in milk is checked. In chilling process the temperature of milk should be reduced to less than 10^{o}C preferably 3–4^{o}C. Milk inside the udder is almost sterile and as soon as it leaves the udder, it is exposed to atmosphere. The number and types of microorganisms would depend upon the conditions and the sources of contamination. As soon as microorganisms get into the milk, they start growing rapidly. If the growth of microorganisms is not checked then their growth will continue and several biochemical changes will take place in milk. Due to these changes the quality of milk is adversely affected so much so that sometimes milk becomes unfit for consumption as fluid milk. If milk has to be transported to longer distances, considerable time is involved between production and heating process. During this period milk must be protected from spoilage by the action of microorganisms. Chilling, therefore, is considered necessary soon after it is received at the chilling centers.

Lower temperatures inhibit the growth of most of the microorganisms. Chilling process does not kill microorganisms, nor does it render the milk safe for human consumption. However, psychrotrophic microbes can tolerate such low temperature. It is only a means of checking the growth of microorganisms for sometime.

The methods that are used to chill the milk are:
(i)Surface cooler, (ii) Tubular cooler, (iii) Plate chiller or even (iv) Bulk milk cooler

III. Lactoperoxidase treatment of raw milk

The Lactoperoxidase system (LP system) of raw milk preservation is currently the only approved method of raw milk preservation, apart from refrigeration, in Codex. It was adopted by Codex Alimentarius as a guideline in 1991, following an evaluation by Joint Expert Committee on Food Additives (JECFA). The LP-system operates by the reactivation of the enzyme lactoperoxidase, which is naturally present in raw milk, by the addition of thiocyanate (10 ppm) and a source of peroxide (8.5 ppm of sodium percarbonate). This results in a blocking of bacterial metabolism thereby preventing the multiplication of bacteria present in the milk. The effect is bacteriostatic, but such effect has limited duration which is determined by temperature.

The system is promoted by FAO as an effective means of extending the shelf life of raw milk in developing countries where technical, economical and/or practical reasons do not allow the use of cooling facilities for maintaining the quality of raw milk. Use of the LP-system in areas which currently lack an adequate infrastructure for collection of liquid milk, would ensure the production of milk as a safe and wholesome food. Such system neither improves nor disguises the poor quality milk.

Activation of the LP-system delayed lactic acid formation in yogurt during incubation and storage, but led to an improved keeping quality during storage. LP-system treatment reduced the overall sensory quality of yogurt while it improved that of cheese (*Bambu*i).

IV. Standardization of milk

Milk to be sold as ‘Market milk’ or even for product manufacture (i.e. cheese, paneer, chhana, concentrated and dried milks) is invariably subjected to standardization (for only fat, both fat and SNF, and ratiosof casein/fat or fat/SNF). The examples of the targeted fat and SNF for various market milks is provided in Table 1, while the fat/SNF ratio for condensed and dried milks, casein/fat ratio for cheese and fat content for paneer making is furnished in Table 2.

Table 1. Standardization of milk to targeted fat and SNF content

Type of market milk	Fat and SNF content
Cow milk	3.5 – 4.0% fat, 8.5% SNF
Buffalo milk	5.0-6.0% fat, 9.0% SNF
Full cream milk	6.0% fat, 9.0% SNF
Mixed milk	4.5% fat, 8.5% SNF
Standardized milk	4.5% fat, 8.5% SNF
Toned milk	3.0% fat, 8.5% SNF
Double toned milk	1.5% fat, 9.0% SNF
Recombined milk	3.0% fat, 8.5% SNF

Table 2. Standardization of milk for product manufacture

Intended dairy product	Type of standardization	Value
Cheese (Cheddar)	Casein/fat ratio	0.70 (ratio) (~ 3.5% fat)
Cheese (Mozzarella)	Fat only	2.7-3.0% fat
Paneer	Fat only	4.0% fat
Evaporated milk	Fat/SNF ratio	0.444 (ratio)
Sweetened condensed milk	Fat/SNF ratio	0.409 (ratio)
Whole milk powder	Fat/SNF ratio	0.366 (ratio)
Baby powder (Humanized milk)	Fat/SNF ratio	0.232 (ratio)

Standardization of milk helps in the following aspects:

(a) Enables the milk or milk product to conform to the legal (FSSAI) standards.
(b) Enables to maintain consistency of milk or milk product day to day.
(c) Helps in keeping the price of milk and dairy product under check.
(d) Reduces the losses incurred in product manufacture
(e) Controls the body and texture of product (i.e. cheese, paneer, etc.)

