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Whipping properties of dairy creams
G. C. Hillbrick, P. Udagabe and M. A. Augustin

Dairy creams have a role in imparting flavour and creating textures in food. In many applications, creams with good whipping properties are desirable. Understanding the factors that affect the whipping properties of creams is essential for improving the properties and consistency of creams.

Creams contribute to the flavour and texture of foods. In many applications, creams with good whipping properties are desired. This paper reviews the literature relating to the whipping properties of creams.

Dairy cream is obtained by centrifugation of whole milk to produce a milk fat rich fraction that undergoes a pasteurisation treatment. Dairy creams on the market are specified on their fat contents. Regular cream, pure cream and whipping cream contain a minimum of 35% milk fat. Reduced fat creams have a minimum fat content of 25% and light creams have a minimum fat content of 18%. Rich or double creams have a minimum fat content of 48% milk fat (Australian Dairy Corporation 1999). Apart from the inherent milk components, the milk solids non-fat (MSNF) and milk fat, creams may contain added stabilisers (eg carrageenan, gelatin) and emulsifiers (eg mono- and di-glycerides). These ingredients may be used to alter the physical and functional properties of creams, enabling the production of creams with different viscosities and whipping properties to suit their target end use.

Most of the dairy creams in the Australian market are pasteurised dairy creams. Alternatives to these are available and include frozen cream, cream powders, ultra high temperature (UHT) creams and recombined dairy creams. In frozen creams, made by the quick freezing of pasteurised cream, the desirable dairy flavour is preserved. Cream powders and UHT creams, obtained respectively by spray-drying and UHT processing of creams with added stabilisers, are used as convenient alternatives to pasteurised creams. Both these products do not require refrigeration during storage. Recombined dairy creams are made by recombination of a source of MSNF (usually skim milk powder), anhydrous milk fat, emulsifiers and stabilisers. An alternative fat source to milk fat (eg vegetable fat) may also be used for recombination with MSNF. The resultant product is called a filled cream.

Whipping of creams
Creams are complex two-phase oil-in-water emulsions consisting of a fat phase and an aqueous phase. The two-phase system of cream is transformed to a three-phase foam upon whipping or aeration.

Desirable properties are a short whipping time, a high overrun, sufficient stiffness in the whipped cream to allow piping and shaping and lack of syneresis (Towler 1986).

Overrun is the percentage increase in volume when cream is whipped. Creams are normally whipped to their maximum overrun. Whipping time is the time taken under standardised conditions to reach a consistent overrun which is either the maximum overrun (Banks & others 1989) or maximum stiffness (Brooker 1990). An overrun of greater than 80% is considered desirable (Hoffman 2003).

On storage of whipped cream syneresis can occur, which is where serum separates out from the whipped cream. Also, on extended storage a more concentrated fat rich fraction can separate to the top of the cream, referred to in this paper as fat separation. In some papers this phenomenon is referred to as creaming (Precht & others 1988). This can be a particular problem in UHT creams stored for extended periods. The fat rich cream fraction can coalesce forming a cream plug that cannot be distributed back into the rest of the cream. If further coalescence or fusion of the fat globules occurs the individual fat globules can form into a plug of fat. Related to cream coalescence and cream plug formation is adhesion, where fat globules stick to the walls of the container in which the cream is stored.

During whipping or aeration, air is introduced into the liquid cream and the air bubbles first formed are stabilised by whey proteins and β-casein attaching at the air-water interface with little involvement of fat globules (Brooker 1990, Brooker & others 1986, Needs 1990). These air bubbles are broken down into smaller bubbles as whipping progresses (Noda & Shinioki 1986). Whipping also causes the exposure of new fat surfaces, which attach to the air interface (Sone & others 1986). The whipped structure becomes stiffer during the whipping process because the distance between the air bubbles decreases and this allows the network between the air bubbles to increase.

In fully whipped creams, the air bubbles are stabilised by fat globules and proteins attached to them (Needs & others 1988). Brooker (1990) believes that in the final whipped cream the bubbles are predominantly stabilised by fat globules with only remnants of the initial protein interface remaining. The remnant of the protein that was at the original air-water interface does not contribute to the mechanical properties of the foam (Brooker & others 1986).

