Microbiology of Cream and Butter

YA Budhkar, SB Bankar, and RS Singhal, Institute of Chemical Technology, Mumbai, India

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Cream

Definition and Types

Creams are dairy products enriched to varying degrees with milk fat. Creams may be acidified or nonacidified, whipped, and may or may not have additives. Classification of cream is on the basis of fat content, application, and manufacture. Cream types available in the European market are slightly different from those available in the United States. Table 1 lists different types of commercial creams. The Food and Agriculture Organization classification of cream is given in Table 2. In Germany, coffee cream and whipping cream with 10 and 35% minimum fat, respectively, are also available.

Manufacture

The quality of cream depends on the physicochemical and microbiological properties and handling of the milk from which it is prepared. Milk should be handled carefully to prevent damage to the fat globules during pumping and agitation, since this may result in free fat, which may coalesce or 'churn,' making the separation difficult. General steps involved in industrial manufacture of cream follow.

Table 1 Commercially available creams

Cream type	*Fat content (% by weight)*	*Applications*
Half-cream or single cream	10–18	As pouring cream for use in desserts and beverages; as breakfast cream poured over fruit and cereals; used industrially as an ingredient of canned soups and sauces
Coffee cream	Up to 25	To give an attractive appearance to coffee with appropriate modification in flavor
Cultured or sour cream	<25 normally (occasionally up to 40)	In confectionery, and in meat and vegetable dishes
Crème fraîche	28–30	It is another sour cream, but with a higher fat content
Whipping cream	30–40	For toppings and fillings for baked goods
Double cream (marketed in Europe)	>48	Used in desserts and whipped in gateaux
Clotted cream	>55	Used as spread on scones in conjunction with fruit preserves
High-fat creams (plastic cream)	70–80	For ice cream manufacture

Production of Milk on the Farm

Milk production on the farm should be done in utmost hygienic manner. Although vegetative cells may be killed by subsequent heat treatment, spores and organisms such as *Bacillus cereus* can survive and cause subsequent spoilage of the milk.

Transport and Storage

Milk should be stored below 5 °C in silos or suitable tanks until cream manufacture. It is common practice to hold milk at 5 °C for up to 48 h in creameries.

Separation and Standardization of Cream

Milk is heated at 44–55 °C for separation of the cream. Although temperatures below 40 °C yield a highly viscous product and the possibility of lipolytic off-flavors, those above 55 °C may cause rapid and excessive thickening of the cream during storage. Nanofiltration followed by deoxygenation by nitrogen gas dispersion treatment prior to conventional cream separation is reported to give a clean aftertaste. Cream separation is carried out continuously in centrifugal separators that have separate ports for skimmed milk and cream. The mechanics of keeping cream separated from skimmed milk depends on the type of centrifugal separator used. Centrifugal separators of disc stack type are mostly used in modern dairies. Some separators used to produce high-fat creams (40% fat content) can operate at 5 °C, at which microbial growth would be insignificant. Very recently, ultrasound has demonstrated a potential to predispose fat particles in milk emulsions to creaming in standing wave systems and in systems with inhomogeneous sound distributions, which could have implications in cream separation in future.

Homogenization of Cream

Homogenization increases the viscosity, which is preferred by consumers, but also increases the potential for light-induced rancidity (manifested as oxidized flavor) owing to the increased surface area resulting from homogenization. It is used only for some types of creams, such as half cream or

Table 2 Food and Agricultural Organization (FAO) classification of cream

Product type	*Fat content (%)*
Cream	18–26
Light cream (cream with additional terms such as coffee cream/table cream)	>10
Whipping cream (light whipping cream)	>28
Heavy cream (heavy whipping cream)	>35
Double cream (extra-heavy cream/manufacturer's cream)	>45

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single cream, to prevent fat separation. Double cream may also be lightly homogenized. Whipping creams are generally not homogenized since it inhibits formation of stable foam. Homogenization is carried out after standardization at 65 °C and 17 MPa, but certain automated separating processes can carry out standardization at a preferred temperature of 40 °C.

Heat Treatment of Cream

Cream is a high-moisture product with a short shelf life. Heat treatment extends the shelf life by inhibiting the growth of pathogenic and spoilage organisms and denaturing indigenous lipases, which may promote rancidity. According to International Dairy Federation, heat treatments must conform to one of the following minima:

- Pasteurization at 63 °C for ≥30 min or ≥72 °C for 15 s (for creams with fat content of up to 18%); temperatures up to 80 °C for 15 s (for creams with fat content of 35% or more) are also used. In the United States, dairy products containing more than 10% fat receive a heat treatment of 74.4 °C for 15 s
- Sterilization at 108 °C for 45 min
- Ultrahigh temperature (UHT) treatment at 140 °C for 2 s

Pasteurization reduces viscosity of cream and also produces some sulfurous notes that disappear on storage. Higher temperatures result in cooked flavors and may impair cream quality by possibly activating bacterial spores. A major defect of nonhomogenized pasteurized cream is formation of 'cream plugs.' This is attributed to the free fat that welds the globules together and in extreme cases solidifies the cream. Fat composition and rate of cooling of the cream also affect plug formation. High-temperature short-time (HTST) treatment of creams presently is used in most commercial creameries for sterilization.

Efficacy of heat treatment must be checked by testing for phosphatase. Rapid and sensitive tests based on fluorimetry and chemiluminescence have been developed to check for phosphatase. The use of phosphatase test in pasteurized creams, however, can be problematic owing to its reactivation on storage.

