Chapter 17
Dairy Creams and Related Products

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1 Introduction

Milk fat globules, which are the building blocks of cream, are naturally secreted in the bovine mammary gland. The secretion process involves accumulation of small triacylglycerol (TAG) microdroplets followed by covering up from three-layered membrane and eventual release as fat globules in bulk milk. Since the fat globule contains a larger proportion of TAG at their core and a membrane with numerous health-promoting substances, it is considered as a food ingredient with a source of both energy and functional compounds.

According to Codex (2014), a cream is the fluid milk product comparatively rich in fat, in the form of an emulsion of fat-in-skimmed milk, obtained by physical separation from milk and containing milkfat not less than 10% (w/w). In Australia, a regular dairy cream sold as "cream" must be cream with not less than 350 g/kg of milkfat (FSANZ, 2016). A cream may contains approved food stabilisers and thickener as additives singly or in combination if the use of such ingredients is justifiable (Codex, 2014). There are numerous varieties of cream in the market with varying in fat content, acidity, and texture. The common varieties of creams available in the Australian market are tabulated in Table 17.1. Depending upon types of cream, the manufacturing steps may involve standardization, heat treatment, homogenization, fermentation and packaging.

Creams can be broadly divided into two types based on the nature of origin: natural and recombined cream. Natural cream is concentrated form of naturally synthesised milk fat globules, whereas recombined cream is concentrated form of mechanically created fat globules from a mixture of anhydrous milk fat and suitable emulsifier(s). A recombined cream might contain a natural or artificial emulsifier.

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T. Truong et al. (eds.), *Dairy Fat Products and Functionality*,
https://doi.org/10.1007/978-3-030-41661-4_17

Table 17.1 Various types of market cream in Australia (data from self-survey)

Cream type	Fat content (% w/w)	Food additives	Possible functionalities of the respective additives	References
Sour cream	38.2	Culture	Fermentation	Born (2013)
Light sour cream	19.3	Milk solids	Body of cream	UOG (2018)
		Gelatine	Melt-in-mouth gel	Williams, Phillips, and Vries (2004)
Light thickened cream	18	Potassium alginate	Gelling agent	Williams et al. (2004)
		Gaur gum	Thickener and stabilizer	Mudgil, Barak, and Khatkar (2014)
Double cream	45	Pectin	Short texture	Williams et al. (2004)
		Carrageenan	Low concentration gelling agent	Williams et al. (2004)
Thickened cream	35	Carrageenan	Forms gel at low concentration	Williams et al. (2004)
		Gaur gum	Thickener and stabilizer	Mudgil et al. (2014)
Whipped cream (Canister)	27.5	Sodium alginate	Rapid setting cold gelling agent	Williams et al. (2004)
		Carrageenan	Low concentration gelling agent	Williams et al. (2004)
		Mono- or di-glycerides of fatty acids	Induce partial coalescence	Fredrick et al. (2013)
		Nitrous oxide	Water soluble, odourless, tasteless, non-toxic and no after taste	Getz, Smith, Tracy, and Prucha (1937)
Cream powder	≥42	Modified starch	Emulsifier-filler	Keogh (2004)
		Gum acacia	Emulsifier-filler	

2 Natural Cream

2.1 Gravity Separation

Natural cream can be prepared by either gravity separation or centrifugal separation method. Gravity separation method follows the Stokes' equation for settling velocity. If milk is allowed to stand; fat globules being lighter than milk serum (skim-milk), start to rise with upward gravitational force (f_u) given by equation (Towler, 1994):

$$f_u = 4\pi r^3 g\left(\rho_s - \rho_f\right)/3 \tag{17.1}$$

where r = radius of globule; g = acceleration due to gravity; ρ_s = density of milk serum; and ρ_f = density of fat globules.

In the case of equilibrium, the upward force is equal to the frictional force experienced by fat globules. The frictional force given by Stokes' Law is

$$f_r = 6\pi\eta r v \tag{17.2}$$

where η = viscosity of milk serum; and ν = velocity of the fat globule.

By combining two Eqs. (17.1) and (17.2), the upward velocity of rising fat globules can be written as:

$$v = D^2 g\left(\rho_s - \rho_f\right)/18\eta \tag{17.3}$$

where D = diameter of fat globules (Fig. 17.1).

The Eq. (17.3) indicates that the upward velocity of fat globule is directly proportional to the square of its radius and density difference between milk serum and fat globules and is inversely proportional to the viscosity of milk serum. The viscosity of milk serum and densities of fat globules and milk serum can be varied by changing the temperature of milk (Towler, 1994). The gravity separation method is not time efficient and requires a great deal of attention to assure food safety. Therefore, it is not a common practice at the industrial level. Artisanal milk product manufacturers often use this method.

Beside fat globule size and density, the other important factor that promotes gravity separation of fat globules in raw milk at a lower temperature is agglutinin. Agglutinin promotes attachment of cryoglobulins (lipoproteins and immunoglobulins) on milk fat