In good quality whipped creams there are only a very small number of fat crystals that penetrate the air/water interface of some of the air bubbles. However, in defective whipped creams there are large numbers of needle-like crystals that penetrate the air/water interface of every air bubble. This results in reduced numbers of fat globules adsorbing to the interface (Brooker 1990). These defective creams have large amounts of free fat which result from damage to the fat globule during processing and storage (Brooker 1990). Good quality or normal whipping cream will contain some free fat and the process of whipping also results in some free fat. In defective creams the large number of fat crystals adsorbed to the air bubbles inhibits the fat globules reaching the air/water interface of the bubbles. This hinders the important step of fat globules attaching to the air/water interface of the bubbles and hence the formation of a network of globular fat which is necessary for a whipped cream with high viscosity and low serum leakage (Brooker 1990). The agglomeration of the
fat globules is considered the most important factor for foam stability (Flack 1985).

Effects of composition on whipping
The components of cream, fat, MSNF, added stabilisers and emulsifiers have a major influence on whipping properties. Variations in the composition of the milk, from which the cream is made also affect the composition of the cream and hence its whipping properties.

**Fat content**
The fat content and properties of the fat influence the whipping properties of creams. Morr & Huughebaert (1982) found that when the fat content was increased from 32 to 38%, creams had reduced overrun and increased firmness, and decreased serum leakage. When the fat content was raised from 38 to 42%, there was a reduction in whipping time and overrun, and an increase in firmness. However, serum leakage from whipped creams was not affected. Towler (1986) reported that increasing the fat content of raw, batch pasteurised and vacretreated creams from 30 to 38% decreased the whipping time and overrun. Banks & others (1989) found that whipped cream containing 35% fat had a higher overrun, a longer whipping time and more serum leakage than creams with 40% fat.

Thus increased fat content in the range of 32 to 42% fat gives decreased whipping time and overrun, increased firmness, and generally decreased serum leakage of the whipped cream. Increased solid fat content of creams within certain limits gives decreased whipping time and overrun, increased firmness, and decreased serum leakage of the whipped cream, which are the same trends that occur when the fat content of cream is increased.

The solid fat content of the fat component, which is an indication of the ratio of solid fat to liquid oil as a function of temperature and hence the hardness of a fat, affects the aeration properties as well as the texture of the final whipped cream. Precht & others (1988) found that summer cream from pasture fed cows had longer whipping times and was more prone to serum leakage compared to winter cream from barn fed cows. The milk fat in the summer cream was softer than that of winter cream in this study so the results are as expected. In another study where summer cream had a higher iodine value (ie more unsaturated and therefore softer fat) than winter cream, the whipped summer creams were softer than whipped winter creams as expected, but the softer summer creams took less time to whip and there was no change in overrun (Needs & others 1988). Obviously other seasonal factors which were not fully explained were having an effect. The short whipping time may have been due to the change in the composition of the fat or the milk fat globule membrane, which would allow fat globules to coalesce more easily. In other studies, it was found that increasing the solid fat content of the fat (ie increasing hardness) used to make recombined creams, increased viscosity and reduced whipping time. However, overrun was increased to a maximum at a solid fat content of about 50%, but beyond this level of solid fat overrun decreased (Noda & others 1984). This is possibly because if the majority of the fat is solid, coalescence or partial coalescence will not occur and similarly if the solid fat content is too low coalescence will not occur. A suggested optimum range for the solid fat content for partial coalescence to occur is 10 to 50% (Euston 1997).

**Milk proteins and milk solids non-fat**
The milk proteins in the MSNF component of dairy creams have an impact on the properties of cream. Proteins, being amphipathic in nature, are surface-active and have a role in the stabilisation of the air-water-oil interface in creams. The addition of protein tends to have a small or no effect on the whipping time or the overrun, but increases the viscosity and stability of the whipped cream as described below.

Whey proteins and β-casein are adsorbed on the surface of fat globules during the initial stages of whipping (Brooker & others 1986). When whey protein or caseins were added to washed creams (from which proteins had been removed), it was found that whey proteins had a greater influence than caseins on the overrun of the cream when it was whipped for 90 seconds (Needs 1990). The addition of whey protein or β-lactoglobulin in an amount of 1 g/L to 38% fat cream did not significantly alter the whipping time (Christiansen 1980a).

In UHT whipping cream, increasing the solids non-fat concentration in the cream from 3 to 9%, by addition of medium heat skim milk powder, resulted in increased viscosity, decreased creaming and decreased formation of free fat during storage (Towler 1988). Salem & Zeidan (1993) observed changes in the pH, viscosity and whipping properties of creams with the incorporation of four different protein additives (skim milk, sodium caseinate, and whey protein concentrate or soy protein isolate). Skim milk powder and sodium caseinate increased the viscosity of the whipped cream the most. The shortest whipping time was obtained with whey protein concentrate followed by sodium caseinate. The highest foam stability was obtained by using either whey protein concentrate or soy protein isolate.