In several cheese varieties, or industrial production settings, the consistency in the composition of cheese may be controlled by standardization of the incoming milk, generally in terms of manipulation of the ratio of fat/casein or fat/total protein, by centrifugal separation and proportional mixing of cream whole milk and/or skim milk, by membrane filtration, or by addition of sources of milk protein.

V. Thermization of milk

Thermization is a subpasteurization operation sometimes applied to raw milk that is intended to be held after intake for extended periods of refrigerated storage before manufacture of certain products (e.g. Dutch-type cheese). The primary issue of concern in such cases is the growth of psychrotrophic bacteria during cold storage and consequent secretion of heat stable extracellular proteinases and lipases by such bacteria into the milk.

Thermization is typically heating milk to 57-68°C for a period of 15 sec, which will inactivate psychrotrophic bacteria and thereby prevent enzyme production. Thermized milk has markedly better microbial quality during refrigerated storage than raw milk.

Thermization has little effect on cheese making properties of milk, and may increase cheese yield by preventing pre-manufacture hydrolysis of milk proteins by bacterial proteinases and by partially reversing low-temperature dissociation of β-casein and calcium from the casein micelles.

Other thermization maybe used to prolong the shelf life of cultured milk products (either before or after packaging), by inactivating starter and other microflora in products, preventing defects such as post-acidification. Thermization reduces the stability of extracellular proteinases and lipases produced by Pseudomonas bacteria to subsequent heat treatment e.g. in Ultra High Temperature (UHT) processes, by inducing low-temperature inactivation.

VI. Fore-warming of milk

Standardized milk for preparing Evaporated milk is forewarmed (pre-heated) to 85-90°C for a period of 10-20 min, to increase milk protein interactions (κ-casein with β-lactoglobulin) necessary to confer heat stability. Other forewarming conditions include 110-125°C for 30 sec to 4 min and 115°C for 2 min and 135°C for 15 sec; the latter two are preferred where direct steam injection heating is used. This has application in manufacture of Evaporated milk (i.e 26.0 % TS concentrated milk) which is subjected to sterilization to have increased shelf life under ambient conditions.

Heat treatment of milk at more severe conditions than those used for conventional pasteurization results in denaturation of whey proteins, interactions between whey proteins and casein micelles, and transfer of soluble Ca, Mg and PO_4 to the insoluble colloidal state. This aspect is used advantageously in the manufacture of *Paneer* (milk heated to 82°C for 5-10 min) and *Chhana* – a base material for sweetmeats like *Rasogolla*, *Sandesh*, etc. (milk heated to boiling momentarily) wherein it gives increased yield as well as desired body and texture too. For cheese-makers, interest has been in increasing yield by exploiting this heat-induced association of caseins with whey proteins, especially at which renneting is not impaired. The effects of heat treatment at temperatures between 72 and 140◦C for holding times between 15 s and 5 min on whey protein denaturation prior to incorporation into cheese has yielded good results. Heat treatment of milk at ~ 110˚C for 60 s increased the protein recovery in curd by 10.0%.

VII. Bactofugation of milk

In milk processing spore-formers can cause considerable problems. In the production of fresh milk, aerobic spore-formers (*Bacillus cereus*) impair shelf life as a result of sweet curdling. In the production of milk powder, especially 'low heat' products, aerobic and anaerobic spore-formers (*Bacillus cereus*, *Clostridium perfringens*) lead to the product spoilage. Under certain conditions, the removal of bacteria secures shelf life in soft cheese products – for example, in cases where the so-called ascospores of the molds *Byssochlamys nivea* or *Byssochlamys fulva* have a negative impact on quality. Lactate-fermenting anaerobic spore-formers which are not killed by normal milk heating can lead to butyric acid fermentation in the production of cheese. Sporeformers of the genus *Clostridium tyrobutyricum* can cause 'late blowing' in cheese.

Bactofugation is a process in which a specially designed centrifuge called a 'Bactofuge' is used to separate micro-organisms (especially sporeformers) from milk (for cheese making or UHT milk). Originally the Bactofuge was developed to improve the keeping quality of market milk. At the present time, bactofugation is used to improve the bacteriological quality of milk intended for products such as cheese, milk powder and whey used for baby food.

Bacteria, especially heat resistant spores, have higher density than milk. A Bactofuge is therefore an efficient means of getting rid of bacterial spores from raw milk. The original Bactofuge was a solid bowl centrifuge with nozzles in the perpihery of the bowl. It was long considered necessary to have a continuous flow of the heavy phase, either through a peripheral nozzle or over the heavy phase outlet of the Bactofuge, to achieve efficient separation. In the modern self-cleaning separators with a sludge space outside the disc stack, bacteria and spores can be collected over a period of time and intermittently discharged at preset intervals. Since the spores are resistant to heat treatment, the Bactofuge makes a useful complement to thermization, pasteurization and sterilization.