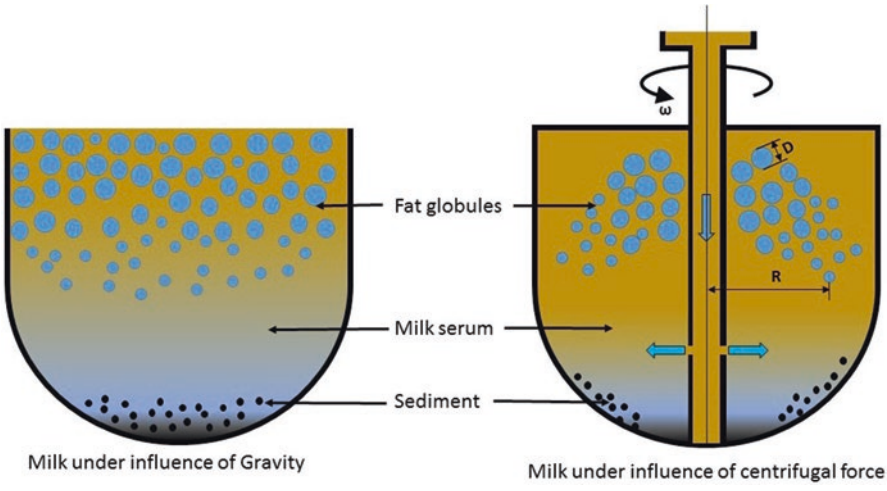

Fig. 17.1 Difference between the path of fat globules during gravity (left) and centrifugal (right) separation; D diameter of fat globules, R radial of fat globules from the axis of rotation; and ω angular velocity

globule surface and causes flocculation. However, warming up of milk above 37 °C reduces such flocculation because of the detachment of cryoglobulins (Everett, 2007). In addition, pasteurisation of milk at relatively high temperature denatures agglutinin causing a significant slowdown of gravity separation (creaming) (Wilbey, 1996).

2.2 Centrifugal Separation

A widely used method for manufacturing of commercially natural dairy cream is centrifugal separation, which enables rapid separation of a fat fraction of milk from milk serum. Technically, the centrifugal separation method can be considered as an accelerated gravity separation method where the upward velocity of fat globules increased by many folds using external force.

Centrifugal separation of cream is based on the use of centrifugal force to separate particles and liquids of different density and size (Saravacos & Kostaropoulos, 2016). Use of external force dramatically increases the settling velocity of fat globules resulting in rapid separation of fat globules from milk serum. The resultant fat globule velocity can be expressed as following by replacing "g" with centrifugal parameters:

$$v = D^2\left(\rho_s - \rho_f\right)R\omega^2 / 18\eta \tag{17.4}$$

where R = radial of fat globules from the axis of rotation (Fig. 17.1); ω = angular velocity (radians s^{-1})

Equation (17.4) can be rewritten as:

$$v = 2\pi^2 D^2\left(\rho_s - \rho_f\right)RN^2 / 9\eta \tag{17.5}$$

where N = rotational frequency (revolutions s^{-1}).

The Eq. (17.5) indicates that the settling velocity of fat globule is proportional to the square of the rotational speed of cream separator. Difference between the principle of centrifugal and gravity separation is schematically given in Fig. 17.1.

2.3 Working Principle and Construction of Cream Separator

In the cream separator, milk is fed into the rotating bowl through the milk inlet. When the milk reaches to centrifugal zone, the fat globules (lighter portion) experience less force than milk serum (heavy portion). Therefore, milk serum is forced towards to bowl wall while fat globules move towards the centre. Also, the velocity of the lighter dispersed fat phase depends on their size as larger size move relatively faster than the smaller size globules (Eq. (17.5)). Such action results in separate phases of cream and skim milk coming out through the different outlets. In the case

of commercial cream separator (Fig. 17.2), numerous separating cones are integral parts and these discs form numerous narrow channels that substantially increase the efficiency of the separation process.

The fat separation efficiency of cream separator depends upon various factors such as disc configuration, the rotational frequency of separator, temperature of milk, the feed rate of milk, fat globule size and rotational frequency of separator. Temperature not only decreases the viscosity of milk but also increase the density difference between milk serum and fat phase that cumulatively increases the efficiency of the separation process. The bowl diameter, number of separating cones, the position of holes in separating cones and gap between adjacent separating cones play a vital role in centrifugal separation process (Towler, 1994). At a fixed rotational frequency, wider bowl results in better separation and so is true for a condition with a small gap of separating cones. Wider bowl (1) increases residence time of fat globules under the influence of centrifugal time; (2) ensures complete migration of fat globules towards centre; (3) narrow gap of separating cones which dramatically decrease the distance to be travelled by fat globules and (4) ensures no remixing by providing laminar flow of fluid within the narrow channel. The feed rate of milk controls the residence time of fat globules within separating zone. The lower the feed rate, the higher the separating efficiency; however, a very low feed rate may decrease the separation efficiency as thick cream may hinder outflow of the cream itself. Similarly, centrifugal speed of separating bowl plays a very crucial role in determining the efficiency of a cream separator. Provided all the other parameters

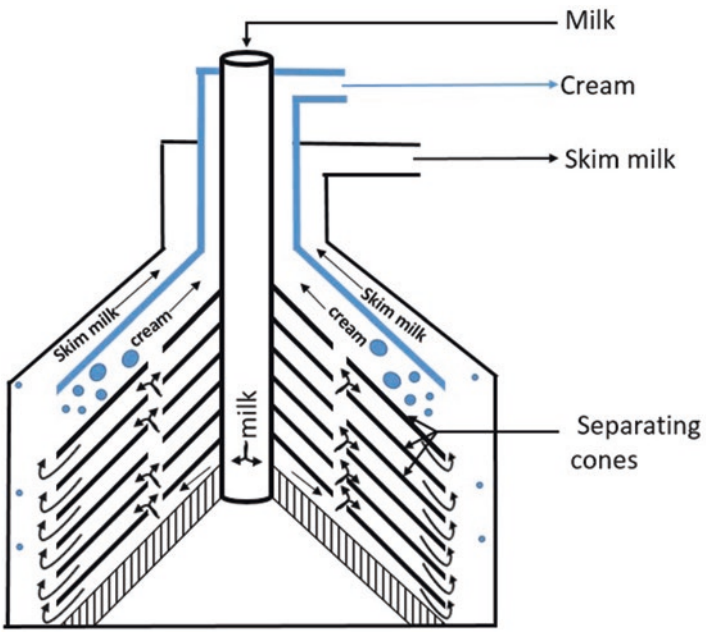

Fig. 17.2 Schematic diagram of a centrifugal cream separator

constant in Eq. (17.5), i.e., at a fixed dimension of separating bowl and fixed cream separation temperature, higher centrifugal speed increases the efficiency of the cream separator by increasing separation velocity of fat globules. This highlights that a reasonable degree of cream separation efficiency can be achieved by decreasing bowl size and increasing rotational speed or vice versa.