Cooling and Storage after Heat Treatment

Pasteurized cream should be cooled immediately after heat treatment to ≤5 °C, typically using hyperchlorinated water to minimize the risk of postprocess contamination (due to potential seam leak and growth of thermoduric organisms), and then packaged quickly.

Packaging

Pasteurized cream for domestic consumption is packed in plastic pots or cardboard cartons. Polystyrene containers can cause taints and hence should be avoided; polypropylene pots are generally preferred. These packaging materials generally are used for holding about 5–10 l of cream. Sterilized cream is mostly produced in cans. Cans are sterilized with superheated steam, while aerosol cans are sterilized by hydrogen peroxide. Bulk quantities of cream (2000–15 000 l) are transported in stainless steel tankers.

Further Cooling, Storage, and Distribution of Cartoned Cream

A temperature of ≤10 °C during storage and distribution is recommended; 5 °C is preferred. Cream should be stored away from odoriferous materials (disinfectants, paints, varnishes, scents, or strong-smelling foods), since the cream may be rendered inedible. Sometimes aging and rebodying of cream is carried out to increase its whipping properties and viscosity, respectively. Aging of pasteurized cream is done for 24 h. In rebodying, the cream is cooled rapidly to 28–30 °C and then to 4 °C slowly over the next 24 h. This is attributed to improved crystal structure on slow cooling.

Sale – Possibly a Multistage Operation

Cream presents more problems than milk owing to distribution methods and the requirements for longer keeping quality. Sales are erratic, depending on the weather, holiday seasons, local activities, and so on. Cream should be dispatched throughout the distribution chain from manufacturing dairies to smaller retailers under chilled conditions.

A typical flow sheet for manufacture of sterilized and clotted creams is shown in Figures 1 and 2, respectively. Apart from clotted cream, most creams are produced by mechanical separators. Clotted cream has a very high viscosity, a golden creamy color, and granular texture.

In whipping creams, air is incorporated at the air–water interface and there is a disruption of the milk-fat globule

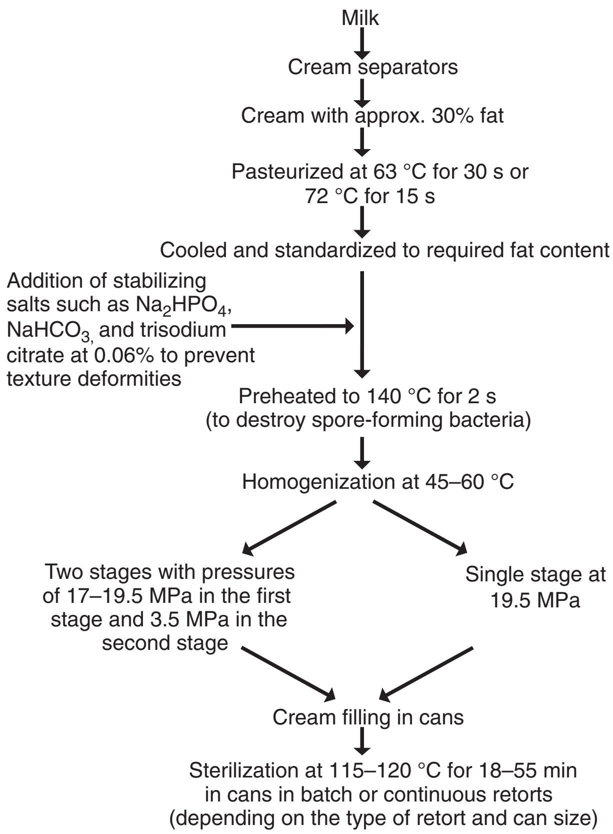

Figure 1 Flow sheet of typical manufacturing process for sterilized cream.