Bactofugation is typically done on the raw milk stream and can be done in one stage or two, depending on the desired bacteria reduction. The bactofugation can be done on the raw milk stream or on the skim line in conjunction with high temperature treatment of cream. The result is a cleaner final product which can produce an extended shelf life (ESL) milk, or can be used to improve the quality of milk powder and milk protein concentrate (MPC). The optimal bactofugation temperature is 55–62°C. Higher bactofugation temperature increases the amount of protein in the bactofugate. This is because some of the larger casein micelles are separated out together with the bacteria and spores.

There are two types of Bactofuge

- ***Two-phase Bactofuge***: It has two outlets at the top; one for continuous discharge of bacteria concentrate (bactofugate) via a special top disc, and one for the bacteria-reduced phase.

- ***One-phase Bactofuge***: It has only one outlet at the top of the bowl for the bacteria-reduced milk. The bactofugate is collected in the sludge space of the bowl and discharged at preset intervals.

Bactofugation efficiency is stated as a percentage reduction of the incoming level of bacteria and spores. Generally, the efficiency ranges between 98.0-99.5% for anaerobic spores. Depending on the desired reduction, this can be performed in one step or two. If a single-stage bacteria removal process is not adequate to produce cheese without the addition of nitrate, for example, it is possible to arrange two bacteria-removing separators in series.

Centrifugal removal of bacteria enables spores to be reduced by a factor of more than ten, corresponding to more than 3.5 generations. The amount of bactofugate from the two-phase Bactofuge is about 3.0% of the feed, while the corresponding amount from the one-phase Bactofuge can be as low as 0.15% of the feed.

Bacteria belonging to the genus Clostridium (i.e. anaerobic spore-forming bacteria) are among the most feared by cheese makers, as they can cause 'late-blowing' of cheese even if present in small numbers. Hence, cheese milk is subjected to 'bactofugation'. Bactofugation is most commonly used in the production of Swiss cheese; it is a nitrate-free method of preventing 'late-blowing' spores that can severely affect the quality of cheese. Bactofugation is used in the manufacture of other types of cheese to minimize undesirable bacteria.

VIII. Homogenization of milk

The primary aim of homogenization of milk is to reduce the size of the fat globules, thereby delaying their creaming rate. In raw milk, fat globule size commonly ranges from ~ 0.2–15 μm, and homogenization generally aims to reduce the maximum to < 2 μm. For this purpose, two-stage valve homogenizers are commonly used, which operate at pressure of ~ 20 MPa (2900 psi). More recently, novel homogenization devices, e.g., high-pressure homogenizers and microfluidizers, which can operate at pressures of several hundred MPa and achieve greater reductions in fat globule size, have been developed. In cheese-making, homogenization of cheese-milk can be of interest for the purpose of preventing creaming of fat globules, reducing fat losses in the whey or controlling development of free fat in the cheese.

Due to the reduction in fat globule size on homogenization, the total surface area of the fat globules increases and the amount of original fat globule membrane material is by far insufficient to fully cover the newly-formed surface. As a result, other surface-active components of milk, primarily caseins and, to a lesser extent, whey proteins, become adsorbed onto the surface of the newly formed globules. The adsorption of caseins onto the fat globules has the following implications for cheese-making characteristics of milk:

(i) casein surface area in milk is increased, but the amount of micellar casein is reduced;
(ii) two types of particles with a casein micelle surface layer exist: native casein and fat globule membrane material

The primary function of homogenization is to prevent creaming, or the rising of fat to the top of the container of milk (whole or some low-fat milk). 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 permanently emulsifies the fine fat globules by a method that pumps milk under high pressure (i.e. 2000–2500 psi) through small mesh orifices of a homogenizer; temperature of homogenization should be > 60^{o}C in order to inactive native lipase enzyme in milk as far as possible.

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.

Some 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 flavourful due to smaller fat particles.
- 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.

IX. Pasteurization of milk

Perhaps the simplest and earliest technological intervention, driven by safety concerns, was the pasteurization of milk, first carried out in vats or kettles at temperatures around 63–65◦C (low-temperature, long-time, LTLT, pasteurization) and more recently in continuous-flow plate heat exchangers at 72–74°C for 15–30 s (high temperature, short-time, HTST, pasteurization). For a high proportion of cheese varieties, pasteurization is the sole treatment applied to the cheese-milk. Pasteurization also inactivates some enzymes, reverses shifts in the mineral balance of milk induced by cold storage, and influences the microflora of non-starter lactic acid bacteria (NSLAB) in the final cheese. There has also been interest for some time in the application of heat treatments more severe than pasteurization, which will result in significant denaturation of whey proteins and their resulting incorporation into cheese curd, with significant effects on cheese yield and composition.