3 Fractionation of Natural Cream Based on Milk Fat Globule Sizes

Natural cream is concentrated form of native milk fat globules. Size of milk fat globules varies from 0.1 to 20 μm (Pieter Walstra, 1999). It is now well established that there is a considerable variation in physicochemical and nutritional properties of fat globules depending upon their size. These variations are associated with compositional differences in TAG core, milk fat globule membrane (MFGM) and size itself.

Size of milk fat globule significantly affects physical properties such as creaming stability, viscosity etc. Creaming stability, viscosity, and whiteness of milk/cream increase with a decrease in milk fat globule size. In contrast, milk fat crystallisation temperature and melting enthalpy, and electrical conductivity of globules decrease with decrease in size of fat globules (Truong, Palmer, Bansal, & Bhandari, 2016a). Native smaller sized fat globules were rich in medium-chain and unsaturated fatty acids (palmitoleic acid and linoleic acid), conjugated linoleic acids whereas lager native fat globules were rich in stearic acid (Lopez et al., 2011; Mesilati-Stahy, Mida, & Argov-Argaman, 2011; Michalski, Briard, & Juaneda, 2005). There have been numerous studies, which have distinctly differentiated the functionalities of smaller and larger fat globules. Larger fat globules shortened whipping time, yielded more unctuous and more melting-in-mouth butter. Smaller fat globules increased the stability of whipped cream, increased yield in Camembert cheese and smoother full-fat yoghurt (Edén, Dejmek, Löfgren, Paulsson, & Glantz, 2016; Goudédranche, Fauquant, & Maubois, 2000). St-Gelais, Passey, Haché, and Roy (1997) reported improved sensory attribute of low-fat Cheddar cheese produced from lager fat globule enriched milk (D[3,2] = 2.4 μm vs 1.6 μm). Small fat globules (D[4,3] 2.5–3 μm) enrichment helped increase in stretching, moisture content and yellow index in Emmental cheese (Michalski et al., 2006). Similarly, Luo, Wang, Guo, and Ren (2017) reported accelerated casein aggregation, a high storage modulus of curd with fine strands smaller fat globules (D[4,3] = 1.87 μm). The importance of having differentiated sized native milk fat globules lies not only on compositional differences of TAG core and size but also on native milk fat globule membrane (MFGM). Native NFGM possesses numerous health-promoting compounds such as phosphatidylserine, phosphatidylinositol, phosphatidylethanolamine, phosphatidylcholine and sphingomyelin, which is absent in homogenised and recombined MFGM (Deeth, 1997; Lopez et al., 2011). Besides, presence of

intact native MFGM makes fat globules as an inert filler (structure breaker) in milk acid gel since native MFGM interact with protein matrix poorly; however, homogenised milk fat globules act as active filler because of the interaction of MFGM with protein matrix (Vliet & Dentener-Kikkert, 1982). Native milk fat globules have also been found easily digestible than milk fat globules created after homogenization. Berton et al., 2012reported that although the surface area of homogenised fat globules (D[4.3] 0.18–0.29 μm) increases 25-folds, the homogenised fat globules is only twice the enzymatic activity (human pancreatic lipase) as compared to the native fat globules (D[4.3] 4.11–4.31 μm). Moreover, the catalytic activity of human pancreatic lipase was 4.6 times higher on native milk fat globule of D[4,3] 1.8 μm than 6.7 μm (Berton et al., 2012).

In recent days, few methods are developed to fractionate native milk fat globules on size basis for accessing the possibilities of the industrial significance of the heterogeneity in size-based milk fat globules properties. Most of the methods/processes for the production of size based fractionated natural cream comprises two stages: (1) fractionation of milk into various streams having different average fat globule size and (2) normal cream separation of the respective streams. In all size-based fractionated cream production processes stage 1 is different depending up-on nature of process; however stage 2 can be applied to all to obtain cream with different average fat globule sizes (Dhungana, Truong, Palmer, Bansal, & Bhandari, 2017; Edén et al., 2016; Goudédranche et al., 2000; Luo et al., 2017; Olsson & Mamic, 2015).

3.1 Gravity Separation

Gravity separation method utilises the size variation and size-dependent variation in creaming velocity of milk fat globules due to the difference in density between dispersed fat and serum phases.

It is apparent from the Eq. (17.3) that large fat globules in milk at constant temperature and serum composition rise at the top at higher velocity resulting in more substantial proportion of larger fat globules in top layers of milk at a fixed time interval.

Figure 17.3 depicts the theoretical distribution of fat globules in a gravity separation vessel. Each of the layers is then separated in typical cream separator to get creams having different average fat globule size. In early days, Zannoni (1981) reported a common practice of gravity separation method typically used in various part of Italy involved storage of raw milk in a shallow basin at 10–16 °C for 6–12 h to obtain desired fat content and average fat globule size. Rate of creaming or fat content and size of a certain fraction of milk during gravity separation can be varied by manipulating the milk storage temperature (Ma & Barbano, 2000). The second stage of the gravity separation method can be done by carrying out normal centrifugal cream separation of the semi-skimmed milk layers such as A, B and C in Fig. 17.3. A similar approach has been used to get size based fractions of cream by Olsson and Mamic (2015).