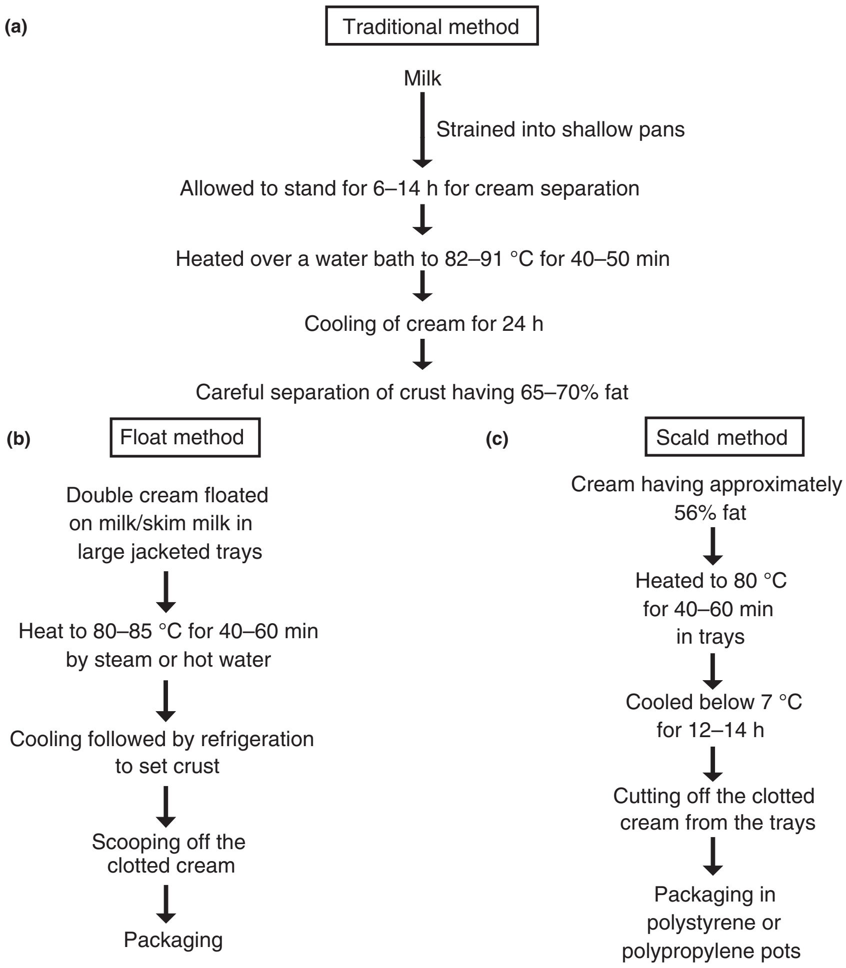

Figure 2 Flow sheet of typical manufacturing processes for clotted cream. (a) Traditional process. (b, c) Commercial processes.

membrane. Whipping using nitrogen reduces the chances of microbial growth.

Some important factors for whipping cream are as follows:

- Extent of beating required to form a stable aerated structure
- Overrun, expressed as percentage volume increase of cream due to air incorporation
- Stiffness and serum leakage from whipped cream due to overwhipping leading to sogginess if used in cakes

Factors affecting whipping properties of cream apart from rebodying are the fat content, temperature (should be $<10\ ^\circ C$), distribution, and size of fat globules and membrane structure. Whipping creams can also be foamed by aerosols. In this process, cream is filled into hermetically sealed cans that are prefilled with an inert gas, such as nitrogen. Low foam stability in aerosol-foamed creams can be compensated for with stabilizers; this also prevents microbial spoilage.

Sour cream is made by inoculating cream with cultures of lactic acid–producing bacteria, such as *Lactococcus lactis* subspp. *lactis* and *cremoris*, and flavor-producing bacteria, such as *Leuconostoc mesenteroides* subspp. *cremoris* and *dextranicum*. Souring takes place at 20 °C and avoids spoilage by thermophilic organisms.

Creams are processed in different ways and sold accordingly. For example, sterilized cream has a distinct caramelized flavor due to the in-can sterilization process and has a shelf life of about two years. Temperatures employed are 110–120 °C for 10–20 min. This severe heating brings about protein denaturation, Maillard browning, and fat agglomeration, which collectively modify the texture and flavor of the cream. A process for rapid sterilization of cream, known as autothermal thermophilic aerobic digestion (ATAD) friction process, consists of preheating the cream to about 70 °C and then heating to 140 °C for 0.54 s. This process can be applied successfully to creams ranging in fat content from 12 to 33%. Double, whipping, single, and half cream may be UHT treated or frozen after adequate pasteurization. UHT sterilization at 135–150 °C for 3–5 s followed by aseptic packaging does not induce chemical changes, but creaming and fat agglomeration does take place on storage. In this process, the shelf life is limited by biochemical rather than microbiological considerations. Since all forms of microorganisms are destroyed, the cream can be stored indefinitely without refrigeration. Calcium–casein interactions destabilize the emulsion, and any proteases surviving the heat treatment may bring about gelation. Development of a stale or 'cardboardy' flavor generally limits the shelf life to 3–6 months. Problems arise in controlling the UHT method for high-fat creams.

Bulk storage of surplus cream may be done by freezing at −18 to −26 °C after pasteurization. A shelf life of 2–18 months (average 6 months) is achieved. Cream is frozen in rotary drum freezers or plate freezers or is frozen cryogenically using liquid nitrogen. Every technique has its advantages and disadvantages; however, for a good freeze-thaw stability of frozen creams, care must be taken to preserve the natural milk-fat globule membrane. Hence, frozen creams are not homogenized.

Additives for stabilization and improvement of whipping properties of cream are permitted in many countries. Gelatin and carboxymethylcellulose mainly increase the viscosity, while alginates and carrageenan interact with calcium–casein–phosphate complex to enhance whipping properties. Emulsifiers and stabilizers improve the freeze-thaw stability of cream. Sugars such as glucose and sucrose also impart freeze-thaw stability. Nutritive sweeteners and characteristic flavoring and coloring ingredients are also used sometimes. Cream powders and imitation creams, produced by emulsifying edible oils and fats in water, are other products available for industrial use.

Keeping quality of creams can be enhanced by following good manufacturing practices. Steps that can ensure this quality assurance to the manufacturer and the consumer are as follows:

- Sanitizing all items coming in contact with cream at any stage by heat or chemical disinfectants, such as chlorine compounds
- Ensuring good supervision
- Controlling air contamination around the fillers (this often is neglected)
- Packaging creams in rooms away from processing activities
- Using water containing 5 ppm available chlorine
- In-line testing of cream equipment

Microflora of Retail Cream

Cream is the main source of microorganisms in butter. Fat globules in the raw milk carry pathogenic and spoilage organisms that originate from the udder or hide of the cow and milking lines used in the processing.