The addition of milk protein concentrate at a level of 10 g/kg of cream decreased the rate of cream separation in whipping cream and a combination of carrageenan and milk protein concentrate was useful for reducing cream separation (Eyer 1997).

**Phospholipids**
The whipping properties of creams may be influenced by the content of phospholipids in the creams (Thome & Erikson 1973a). Recombined creams, with excellent whipability, have been made by the homogenisation of milkfat and a mixture of skim milk and phospholipid-rich dairy fractions (eg buttermilk) (Bratland 1968). Others have also found that the addition of buttermilk improves the whipability of cream. Whipping times were shorter and overrun was increased when 40% fat cream was standardised to 25% fat with buttermilk compared to skim milk. Thome & Erikson (1973b) subsequently found that the phospholipids exist with protein and are in the form of lipoproteins rather than free phospholipids. Lipoproteins have far better emulsifying and stabilising properties because they are more hydrophilic and easier to disperse in the cream than free phospholipids.

**Salts**
Salts have been used in the dairy industry to alter the functional properties of milk and dairy products (Augustin 2000). Increased calcium improves whipping properties of UHT whipping cream but increases fat separation on storage, whereas reducing the level of available calcium by addition of ethylenediaminetetraacetic acid (EDTA) or sodium di-hydrogen phosphate reduces whipability of cream and reduces fat separation after whipping (Kieseker & Zadow 1973).
Changing the pH of cream affects the properties of cream. Impaired whipping properties, decreased viscosity and decreased fat separation occur with an increase in the pH of UHT whipping cream containing 36% fat (Kieseker & Zadow 1973). As increasing pH reduces the citric activity of milk and increases the amount of calcium in the casein micelle, the effect of pH may be partly due to changes in the calcium balance and the integrity of the casein micelles.

Non-dairy additives

The addition of non-dairy surface-active agents can be used to improve whipping properties of cream. The addition of citric acid ester of monoglyceride and distilled monoglyceride to cream prior to homogenisation and UHT treatment results in a cream that when whipped has foam structures that resemble those of whipped cream from pasteurised unhomogenised cream (Flack 1985). The addition of monoglycerides at a concentration of 1% improves the properties of whipping cream but gives the cream an unacceptable taste (Thome & Erikson 1973b).

The addition of locust bean gum and λ-carrageenan mixtures to cream was found to increase the whipping time and decrease the overrun of whipped cream, as well as decrease the consistency and elastic character of the whipped cream (Camacho & others 1998). An emulsifier mixture (4:1 glycerol monostearate and polysorbate 80) up to a level of 0.1% gave reduced whipping times and increased overruns in UHT whipping cream (Towler 1988).

Precht & others (1988) found that fat separation in 30% fat UHT cream could be reduced by addition of 0.015% carrageenan and 0.25% protein-fat mixture (whey proteins and high-melting milk fat fractions with yield point of 38.4°C and dropping point of 38.8°C). The carrageenan and protein-fat additions reduced cream separation to a level similar to that with two-stage homogenisation at pressures of 2.5 and 1.5 MPa, but with the advantage of reasonable whipping times.

In UHT whipped cream, carob and xanthan gums act synergistically and have good freeze-thaw stability and good high temperature processing properties. Carboxymethylcellulose (CMC) or alginates can react with calcium ions to cause excessive thickening in UHT whipped cream (Flack 1985).

Sugar added to whipped cream to make it sweeter, either before or after whipping, reduces the stiffness of the whipped cream (Babcock 1922).

Effect of quality of milk

High somatic cells in milk have been associated with increased whipping time and stiffness, and decreased overruns in whipped cream (Needs & others 1988). Mastitis results in increased proteolytic activity, phospholipids, free fatty acids and partial glycerides (Needs & others 1988). Proteolytic activity results in increases in proteose peptones, in particular proteose peptone component 5, which are highly surface active (Shimizu & others 1989). Proteose peptone 5, phospholipids, free fatty acids and partial glycerides are all strong foam depressants (Needs & others 1988). As these low molecular weight surface active molecules are likely to be elevated in milk from cows with mastitis (ie milk with high somatic cell counts), their presence will alter the composition and nature of the oil-water-air interfaces and hence the whipping properties of creams. The phospholipids that are increased in mastitis must have different properties to the phospholipids in buttermilk as they apparently have different foam stabilising properties, unless minor components associated with the phospholipid fractions are masking the true functional properties.