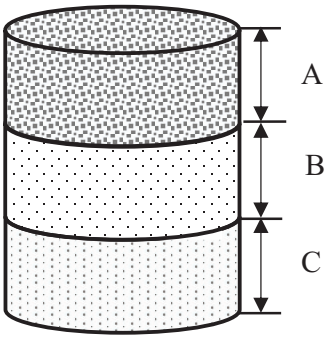

Fig. 17.3 A schematic diagram showing size-based layers of milk formed during gravity separation at a point of storage time; The proposed order of the average size of fat globules in each is A > B > C

3.2 Ultrasonically Assisted Gravitation Separation

Ultrasonically assisted separation occurs when acoustic radiation forces generated from standing wave sound field displace the fat globules towards pressure nodes and antinode plane (Leong, Johansson, Juliano, McArthur, & Manasseh, 2013). The underlying mechanism of milk fat separation on size basis using ultrasonication has been fully covered in Chap. 18. In general, facilitation of milk fat globule separation by ultrasonication depends upon many factors viz. size, surface properties of fat globules and acoustic force. The ultrasonic treatment has been found more effective for larger fat globules than small fat globules. Rate of creaming at low temperature (5 °C) is much efficient with high-frequency ultrasound treatment than that of low frequency as high frequency produces more significant acoustic force than low frequency (Leong et al., 2016).

3.3 Separation with Modified Cream Separator

An emerging method to produce cream with different average fat globules size is the use of modified cream separator. Manufacture of creams with this method follows two-stage centrifugal separation. The first stage is a "fractionation" process, whereas the second stage is a concentration (normal) process. Modification of cream separator involves either partial (Edén et al., 2016) or complete removal (Dhungana et al., 2017) of separating cones from separating disc. It is suggested that complete removal of separating cones increases the efficiency of size-based fractionation of fat globules. Removal of separating cones still provides free space to the milk fat globules inside the disc to experience centripetal force. When milk fat globules in the milk are released inside the rotating disc, the amount of the centripetal force experienced by the fat globules differs depending upon their size. Large fat globules, being less dense and bigger in size, acquire less speed than denser small fat globules. Therefore, under the right combination of milk feed temperature and feed rate, the small milk fat globules reach the inner wall of the separating disc much

earlier than larger milk fat globules (Dhungana et al., 2017). Small fat globules follow the route of skim milk whereas large fat globules exit through the cream outlet. In the second stage, called concentration, each of the two streams from the first stage is subjected separately to a normal cream separation process to get creams with entirely different average milk fat globule size. A schematic view of two-stage separation is given in Fig. 17.4.

4 Recombined Cream

A dairy cream can be recreated by mixing milk fat concentrates (cream or anhydrous milk fat) and suitable emulsifier(s) and/or stabiliser(s); and followed by application of heat and suitable mechanical treatment (Fredrick et al., 2013; Towler, 1994). There are numerous types of emulsifiers and stabilizers, which could be of either protein (dairy and non-dairy) or phospholipids or surfactants or carbohydrate-

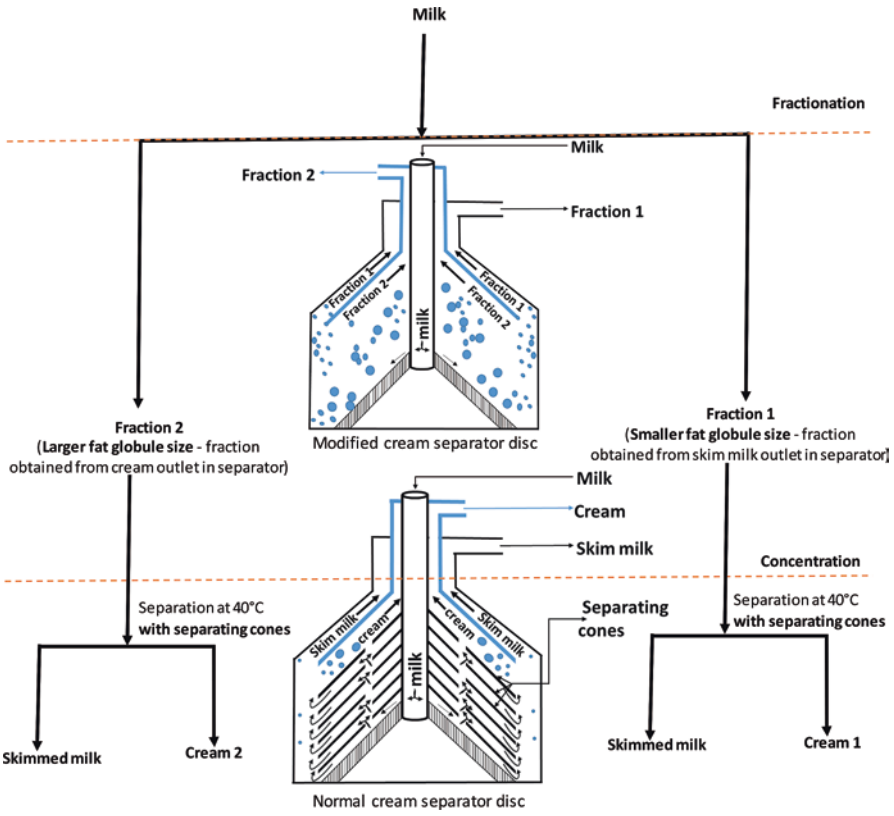

Fig. 17.4 Schematic of two-stage centrifugal separation method for production of size based fractionated creams (adapted from Dhungana et al., 2017)

based compounds. An emulsifier might be called as a stabilizer or texture modifier depending upon their intended functionalities (Chen, 2015; Ozturk & McClements, 2016). Casein is the most widely used protein-based emulsifier because of its milk origin, excellent heat stability, interfacial properties and nutritional value (Hu et al., 2015; van Lent, Le, Vanlerberghe, & Van der Meeren, 2008). Casein stabilised recombined cream had lower crystallisation temperature, and better stability towards coalescence than that of whey protein stabilised cream (Relkin, Sourdet, & Fosseux, 2003). The reported mechanical means to prepare recombined dairy cream are homogenisation, high-pressure homogenisation, microfluidization and ultrasonication (Truong, Palmer, Bansal, & Bhandari, 2016b).