Generally, Gram-negative organisms, yeasts, and molds are destroyed, whereas psychrotrophic *Bacillus* and *Clostridium* spp. and their spores survive cream pasteurization and so do heat-resistant microbes, such as some strains of *Lactobacillus*, *Enterococcus*. More specifically, *B. cereus* contributes to product failure in late summer and early autumn than at other times of the year. *Bacillus cereus* can reduce methylene blue and hence lead to failure of the official Public Health Laboratory Services test. *Candida lipolyticum* and *Geotrichum candidum* are of greatest importance. Survival of *Mycobacterium paratuberculosis* during cream pasteurization has been confirmed by polymerase chain reaction (PCR) of cultures isolated from previously inoculated and pasteurized samples. In unpasteurized cream, *Streptococcus agalactiae*, *Streptococcus pyogenes*, *Staphylococcus aureus*, and *Brucella abortus* survive for varying periods of time and find their way into butter. Pasteurization at 62.8 °C for 30 min of butter made from contaminated cream can eliminate these organisms. Spoilage of UHT cream normally is due to failure of packing systems and entry of postprocessing contaminants. Endospores of *Bacillus* species may survive both UHT and in-container sterilization. In pasteurized clotted cream, the microflora depends on the nature of the process, the degree of control and the standard of hygiene. In most cases, *Bacillus* spp. are dominant, although non-endospore-forming thermoduric species, such as *Enterococcus*, are present in cases in which lower cooking temperatures are used.

Development of flavor defects in cream is attributed to high numbers ($>10^7$ ml^{-1}) of psychrotrophs due to postprocessing contamination of milk or cream. These produce lipolytic enzymes that cause hydrolytic rancidity. Rancid flavor is caused mainly by fatty acids of C_4 to C_{12}, while long-chain acids of C_{14} to C_{18} make little contribution. Agitation of milk at 5–10 °C or 37 °C increases the lipase activity associated with the cream several fold. Transferred enzyme is bound to the milk-fat globule membrane, wherein it has enhanced heat stability. This redistribution is of relevance in butter manufacture. Homogenization of the cream at high pressure, slow cooling and subsequent storage at higher temperatures, slow freezing, and repeated freeze-thawing also promote lipolysis. Difficulties have been experienced in churning cream made from rancid milk. The cream foams excessively and may take up to five times longer than normal cream to churn. Lipolyzed milk and products prepared there from may slow down the manufacture of fermented products (in this case, sour cream) owing to the inhibitory effects of free fatty acids developed during the hydrolytic rancidity. The causative factors for defects and spoilage of cream and their implications are summarized in Table 3. All these are common waterborne organisms. The presence of non-spore-forming organisms in sterilized cream indicates contamination after sterilization, and in canned cream, it indicates a defective or leaking can.

Butter

Butter, one of the first dairy products manufactured, has been traded internationally since the fourteenth century. Large-scale manufacture became possible only after development of the mechanical cream separator in 1877. World consumption of butter and butterfat products was more than 5 250 000 tons in 2009, with EU nations taking the second place with about 1 500 000 tons consumption after the largest consumer India, with about 3 750 000 tons consumption.

Manufacture and Typical Microflora of Fresh Butter

Butter is a water-in-oil emulsion with fat as the continuous phase, obtained by the phase reversal of cream during the churning process in its manufacture. Typically, butter contains at least 80% fat, 15–17% water, and 0.5–1% carbohydrate and protein. Manufacture of butter is shown in Figure 3 and steps involved along with their process conditions and significance are outlined in Table 4.

Improvement in Butter-Making Process

Up to the late nineteenth century, cream was separated from raw milk by standing raw milk overnight in bowls. This cream was then separated and churned in wooden bowls without pasteurization. Growth of natural microflora was considered

Table 3 Spoilage and defects in creams and their causative factors

Spoilage and defects	*Causative factor*	*Action*
Bitterness	*B. licheniformis*, *B. subtilis*	Proteolytic activity of enzymes
	Proteus	Attack on proteins and production of peptides
	Rhodotorula mucilaginosa	Associated growth in sour creams containing lactic acid organisms like *Lactococcus lactis*
Thinning	*B. licheniformis*, *B. subtilis*	Lipolytic activity of enzymes
Coagulation	*B. licheniformis*, *B. subtilis*	Proteolytic activity of enzymes
Gas and acid curdling	*Lactococcus lactis*, coliforms	Fermentative action
Fruity flavors	Yeasts like *Torula cremoris*, *Candida pseudotropicalis*, *Torulopsis sphaerica*	By survival and multiplication in whipped cream containing added sugar
Rancidity	Psychrotrophs like *Bacillus* spp., *Clostridium*	Low carbon (C_4 to C_8) fatty acids resulting from lipolysis
Flavor and chemical taints	Herbage-derived substances	Presence of undesirable volatiles (these can be readily removed by steam distillation)
	Cow feeds containing garlic and decaying fruit	