X. Lactose hydrolysis of milk

Lactose intolerance is being reported in many populations. Some people cannot tolerate and digest lactose due to a lack of β-galactosidase in their intestine. Consuming milk and dairy products by these people leads to cramp, flatulence, vomiting, etc. Yet, milk is highly nutritious and methods are being explored to use milk while limiting the lactose content. Significant improvement in absorption with 90.0% lactose hydrolyzed milk has been observed in low lactase subjects. Lactose hydrolyzed milk may serve as an important alternative for food planners wanting to provide milk to high risk populations with low lactase levels. Regardless of the medical implications of the lactose intolerance, even the most innocuous symptoms such as flatulence or intestinal discomfort may cause many potential milk consumers to avoid drinking milk or to consume other lactose containing dairy products. Lactose in milk can be hydrolyzed by adding an enzyme β-D-galactosidase into milk, which breaks down lactose into glucose and galactose. The resulting milk is sweeter than the original milk too. The concentrated products made out of such milk (i.e. sweetened condensed milk) are less prone to lactose crystallization. The main sources of β-galactosidase are microorganisms, for instance, *Saccharomyces fragilis*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, etc. Commercially it can be produced from the yeast *Kluyveromyces fragilis* with an optimum pH of 6.5-7.0 suitable for the treatment of milk, or from the fungus *Aspergillus oryzae* or *A. niger* with optimum pH of 4.5-6.0 and 3.0-4.0 respectively, suitable for whey hydrolysis. The immobilized β-galactosidase preparation could hydrolyze 89.0% of lactose in whey in 3 h and 79.0% of the lactose in milk in 4 h.

The market for lactose hydrolyzed dairy products has been steadily increasing at the rate of 20.0% per year in US alone, stimulated by the awareness for lactose intolerance problems. 'Lactose hydrolyzed' and 'lactose-free dairy products' should be considered an important physiologically functional dairy food.

XI. Membrane processing of milk

Milk may be subjected to membrane processes (pre-treatment) like microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO) and nanofiltration (NF) in order to prepare 'milk enriched in protein content' or for preparing 'pre-cheese' to be subsequently converted in cheese products. Even use of UF and RO in the manufacture of condensed and dried products helps in concentrating the milk solids that is cheaper than condensing of milk with heat under vacuum; the flavor and nutritive value of such concentrated/dried product is also superior owing to the less severe heat treatment. The gel-forming properties of high-heat-treated milks may be partly restored by UF of milk to higher protein levels prior to cheese manufacture. The examples of milk product manufacture in which they utilize membrane processed milk is furnished in Table 3.

Table 3. Examples of membrane processing of milk in product making

Product making	**Type of membrane process**	**Effects/Advantages**
ESL* milk	Bactofugation, Microfiltration	Extended shelf life of milk (i.e. 90 days) at refrigeration temperature
Cheese making (soft ones)	Ultrafiltration with Diafiltration	Savings in starter culture and rennet, less problems of whey disposal, increased cheese yield
Condensed milk	Ultrafiltration, Reverse osmosis,	Less destruction of nutritive value, economical way to concentrate milk solids
Milk powder	Ultrafiltration, Reverse osmosis, Nanofiltration	Enable preparing 'low-heat milk powder', less destruction of nutritive value, economical way to concentrate milk solids
Khoa	Reverse osmosis plus ultrafiltration	Economical way to concentrate milk solids

* Extended shelf life milk

Finally to sum up, the pre-treatments that is involved in preparation of 'market milk' or 'milk products' is shown in a tabular form in Table 4.

Table 4. Pre-treatments involved in preparing certain dairy products

Milk/milk product	**Pre-treatments involved**
Market milk	Filtration/Clarification, chilling, homogenization, lactose hydrolysis, pasteurization
Cream products	Centrifugal separation, chilling, homogenization, pasteurization
Cheese	Filtration, Bactofugation, chilling, thermization, pasteurization
Evaporated milk	Filtration/Clarification, chilling, fore-warming, pasteurization

Conclusion

The role played by pre-treatments to milk is immense and such treatments can help in preserving the milk solids for long duration and help in improving the quality as well as yield of resultant product. Each dairy product manufacture entails use of varying pre-treatments suiting its composition as well as end use applications. Use of newer treatments such as High Pressure Processing (HPP), microfluidization (MFl), pulsed Electric Field (PEF) etc. will also play an important role in the times to come in India.