The use of recombined dairy cream is increasing steadily because of some distinct advantages such as lower storage cost of raw materials, and ease of making a cream with desired characteristics, and independent of milking season (van Lent et al., 2008). A major change that is consistently being observed in recombined cream is the creation of an entirely new type of membrane with characteristic composition and microstructure. In addition, the recombination process also enables the creation of fat globules of a desired size range.

4.1 Homogenization

Homogenization refers to the process of disintegration of large particles into numerous small particles with mechanical force. In the case of the dairy industry, high-pressure homogenisation is widely used. The homogenization results in breakage of large milk fat globules into small globules by the action of shear force. Shearing is developed by pumping milk through a small opening and striking the milk jet over a solid surface called homogenization head. In case of two-stage homogenization, disintegrated fat globules in cluster due to the lack of time for complete fat globule membrane formation are subjected to another mild homogenization stage (works at a lower pressure than the previous stage) to keep fat globules distinctly apart. In a typical commercial two-stage homogenizer, pressure ranges from 10 to 30 MPa for the first stage and 3–5 MPa for the second stage are used while working temperature ranges from 50 to 60 °C (Pieter Walstra, 1999).

The extent of size reduction of milk fat globules can be as much as tenfold by homogenization at 20 MPa along with a significant reduction in the range of fat globule sizes (Lopez, 2005). Another variant of homogenization, ultra-high pressure homogenization, works at relatively high pressure up to 350 MPa. Ultra-high pressure homogenization can reduce the fat droplets to nanometric size; however, it requires a higher amount of emulsifier in the emulsion to make it stable. If not, there will not be a considerable difference between the performance of conventional and ultra-high pressure homogenization as insufficient emulsifier causes increase in globule size (Hayes & Kelly, 2003; Serra, Trujillo, Quevedo, Guamis, & Ferragut, 2007; Thiebaud, Dumay, Picart, Guiraud, & Cheftel, 2003). In a suitable condition (0.5–3.0% whey proteins and sodium caseinate), ultra-high pressure homogenizer

operated at 87–123 MPa producing recombined emulsion from anhydrous milk fat with mean globule diameter as small as 200 nm (Truong, Palmer, Bansal, & Bhandari, 2013).

4.2 Microfluidisation

Microfluidisation is the process where two high-speed micro streams colloid each other thereby disintegrating the larger particles into small ones, especially to nanometric sizes (Truong et al., 2016b). Although it shares basic steps viz shear, cavitation, turbulence, with homogenization, its effectiveness on getting the same size at constant pressure is much higher than that of high-pressure homogenisation (Dalgleish, Tosh, & West, 1996; Hardam, Imison, & French, 2000). The efficiency of microfluidisation process depends upon various factors such as operating pressure, fat content of the final product and amount of emulsifier (Hardam et al., 2000; Truong et al., 2013); therefore an optimum condition based on prevailing operating condition is necessary to realize better performance (Mahdi, He, & Bhandari, 2006). For example, it was reported that the increase in total protein in native cream from 2.2% (w/w) to 3% (w/w) significantly decreased the size of microfluidised cream from D [3,2] 1.35 μm to 0.26 μm when the cream was microfluidised at 62 MPa and 40 °C (Panchal et al., 2017). However, no significant decrease in average droplet size was observed on further increase in protein content of native cream. Similarly, microfluidisation of recombined mass of anhydrous milk fat, sodium caseinate and water; and commercial cream and sodium caseinate each at fat: protein ratio of 5:1 created creams with D[4,3] 0.37–0.40 μm and 0.16–0.20 μm, respectively, when microfluidisation was done at 45–85 MPa (Hussain, Truong, Bansal, & Bhandari, 2017).

4.3 Ultrasonication

Ultrasonication method has been widely used to homogenise or reduce the droplet size of the emulsion (Hardam et al., 2000; Muthupandian et al., 2010; Villamiel & de Jong, 2000; Wu, Hulbert, & Mount, 2000). Ultrasonication is the process characterised by the acoustic cavitation as a result of mechanical vibration powered by high-frequency sound (~20 kHz) (Truong et al., 2016b). During sonication, a disintegration of larger emulsion droplet happens because of pressure difference created during bubble collapse (Mason, Wilking, Meleson, Chang, & Graves, 2006). The degree of homogenization achieved by ultrasonication depends upon the applied acoustic power, treatment time, and working temperature. In ordinary cases, the use of high acoustic power, longer treatment time coupled with high temperature result in smaller fat globule size (Villamiel & de Jong, 2000; Wu et al., 2000). Sonication of whole milk for 10 min with 180 W and 450 W reduced aver-

age fat globule size from 5.5 μm to 2.36 and 0.73 μm, respectively (Ertugay, Sengul, & Sengul, 2004).