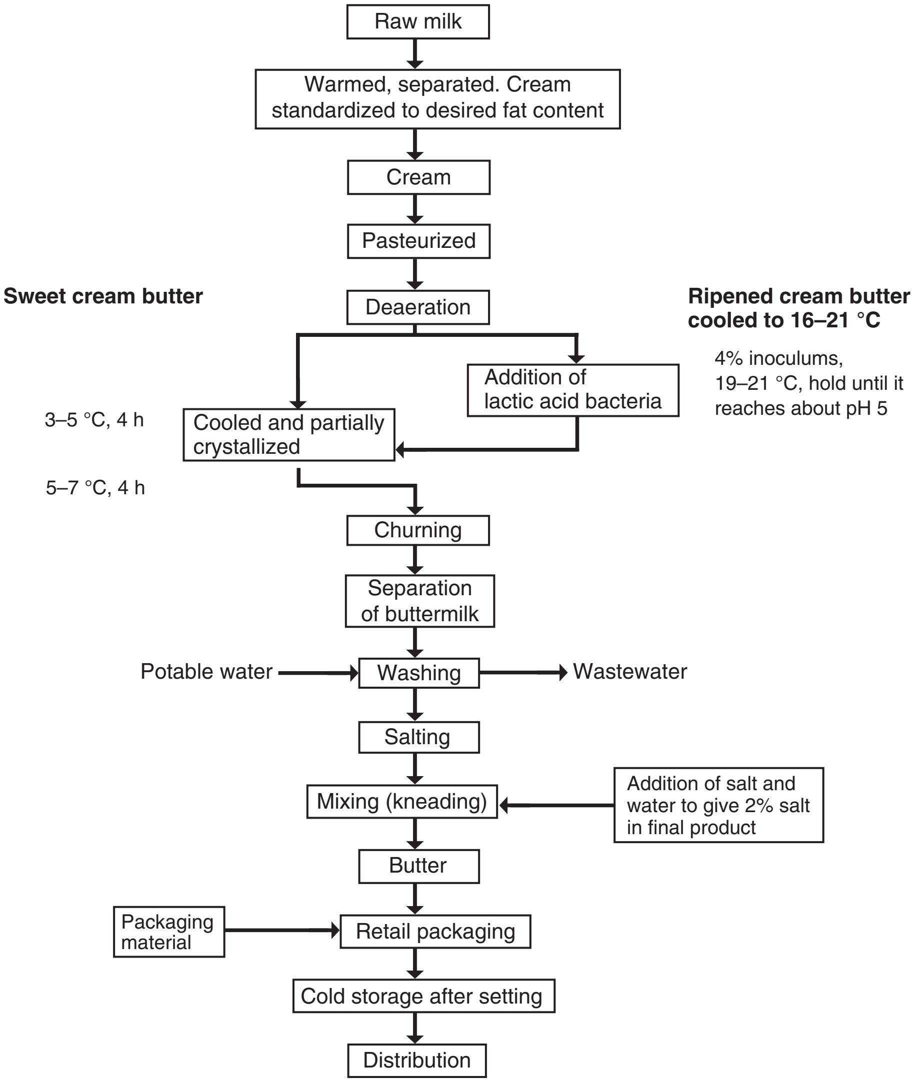

Figure 3 Flow sheet for manufacture of butter.

Table 4 Steps in butter manufacture

Step	Process	Significance
1. Concentration of fat phase in milk	Using cream separators	For separation and standardization of resultant cream to the desired fat content
2. Crystallization of fat phase	• For sweet cream – cooling at 5 °C for at least 4 h after pasteurization of cream at 66 °C for 30 min • For ripened cream – addition of lactic acid bacteria to pasteurized cream after cooling to 16–21 °C until a pH of 5.0 is reached and then followed by cooling to 3–5 °C	Develops an extensive network of stable fat crystals
3. Phase separation and formation of water-in-oil emulsion	Churning and working a proper blend of solid and liquid fat, usually at 5–7 °C	• Disrupts membranes on milk fat globules, followed by effective clumping that further causes butterfat to harden • Enhances diacetyl production in ripened cream butter
4. Washing	Rinsing with water	Removes excess buttermilk
5. Salting	Using finely ground salt or brine containing 26% w/w salt, or slurries of salt in saturated brine containing 70% sodium chloride	Inhibits microbial growth
6. Packaging	Cardboard boxes lined with vegetable parchment, aluminum foil or plastic films for bulk packaging	Protection from air, workers, plant environment, and temperatures that may promote spoilage
7. Storage	−15 to −30 °C	
8. Repackaging for retail outlets		

Source: Early, R. (Ed.), 1992. The Technology of Dairy Products. Blackie, Glasgow.

normal and added flavor to the butter. Washing the butter grains with untreated water removed nonfat solids present in the milk, which removed the substrate for microbial growth but added new waterborne microorganisms to the butter, making addition of salt necessary in this process.

Mechanization and scale-up of butter-making process began in nineteenth century. Since the churns were then made of wood, cleaning was still complicated, although the incidence of microbial contamination was reduced due to introduction of pasteurization. Subsequent replacement of wood with stainless steel or aluminum improved the hygiene conditions considerably. They also eliminated flavor problems arising due to yeasts and molds, but produced a cream that was bland. This led to different practices, such as the addition of salt or a starter culture to the cream for souring.

According to current practices, cream for butter manufacture should have at least undergone a heat treatment of 74–76 °C for 15 s, should have a fat content of about 40% so as to be amenable for continuous butter-making, and should be cooled to 10–11 °C for at least 4 h. This allows the completely liquefied butterfat to crystallize into large numbers of small crystals. This process, known as aging, allows a stable matrix of α and β forms of fat crystals to develop, which is important for the physical properties of the final product. If butter is to be ripened using a starter culture, however, it is cooled to only 19–21 °C. If cooling is too slow, bacterial spores that survive pasteurization might germinate and grow. This is followed first by agitation, washing, salting, packaging, storage, and then repackaging.

Butter may be either sweet cream butter, which may or may not be salted, or ripened cream butter in which lactic acid bacteria ferment the citrate in cream to flavor-imparting compounds, such as acetoin and diacetyl. Sweet cream butter (pH 6.4–6.5) is bland in taste but has a nutty or boiled milk flavor; this is preferred in America, Australia, and New Zealand. In Europe, Latin America, and Asia, the preference is for intense flavor, which can be developed using milk cultures. In ripened cream butter, diacetyl formation can be enhanced by incorporating air by intensive stirring of the cream, using ripening temperatures below 15 °C, maintaining an optimal pH below 5.2, and adding 0.15% citric acid to cream. The level of diacetyl in ripened cream butter is 0.5–2.0 mg kg^{-1} butter. Diacetyl also inhibits Gram-negative bacteria and fungi. Another type of butter is whey cream butter, which is processed from whey cream. Whey cream is obtained from milk fat recovered from cheese whey. In the manufacture of ripened cream butter, pasteurized cream is cooled to 6–8 °C for 2 h or more to initiate fat crystallization followed by warming to 19–21 °C and then inoculated with pure or mixed strains of *L. lactis* subspp. *lactis*, *cremoris* and *diacetylactis*, and *L. mesenteroides*. In some areas of Europe, *Candida krussi* has been tried in mixed cultures. Ripening occurs for 4–6 h until a pH of 4.6–4.7 is achieved, and the product is then cooled to 3–5 °C to stop fermentation. Spoilage microorganisms are controlled primarily through the bacteriostatic effect of lactic acid produced in the fermentation.