Effects of processing factors

Cream separation parameters

Cream separated to a fat content of 55 or 60% and then standardised to a fat content of 36% with skim milk (and then UHT processed) failed to whip, whereas cream that was separated to 36 to 42% fat before standardisation had good whipping properties (Kieseker & Zadow 1973). Defective whipping of cream has been attributed to “free-fat” resulting from separation to higher fat contents before standardisation to a lower fat content (Brooker 1990). Fat contents of 40–42% for creams should not be exceeded by processors because, at higher fat contents, destabilisation of the fat globules at low temperature (<10°C) can occur on mixing or pumping (Hinrichs & Kessler 1997).

Cream separated at low temperature (7–8°C) was found to have better whipping properties than cream separated at 55°C (Christiansen 1980b, 1982). The cold separated cream was more susceptible to adhesion than hot separated cream. Hillbrick & others (2000) found that creams (35–41% fat) obtained by separation of milk at 12°C had shorter whipping times than warm (50°C) separated cream. As the temperature of cream separation is decreased, the phospholipid content of the cream increases and the presence of these surface-active components may be expected to reduce the whipping time of the cream separated at the lower temperature.

Treatment of creams after separation of cream from milk

Heat treatment: Creams are commonly HTST pasteurised (eg 74°C for 18 s) but can also be processed by UHT methods (eg 138°C for 4 s) to give extended shelf life (Bruhn & Bruhn 1988). Precht & others (1988) used 100°C for 40 s. Heat treatment during pasteurisation causes some of the phospholipid to partition from the cream into the serum phase resulting in increased phospholipid in the serum (Thome & Erikson 1973a). Both time and temperature of heat treatment of the cream increases both whipping time and serum leakage (Mestres & Suge 1984). Thermisation (1 hour at 55°C) before separation decreases whipping properties and adhesion of the cream (Christiansen 1980b).

Homogenisation: Pasteurised cream is not normally homogenised as it has a negative effect on the whipping properties. Homogenisation has a far greater detrimental effect on whipping properties than heat treatment (Thome & Eriksson 1973b) because homogenisation results in the formation of new fat globule membrane that is not natural milk fat globule membrane (MFGM). UHT cream, however, needs to be homogenised to reduce cream plug formation during storage (Bruhn & Bruhn 1988). Only a mild homogenisation is recommended to avoid detrimental effects on whipping properties. Pressures in the range of 3.5–4.5 MPa are used at 65 to 78°C for UHT creams; pressures in excess of 5.5–6.0 MPa have a detrimental effect on the whipping properties of UHT creams (Muir & Kjaerbye 1996).

A patented process for the production of a UHT homogenised cream that has an overrun of greater than 135% has been described (Branciaroli 1984). In this
process the cream is heated to 125–142°C (for 1 to 5 s) and then homogenised at a temperature between 60 and 0°C preferably 44°C. The main difference in these processing conditions as compared with conventional UHT cream processing is that the homogenisation temperature is less than 60°C instead of greater than 60°C. In this patent the recommended homogenisation pressure is 5 MPa which is fairly low and may explain how the UHT cream is claimed to have reasonable whipping properties.

Vacreation: Vacreted creams have lower overrun and shorter whipping times than corresponding raw or batch pasteurised creams (Towler 1986), perhaps due to partial destabilisation of the fat globules through heat and mechanical treatment, as possibly indicated by a small decrease in fat globule size. If the steam splitting in the vacreation step is not well controlled then there can be a large effect on fat globule size distribution, similar to the effect of homogenisation, and this would increase the whipping times of creams.

Aging and rebodying: The ageing of pasteurised cream for 24 h improves its whipping properties (Bruhn & Bruhn 1988). Rebodying of cream using a process of heating to 28°C and then cooling to 4°C for 24 hours improves the whipping properties (decreased whipping time, increased overrun and increased viscosity) of 35% fat cream (McCarthy & others 1979). UHT cream and pasteurised creams also show improved viscosity and whipability after rebodying (Thome & Eriksson 1973a).

This is a result of the increased crystal structure within the cream, which would be equivalent to a cream with a harder fat content. It is necessary for some solid fat to exist to have a satisfactory whipped cream (Bruhn & Bruhn 1988).

Conclusion

Many factors affect the physical functionality and the properties of whipped cream. The production of whipping creams of consistent composition and quality requires attention to the quality of the milk, the natural variation in the milk and solid fat content of the fat in milk arising from changes in farm practices and seasonal effects, the conditions for the separation of cream, and the processing treatments.

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References