5 Major Types of Commercial Cream Products and Their Processing

There are various types of cream products manufactured by following the different technologies with typical characteristics and end-use (Table 17.2). The major types of technologically important methods are discussed below.

5.1 Whipping Cream

Whipping cream is a special variant of cream having an excellent capacity to form foam. Whipping cream (aka light whipping cream in the USA) which is pasteurised or ultra-pasteurised and may be homogenised, contains less than 36% but not less than 30% milkfat in cream (FDA, 2015). Manufacturing of whipping cream involves

Table 17.2 Different cream products and their properties

Cream types	Fat content (%)	Additives	Usage	Specialities	References
Whipping cream	30–40	Carrageenan, alginate, starch, gelatine	Whipped cream, flour confectionery	Forms aerated product	FDA (2015)
Sour cream	≥18	Culture (*Streptococcus lactis* and *Streptococcus cremoris*)	Salad dressing	Acidity not less than 0.5% as lactic acid	http://www.idfa.org/news-views/media-kits/milk/definition
Cream powder	40–70	Lactose, proteins, sorbitol	Dried soups, ice cream	Less than 2% moisture, spray-dried	Tamime (2009)
Cream liqueur	>14	Sucrose, citrate, ethanol	As alcoholic beverage	Alcoholic beverage	Tamime (2009)
Coffee cream	≥18	Phosphates, citrates	Feathering of coffee	Double stage homogenization	FDA (2015), Walstra, Wouters, and Geurts (2005)
Dessert cream	Not less than 18	Phosphates, citrates	Dessert dressing	Single-stage homogenization; thicker than coffee cream, carrageenan, alginate	FDA (2015), Walstra, Walstra, et al. (2005)

standardisation of the fat content of cream and addition of optional ingredients like an emulsifier, stabiliser, sweetener, etc.; followed by pasteurisation, cooling, packaging and storage. Pasteurisation could be done either by High Temperature Short Time (HTST; 85 °C for 30 min) or Ultra High Temperature (UHT) method (140 °C for 2 s). Generally homogenization is not done for whipping cream; however, a UHT treated whipping cream could be homogenised after pasteurization at reasonably low pressure of about 3.5–7 MPa to prevent adverse effects of high heat treatment on creaming stability of cream (Varnam & Sutherland, 2001; Walstra, Walstra, Wouters, & Geurts, 2005). Packaging of whipping cream is done after cooling to 5 °C. The whipping cream should be stored at 4 °C for 24 h in the case of immediate use; otherwise, whippability will be impaired because of insufficient solid fat to trigger partial coalescence during whipping (Early, 1998; Sung & Goff, 2010; Walstra, Wouters, & Geurts, 2005). Functionality and emulsion properties of whipping cream depend also on interfacial serum phase materials. Whey protein isolate stabilised whipping cream demonstrated shorter whipping time than sodium caseinate stabilised cream (Hotrum, Stuart, van Vliet, Avino, & van Aken, 2005). Similarly, presence of a higher amount of protein, and other hydrocolloids (locust bean gum, carrageenan etc.) in serum phase of whipping cream increased the whipping time and decreased overrun (Camacho, Martínez-Navarrete, & Chiralt, 1998; van Lent et al., 2008).

5.2 Sterilised Cream

Sterilised cream is available as both coffee and dessert cream. The major difference between them is the degree of clustering, and so is the methods of achieving such conditions. Coffee cream, also known as light cream in Australia and US, contains milkfat not less than 18% with an average of 20% while acidity remains in the range of 0.14–0.15% as lactic acid (FDA, 2015; Walstra, Wouters, & Geurts, 2005). Coffee cream manufacture starts with standardisation of cream mass by mixing high-quality cream, skim milk and stabilising salt to achieve 20% milkfat and desired pH. Coffee cream is heated relatively at a higher temperature (70–75 °C) before double stage homogenization (first stage at 11–20 MPa and the second stage at 3–5 MPa). Variation in pressure during homogenization depends on the technique employed for sterilisation. In case of bottle sterilisation process which is done at 115 °C for 20 min, homogenization is done at lower to mid-range of pressure while homogenization is done at a higher range of each stage if a cream is UHT sterilised (Lampert, 1965; Spreer, 1998; Varnam & Sutherland, 2001). UHT sterilised cream is packaged online in aseptic condition. Packaged cream is then cooled to 25 °C before storage and/or distribution (Lampert, 1965; Spreer, 1998; Varnam & Sutherland, 2001; Walstra, Wouters, & Geurts, 2005).

Unlike coffee cream, dessert cream, which is thicker than coffee cream, is first UHT treated at 140 °C for 10 s followed by cooling to 50 °C before single-stage aseptic homogenization at 10 MPa. The homogenised cream is aseptically packaged

and cooled to 10 °C (Walstra, Wouters, & Geurts, 2005). High heat treatment during sterilisation leads to cooked flavour, irreversible creaming and gelation (Hoffmann & Buchheim, 2006). Addition of just 0.015% of carrageenan improved creaming behaviour and decreased serum loss upon whipping of 30% fat containing UHT cream (Precht, Peters, & Petersen, 1988).

5.3 Sour Cream

Sour cream, also known as cultured sour cream, is the pasteurised and lactic acid-producing bacteria fermented cream containing milkfat not less than 18%(w/v) (IDFA, 2018). However, their fat content may range from 10 to 40% depending upon countries (Hoffmann & Buchheim, 2006). Sour cream must have titratable acidity not less than 0.5%, determined as lactic acid. In case of sour cream with added optional ingredients (such as gelatine, starch), the milk fat content should not be less than 18% of dairy portion and not less than 14.4% milkfat of total weight of cream (FDA, 2015; Hoffmann & Buchheim, 2006).