During churning and working of the cream, most of the starter culture is retained in the buttermilk; however, about 0.5–2.0% remain in the butter.

The Netherlands Institute voor Zuivelondazoek (NIZO) method for manufacture of cultured butter is used in many factories in Western Europe. In this method, instead of just the starter culture, a mixture of diacetyl-rich permeate and starter cultures is worked into butter. The permeate is produced by fermentation of delactolized whey or other suitable medium. This method has advantages of greater control over the manufacturing process, lower risks of oxidative defects, lower chances of hydrolytic rancidity, less need of starter cultures, better quality of butter even after 3 years of cold storage, and elimination of pumping problems often encountered with viscous ripened cream. The pH of butter made with this process is also easier to adjust to the desired range of 4.8–5.3. Salt is added to butter after removal of excess buttermilk. It should distribute evenly in the aqueous phase of the product and can inhibit microbial growth. Salt can be used in finely ground form or as slurry in saturated brine solutions containing up to 70% sodium chloride. *Listeria* is known to survive in saturated brine solution at 4 °C for 132 days; hence water used to prepare brine must be free of *Listeria*. Psychrotrophic organisms multiply in salted butter stored even at −6 °C, owing to a lowered freezing point of water due to salts, which permits the growth of these organisms.

Addition of herbs to butters is also practiced in certain countries to increase the variety of foods. Soft butters that are spreadable at 5 °C can be produced by following ways:

1. Using cream from summer period, which is the softest.
2. Subjecting the butter to extra working.
3. Incorporating about 10% soft vegetable fat with milk fat to give a normal butter composition (80% fat minimum, 16% moisture).
4. Reducing the fat as little as 50%. This low-fat dairy spread contains about 11–15% milk solids and emulsifiers to maintain a stable water-in-fat emulsion.

Traditionally and legally, however, butter must contain ≥80% of only milk fat. The products described in items 3 and 4 cannot be called butter, but they are dairy-type spreads. Recent developments in milk fat fractionation have allowed for the additional control over triglyceride composition, enabling the manufacture of butters with improved spreadability. Continuous processes for butter manufacture are economically advantageous.

Possible Problems During Storage

All commercial butter is produced from pasteurized cream. The only avenue for infection and spoilage during storage is post-pasteurization carelessness. Microbiologically induced flavors developed before pasteurization may be carried over into butter. The introduction of stainless steel equipment has eliminated many flavor problems, particularly those due to yeasts and molds. High humidity in storage area and permeability of packaging material may support the growth of psychrotrophic molds on the surface of butter.

Spoilage of Butter

Low temperatures (<10 °C) employed for bulk storage of butter are inhibitory to the growth of most microorganisms. Lethal effect of temperature is, however, selective. Survival of *Micrococcus* spp. and yeasts generally is more than Enterobacteriaceae. Microorganisms entering during reworking and packaging and those surviving at low temperatures are capable of growing during retail and domestic storage above 0 °C.

Various types of spoilages and defects have been encountered in butter (Table 5). All *Pseudomonas* groups found in butter are psychrophiles and have been traced to wash water. They grow well at refrigerator temperatures and produce putrid or lipolyitc flavors in 5–10 days. These psychrophiles also produce extracellular phospholipases that degrade phospholipids of the milk-fat globule membrane. Most lactic starters used in the manufacture of fermented milk products have a weak lipolytic activity. While natural milk lipase accounts for hydrolytic rancidity in milk and cream, microbial lipases assume greater significance in stored products. Off-flavors of hydrolytic rancidity are described variously as 'bitter,' 'unclean,' 'wintry,' 'butyric,' or 'rancid.' These defects are sometimes evident during manufacture, but they also may develop during storage. Butters made from creams that have undergone hydrolytic rancidity may not show this defect, because the rancid flavors arising due to short-chain fatty acids (C_4 and C_6) are water soluble and are readily lost in buttermilk. This discussion is valid only for sweet cream butter. Ripened cream butter is less susceptible to hydrolytic rancidity. However,

Table 5 Most common spoilage and defects encountered in butter

Nature of spoilage or defect	*Causative factors*
Spoilage	
Bacterial spoilage	Contaminated water supplies Improper distribution of salt Temperature abuse in sweet cream butter
Putridity or 'surface taint' and hydrolytic rancidity	*Pseudomonas* spp., such as *P. fragi*, *Shewanella putrefaciens* (*Alteromonas putrefaciens*), and *P. fluorescens*, grow on butter surfaces at 4–7 °C and produce proteases and lipases
Mold growth producing musty flavor	Growth of *Rhizopus*, *Geotrichum*, *Penicillium*, and *Cladosporium* may cause hydrolytic rancidity Humidity above 70% Improper personal hygiene of workers in the manufacturing plant
Malty flavor, skunk-like odor, and black discoloration	Growth of *Lactococcus lactis* var. *maltigenes*, *Pseudomonas mephitica*, and *Alteromonas nigrifaciens*
Color changes	Surface growth of various fungi produce colored spores
Acid production	Growth of yeast, such as *Saccharomyces*, *Candida mycoderma*, *Torulopsis holmii*
Defects	
Metallic taste and smell	Overacidification of cream, high level of metallic ions in wash water, defects of tinned utensils
Soapy taste and smell	Contamination with cleansing agent residues
Short, brittle structure	Butterfat too hard, improper cooling during ripening
Salvelike, greasy structure	Too much liquid fat in fat globules, defects in ripening, too high buttering and kneading temperature
Streaky, marbles appearance	Uneven salt distribution, blending of butter
Flat or insipid flavor in freshly made butter	Excessive washing of butter grains during manufacture, dilution of cream with water, initial stages of bacterial deterioration
Medicinal flavor in butter	Use of medicaments for treating cows, presence of chlorine compounds in milk or cream

yeasts such as *C. lipolyticum*, *Torulopsis*, *Cryptococcus*, and *Rhodotorula* can grow and cause lipolysis at low temperatures. These are particularly favored at low pH of some cultured cream butter.

It recently has been observed that the addition of garlic cloves to butter inactivates pathogens, like *Escherichia coli* O157:H7, *Salmonellae*, and *Listeria monocytogenes*. Such pathogens are also unable to grow in unsalted butters. Certain spices like black cumin, summer savory, and marjoram have been reported to inhibit yeasts, such as *Candida zeylanoides*, *Candida lambica*, and *Candida kefyr*, which are commonly found species of *Candida* in packaged as well as unpackaged butter.

Microbiological Standards for Cream and Butter

Microbiological standards for cream are not favored by many because of the complexity of the factors involved. A distinction can be made, however, between satisfactory, doubtful, and unsatisfactory types. Suggested standards for cream satisfactory for butter-making are counts of less than 1 cfu ml^{-1} for yeasts, molds, and coliforms, and a total colony count of less than 1000 cfu ml^{-1}. Table 6 gives the limits that have been proposed as microbiological standards for cream and butter. Bacteriological standards for cream in some countries have been outlined as follows:

- Northern Ireland:
  Untreated – bacterial count <50 000 g^{-1}.
  Pasteurized – no coliforms in 1 g
- Canada:
  Count <50 000 g^{-1}.
  No coliforms in 1 g
  Phosphatase negative
- Sweden:
  Count <10 000 g^{-1}.
  Coliforms <10 g^{-1}.
  Aerobic spores <100 g^{-1}

Public Health Concerns

Incidence of documented food poisoning associated with butter consumption was low even before widespread pasteurization of cream for its manufacture. Early outbreaks of diphtheria (caused by *Corynebacterium diphtheriae*) and tuberculosis (caused by *Mycobacterium tuberculosis* or *Mycobacterium bovis* in naturally contaminated cream) in the United States and Europe, and of typhoid fever (caused by *Salmonella typhi*) in the United States from 1925 to 1927, have been reported to be caused by butter. Butter contaminated by a convalescent carrier of *S. typhi* was responsible for 35–40 cases (including six deaths) of typhoid fever in Minnesota in 1913. Some major public health concerns with respect to cream and butter are outlined in the following section.

Aflatoxins

Aflatoxins are secondary metabolites produced by *Aspergillus flavus*, *Aspergillus parasiticus*, and *Aspergillus nomius* and are recognized as extremely potent liver carcinogens for both animals and humans. Of the four types of aflatoxins (AFB1, AFB2, AFG1, and AFG2), AFB1 is the most potent and comes from contaminated feeds. Ingestion of aflatoxin-contaminated animal feed leads to the excretion of the less toxigenic AFM1 in the milk within 12–24 h. Although many countries have legislation regarding aflatoxin limits in animal feed, the United States and many European countries also have legislation for maximum levels of AFM1 in dairy products. European Union have legislated maximum acceptable AFM1 levels of 0.05 and 0.025 μg kg^{-1} in fluid milk and milk destined for infant foods, respectively. In the United States, this limit is 0.5 μg kg^{-1} of AFM1 in milk. Present evidence indicates the level of AFM1 in milk and dairy products to be relatively unaffected by pasteurization, sterilization, fermentation, cold storage, freezing, concentration, or drying. Treatments with hydrogen peroxide, benzoyl peroxide, ultraviolet light, bisulfites, riboflavin, or lactoperoxidase, however, have been shown to be effective in reducing the levels of AFM1 in experimental trials.

Table 6 Suggested microbiological standards for cream and butter

Product	*Test*	*Count or results*[a]
Raw cream for direct consumption	Total bacterial count	<30 000 (10 000) per ml
	Total coliform count	<30 (10) per ml
	E. coli (fecal type)	1 (10) per ml
	Methylene blue reduction time (at 36 °C)	Not less than 7 h
	3 h Resazurin test (at 36 °C, Lovibond disc no. 4/9)	Not less than 4 h
	Staphylococcus aureus (coagulase-positive)	<10 (1) per ml
	Somatic cell count	<500 000 (250 000) per ml
Pasteurized cream	Total bacterial count	<30 000 (5000) per ml
	Total coliforms	<1 (0.1) per ml
	E. coli (fecal type)	Absent in 1 ml
Butter	Contaminating organisms (non-lactic-acid bacteria)	<10 000 (5000) per g
	Total bacterial count (noncultured butter only)	<50 000 per g
	Total coliforms	<10 (1) per g
	E. coli (fecal type)	Absent in 1 g
	Staphylococcus aureus (coagulase-positive)	Absent in 1 g
	Yeasts and molds	<10 per g
	Proteolytic organisms	<100 per g
	Lipolytic organisms	<50 per g

[a]Figures in parentheses are target values.