Basic steps of sour cream processing involve standardisation of cream mix, pasteurisation, fermentation and packaging (Born, 2013; Hoffmann & Buchheim, 2006). The cream mix is prepared from high-quality cream and milk solids not fat. Pasteurisation can be done either by vat (73.9–79.4 °C for 30 min) or HTST (82.2–85 °C) method (Born, 2013). The cream is then cooled to 68 °C before homogenization at 13.8–17.2 MPa pressure. A two single-stage homogenization process would result in an excellent body and texture on cream (Born, 2013; Lampert, 1965).

Lactic acid fermentation is done with 1–4% starter culture of *Streptococcus lactis*, *Streptococcus cremoris,* flavour-producing bacteria *Leuconostoc citrovorum* and *L. dextranicum.* The optimum temperature for growth of these bacteria ranges between 21.1 and 23.9 °C. Fermentation is partially stopped after 12–18 h by cooling cream to below 10 °C or preferably to 2–4 °C once either pH or Soxhlet-Henkle (SH) value reaches to 4.6 to 5.1 and 25–35, respectively (Early, 1998; Lampert, 1965; Spreer, 1998). The optional ingredients (e.g. thickener, emulsifier, food flavouring, nutritive sweeteners, salt etc.) which are safe and suitable can be added to sour cream up to permissible limit in order to improve texture, prevent syneresis, increase palatability and attractiveness and extend shelf life (Lampert, 1965; Spreer, 1998).

5.4 Cream Liqueur

A cream liqueur is a cream-based alcoholic beverage. One of the world-famous cream liqueur variety is Irish cream liqueur, predominantly sold as Baileys Irish Cream (Mitchell, 2016). Industrial preparation method of traditional Irish cream liqueur (17% by volume alcohol) starts with the mixing of water (85 °C) and tri-sodium

citrate followed by addition of sodium caseinate, sugar, caramel and Annatto (Mitchell, 2016). Dairy cream (<10 °C) and spirit are then mixed with a previously prepared base mix in a mix tank, and the final mix is homogenised in a two-stage homogeniser (24.1 MPa and 3.45 MPa) at 55 °C. The homogenised mix is homogenised again as in the previous set of homogenization pressures after addition of flavour. The final liqueur is then cooled to 14 °C followed by packaging in brown colour glass bottles (Hoffmann & Buchheim, 2006; Mitchell, 2016). Brown colour bottle prevents light-induced off-flavour development (Hoffmann & Buchheim, 2006). Stability of cream liqueur largely depends on alcohol content and minerals in the serum phase of liqueur. Increase in alcohol content and the presence of inorganic substances in liquid phase decreased the stability of cream liqueur (Banks & Muir, 1985). These are the major challenges for the production of high alcohol-containing cream liqueur. Another demerit from processors' viewpoint is not being able to produce cream with high alcohol content (Banks & Muir, 1985; Heffernan, Kelly, & Mulvihill, 2009). Banks and Muir (1985) reported that cream liqueur (36–45° proof alcohol and 40% total solids) prepared using washed native cream (reduced inorganic component) where alcohol was mixed before 2 pass homogenization at 31 MPa pressure and 55 °C having better stability than liqueur from whole cream (38 days vs 1 day). In the same report, it was also reported that addition of tri-sodium citrate on washed cream decreased the stability of cream liqueur (Banks & Muir, 1985). However, the addition of tri-sodium citrate enhances the stability of cream liqueur prepared from the whole cream where it acts as calcium sequestrant and protects from casein aggregation. The second approach for the production of high alcohol cream liqueur is the addition of alcohol in two lots. Of the total alcohol to be added, a portion alcohol is added to cream before homogenization and the second portion of alcohol is added to the homogenized mixture of cream and alcohol. Such sequence helps keep emulsion droplet size small (Hoffmann & Buchheim, 2006). Stability of cream liqueur can also be increased by reducing emulsion droplet size, increasing total solid content (as sugar) and addtion of small molecules emulsifier such as monoglycerides. The first two parameters increase viscosity of final product whereas last parameter, when added in optimum amount along with sodium caseinate and tri-sodium citrate, helps reduce phase separaiton (Banks & Muir, 1988; Hoffmann & Buchheim, 2006). Banks and Muir (1988) reported that the cream liqueur would acquire enhanced viscosity, creaminess and whitening strength if 98% of the total fat globules in liqueur were of diameter <0.8 μm. This size range can easily be obtained either by multi-cycle homogenization or by sigle-cycle microfludization (Mitchell, 2016; Panchal et al., 2017).

5.5 Cream Powder

A cream powder is a dried form of liquid cream. Dried cream is used in desserts, ice creams, dried soups, packet cake mixes etc. It contains a maximum of 5% by weight moisture, minimum 42% by weight milk fat and a minimum of 34% by weight milk protein in milk solid-not-fat (Codex, 2014). Spray-dried cream powder/ encapsulated