Only about 0.4–2.2% of the ingested AFB1 appears in milk as AFM1. Furthermore, since AFM1 is water soluble, it partitions naturally during manufacture of cream and butter. Typically, about 10% of the AFM1 in milk appears in cream and about 2% appears in butter. Rigid monitoring of animal feed for AFB1 can control the AFM1 levels in dairy products, including cream and butter.

Brucellosis

Brucellosis is acquired by direct or indirect contact with infected animals harboring any of three of the six bacterial species belonging to the genus *Brucella*. Human brucellosis ranges from a mild, flu-like illness to a severe disease. The severity depends on the species involved, with *Brucella melitensis* being the most pathogenic for humans, followed by *Brucella suis* and *B. abortus*. Osteomyelitis is the most common complication of this infection, followed by skeletal, genitourinary, cardiovascular, and neurological complaints. Cream and butter are unusual sources of *Brucella* spp. with only about 5 out of 916 cream samples being positive in one outbreak-related survey. Both of these products can extend survival of *B. melitensis* and *B. abortus* for 4–6 weeks when stored at 4 °C. These microorganisms can survive even longer in refrigerated butter, persisting for 6 and 13 months in salted and unsalted butter, respectively. Dairy-related brucellosis outbreaks have been virtually eliminated as a result of immunization of livestock, slaughtering of infected animals, and mandatory pasteurization of milk.

Listeriosis

Listeria monocytogenes, the causative agent of this disease emerged in late 1990s as a serious foodborne pathogen that can cause abortion in pregnant women, and meningitis, encephalitis, and septicemia in infants and immunocompromised adults. *Listeria* infections are devastating, with a mortality rate of 20–30%. Dairy-related outbreaks of listeriosis, two in Switzerland and one in the United States in the 1980s have been linked to the consumption of various products, including pasteurized milk. Cream has been implicated in a major outbreak of listeriosis in Halle, East Germany, during the period 1949–57. Butter also was implicated in an outbreak of listeriosis in a hospital in Finland in 1998–99 in which 25 patients were affected and 6 died. The outbreak strain was found in both the packaged butter and the manufacturing dairy. *L. monocytogenes* can attain population of 10^6 cfu ml^{-1} in whipping cream after 8 days of storage at 8 °C. It occasionally has been recovered from commercially produced butter, with survival up to 70 days being reported in butter prepared from inoculated cream.

Salmonellosis

The causative agent is *S. typhi*, which can survive for 2–4 weeks in butter prepared from contaminated cream and can cause outbreaks. It produces infections ranging from a mild, self-limiting form of gastroenteritis to septicemia and life-threatening typhoid fever. Salmonellae can grow at 5–45 °C. The incidence of *Salmonella* spp. in raw bulk tank milk has been estimated at 4.7%. Inadequate pasteurization and postprocessing contamination have occasionally resulted in milk and cream that test positive for *Salmonella*, evidenced by various outbreaks of salmonellosis. The numbers of salmonellae decrease in fluid milk products and butter prepared from inoculated cream during extended storage at ≤7 °C.

Staphylococcal Poisoning

Staphylococcal poisoning results from ingesting preformed, heat-stable enterotoxin, which is produced by *S. aureus*. The bacteria can grow at 10–45 °C at a pH of 4.2–9.3. Ten serologically distinct enterotoxigenic proteins known as enterotoxin types A, B, C_1, C_2, C_3, D, E, F, G, and H are recognized in *S. aureus*. The severe intoxication is of short duration and develops 1–6 h after ingestion of the enterotoxin. The common symptoms are nausea, vomiting, diarrhea, abdominal cramps, and mild leg cramps. Between 1951 and 1970, cream has been implicated in six outbreaks of staphylococcal poisoning in the United Sates involving 131 cases. Large numbers of *S. aureus* are seldom found in butter since the product composition and storage conditions severely limit its growth. However, when cream was inoculated with *S. aureus*, incubated for 24 h at 37 °C and then churned to butter, the finished product contained at least 1 μg of enterotoxin per 100 g, or approximately 10% of the enterotoxin present originally in the cream. Since 0.1 μg of enterotoxin can induce symptoms of staphylococcal poisoning, ingesting such a dose poses a potential health hazard. This has been demonstrated by butter-related outbreaks.

Campylobacter

In 1995, an outbreak of *Campylobacter jejuni* enteritis in the United States, which affected 30 people who had eaten in a local restaurant, was associated with garlic butter prepared on site. The survival of *Campylobacter* in butter, with and without garlic, was later investigated, and it was found that *C. jejuni* could survive in butter without garlic for 13 days at 5 °C. Lately, dairy-related *Campylobacter* infections have been associated only with the consumption of unpasteurized or raw milk.

See also: *Aspergillus*; ***Bacillus*:** *Bacillus cereus*; *Campylobacter*; *Clostridium*; *Enterobacter*; ***Escherichia coli*:** *Escherichia coli*; **Fermented Milks:** Range of Products; ***Listeria*:** Introduction; *Proteus*; ***Pseudomonas*:** Introduction; Rhodotorula; ***Salmonella*:** Introduction; ***Staphylococcus*:** Introduction; **Ultrasonic Standing Waves:** Inactivation of Foodborne Microorganisms Using Power Ultrasound; **Thermal Processes:** Pasteurization.

Further Reading

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