fat powder is made from stabilised emulsions. Proteins, modified starches and other suitable hydrocolloids are the major types of emulsifiers used in such products. Another important component of cream powder is fillers. They can be water-soluble carbohydrates, hydrolysed starches, and gums (Keogh, 2004). Fäldt and Bergenståhl (1995) described a method by mixing sodium caseinate and butterfat in a lactose solution at pH 7. The mix is then heated to 70 °C followed by pre-homogenization with a high-speed stirrer. High-pressure homogenization of liquid mass is carried out at 100 MPa pressure for several cycles. Multiple cycle homogenization of emulsion, although being cost-intensive, effectively decreased the proportion of over-sized fat globules and made emulsion droplet size more uniform which may help to improve the powder properties (Hogan, McNamee, O'Riordan, & O'Sullivan, 2001; Muir & Banks, 1986). The homogenized cream is spray-dried with inlet air at 180 °C, and outlet air temperature is maintained at 80–90 °C. Hogan et al. (2001) and Vignolles et al. (2010) also reported similar methods to obtain fat (soy and sunflower oil, respectively) encapsulated powder. In summary, spray-dried fat powder preparation process involves stabilisation of fat-filled emulsion by suitable emulsifier (preferably caseinate) at suitable homogenization pressure, mixing of filler materials (preferably lactose), and followed by spray drying preferably at 180–190 °C as inlet temperature and 80–90 °C as outlet temperature. Sodium caseinate is preferred as emulsifier over other food proteins as it is the most surface tension reducing food protein ever known (Dalgleish, 1989). Food additives that can be added to legal limits to improve powder properties are stabilizers, firming agents, acidity regulators, anticaking agents, and antioxidants (Codex, 2014).

Since the cream powder is a high-fat content product, it is susceptible to lipid oxidation and caking during handling. Caking occurs when surface fat content is high. It also lacks reconstitutability and fat leakage increases with storage time (Fäldt & Bergenståhl, 1995). The melting point of fat core of emulsion before drying plays an important role in the surface fat content of powder (Keogh, 2004). Fäldt and Bergenståhl (1995), reported that the fat powders prepared from emulsion with low melting point fat (soybean oil) and high melting point fat (high melting point rapeseed oil) as core materials had lower amount of surface fat (3% and 15% respectively) than powder prepared with medium melting point fat, butterfat and hardened coconut butter (~34%). Partial crystallinity occurs significantly in medium melting point fat, which leads to partial coalescence of droplets and ultimately facilitate leakage of fat out to the surface (Coupland, 2018; Fäldt & Bergenståhl, 1995). Lactose, a critical factor responsible for fat encapsulated powder stability and functionality, affects cream powder depending upon its concentration and crystallinity (Fäldt & Bergenståhl, 1995; Keogh, 2004). Lactose acts as a continuous phase in the powder system and helps limit to protein-protein interaction that eventually hinders fat globule coalescence and aggregation in both emulsion and drying stage (Keogh, 2004). An increase in lactose concentration along with sodium caseinate reduced surface fat (Fäldt & Bergenståhl, 1996a). However, these authors did not notice such effect of lactose with whey protein. Lactose also affects cream powders adversely upon moisture uptake in poor storage condition (Fäldt & Bergenståhl, 1996b). Recrystallisation of lactose increases powder particle size, porosity and induces

coalescence resulting in increased free and surface fat of the powder (Fäldt & Bergenståhl, 1996b; Saito, 1985). Emulsion droplet size before spray drying also plays significance role on fat encapsulated powder. Soottitantawat et al. (2005) reported a significant increase in retention of d-limonene in response to a decrease in emulsion size from 2 to 0.5 μm. In addition, same authors claimed a constant decrease in surface oil content when emulsion droplet size decreased from 4.1 to 0.65 μm. The average droplet size of an emulsion with large average droplet size decreased significantly after atomization, which was not significant in emulsion with smaller average size droplets. Soottitantawat et al. (2005) postulated that the increase in surface oil and decrease in d-limonene flavour in spray-dried powder with the increase in droplet size could be due to the break down of large droplets during atomization. Therefore, a careful selection of emulsifier, drying condition and droplet size that compatible with core material is necessary to obtain fat encapsulated powder with better physical properties.

6 Conclusion and Future Remarks

Dairy cream and associated products have been in the utmost preference of consumers across the globe. These products have reached out to culinary of every ethnicity and race. Dairy cream is a concentrated mass of fat globules obtained from bovine milk. It is separated from milk, based on density differences between milk fat globules and milk serum. The most widely used method for cream separation is centrifugal separation. In addition, centrifugal separator with disc fitted with numerous separating cones is the most commonly used device to separate fat from milk. Milk feed rate and inlet temperature, centrifugal speed, number of separating cones and distance between adjacent cones are the major factors influencing the efficiency of fat separation using such separator. Current development in cream processing is the size-based fractionation of milk fat globules and subsequently getting size-differentiated cream. A great deal of research has shown some marked differences in physicochemical properties of native fat globules depending upon their sizes. These differences have also shown significant impacts on cream-based products. One of the current research trend is focusing on the utilization of such size-dependent differences for improvement and manipulation of product performances. Recombined creams, which are concentrated form of newly created—recreated fat globules either using anhydrous milk fat or natural cream, are also gaining industrial importance because of their easy manoeuvrability and potential applications in new product development. However, a large number of research has shown them incapable of maintaining product characteristics when used as a replacement of natural cream.

Thermal and physical stability of cream are the major properties of a cream, which have a direct influence on processability and product characteristics of almost every kind of cream-based products. In native cream, thermal and physical stability slacken off with time. A conventional remedy is mechanical homogenization of

cream, which, if sufficient amount of right emulsifier is provided, effectively increase the physical and thermal stability. However, these achievements come with the expense of native milk fat globule membrane. Since smaller fat globules are more stable towards creaming and thermal stress, selective removal of larger fat globules from milk could improve these properties of resulting creams. However, the lack of cost-effective methodology for size-based fractionation of native fat globules has limited industrial application of such an approach. This could be a future area of research. Some of the specialized cream-based products, especially cream liqueur and cream powder, although having a long history, are still suffering from poor keeping quality. It is postulated that a reduction in cream droplet size in combination with suitable emulsifier could improve this quality. Based on the available literature, future works in the processing of cream-based products could be studied on the effect of nano-sized emulsion droplets on the stability of such specialised creams.

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