10

Significance of Milk Fat in Cream Products

W. Hoffmann and W. Buchheim

10.1. Introduction

Cream is a fluid milk product, comparatively rich in fat, in the form of an emulsion of fat-in-skimmed milk, obtained by physical separation from milk (Codex Alimentarius Commission, 2003). This simple definition does not reflect that the word "cream" has for a long time been considered a premium product or a value-enhancing ingredient in milk products and other foods. The special "creaminess" results from the fine dispersion of the fat globules in the hydrophilic phase and depends strongly on the fat content. In separated cream, the diameter of fat globules ranges from *ca.* 1 to 8 μm. During further processing to the different cream products, this typical oil-in-water (o/w) emulsion is modified or even converted into another physical state. Modification can be achieved by homogenization, which markedly reduces the average fat globule size and improves creaminess. On the other hand, mechanical treatment of chilled cream causes destabilization (i.e., coalescence of the fat globules). This treatment and the concurrent entrapment of air are essential for whipping cream into a stable foam.

The fat content of cream products varies from about 10–50%. Products with a low, internationally not-yet standardized, fat content are "coffee cream" (≥10% fat, Germany), "half-and-half cream" (≥10.5% fat, USA), "half cream" (≥12% fat, UK) or "light cream" (≥12% fat, France). Traditional whipping cream has 30 to 40% fat, whereas double cream contains about 50% fat. Creams of high fat content are also essential ingredients in dairy or non-dairy products such as some fresh cheese varieties or

W. Hoffmann • Federal Research Centre for Nutrition and Food, Location Kiel, Hermann-Weigmann-Str. 1, D- 24103 Kiel. Telephone: +49 (0) 431 609 2272, Fax: +49 (0) 431 609 2309, E-Mail: wolfgang.hoffmann@bfel.de **W. Buchheim** • Lornsenstr. 34, D- 24105 Kiel.

Advanced Dairy Chemistry, Volume 2: Lipids, 3rd edition. Springer, New York, 2006.

cream liqueurs. Butter is manufactured from cream (30–80% fat) by phase inversion. Reviews on cream, cream processing and cream products have been published by Towler (1994), Early (1998), Kessler (2002) and Hoffmann (2003). Two IDF Bulletins (IDF 1992, 1996) deal with pasteurized and UHT creams.

In summary, the significance of milk fat in the different cream products is based on fat content, fat distribution, the physical state of the fat, and last but not least, the chemical, physical, and sensory properties of the non-fat ingredients. In the following, interactions between these factors are described for the most important cream products.

10.2. Coffee Cream

In many countries, coffee cream is a popular long-life product, which competes with evaporated milk, whole milk, and liquid or dried coffee whiteners. In this section, "coffee cream" does not mean a national statutory term, but an appropriate description of a functional property. Such creams usually contain 10 or 12% fat, less frequently 15, 18, or even 20%. Traditionally, coffee creams are sterilized in bottles or cans. During the last 20 years, continuous-flow sterilization in a UHT plant, followed by aseptic packaging, has replaced the former process to a large extent. The products need good stability both during storage and in hot coffee beverages, as well as acceptable sensory properties.

A shelf-life of several months at ambient temperature requires particularly low creaming and sedimentation in the package, which is facilitated by a low fat content (10 or 12%) and optimized processing conditions, mainly heat treatment and homogenization. Coffee creams with $\geq$15% fat need chilled storage to prevent irreversible creaming.

The different creams may contain stabilizing salts, which can be added as an aqueous solution after standardization and preheating (high-temperature pasteurization at 90–95°C). They raise the pH and/or complex Ca^{2+}, resulting in reduced aggregation of casein micelles during sterilization and in hot coffee beverages. With an increasing degree of condensation (chain length), phosphates have a reduced buffering capacity, and increased ion exchange ability. Trisodium citrate has both buffering and sequestering properties and is used also. Whereas phosphates and citrates are essential additives in traditionally-sterilized cream, high-quality flow-sterilized creams (containing 10 or 12% fat) may be produced without additives.

Homogenization of cream results inevitably in the formation of a secondary fat globule membrane, consisting predominantly of micellar casein and (denatured) whey proteins (Walstra *et al.*, 1999). To obtain desirable product properties, the formation of larger, thermally induced protein aggregates, and, particularly, fat/protein complexes must be avoided (Buchheim *et al*., 1986). The number and dimensions of the particles are influenced more by temperature than by heating time during flow sterilization. In general, such adverse structures are reduced by flow sterilization at $\leq$130°C rather than at UHT temperatures ($\geq$135°C). Frequently, a (second) two-stage homogenization step is carried out after heating in order to disrupt heat-induced fat/protein aggregates. Sensory effects of a lower heating temperature and a prolonged heating time ($\geq$1 min, necessary for safe sterilization) are a more pronounced cooked flavor and a more brownish color of the resulting cream. These effects are partially masked after addition to the coffee beverage and are, therefore, of minor relevance.

Physical properties of flow-sterilized cream can be controlled most effectively by homogenizing conditions. Usually, one homogenizer is integrated up-stream (i.e., before flow sterilization) and one down-stream. Both homogenizers often operate at a total pressure of about 20 MPa at 70°C. An optimal coffee cream should have a narrow fat globule size distribution with a volume-mean diameter preferably between 0.4 and 0.6 μm and a very low degree of aggregation (Figure 10.1). This results in low viscosity, high whitening power, slow creaming and high ‘‘coffee stability’’ (i.e., resistance to feathering in hot coffee beverages).

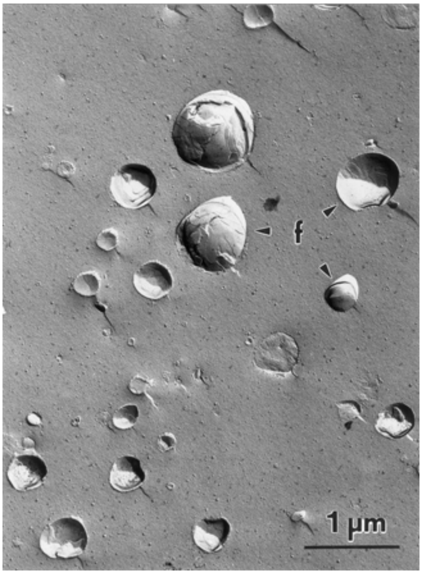

Figure 10.1. Electron micrograph of flow-sterilized coffee cream; f: homogenized fat globules.

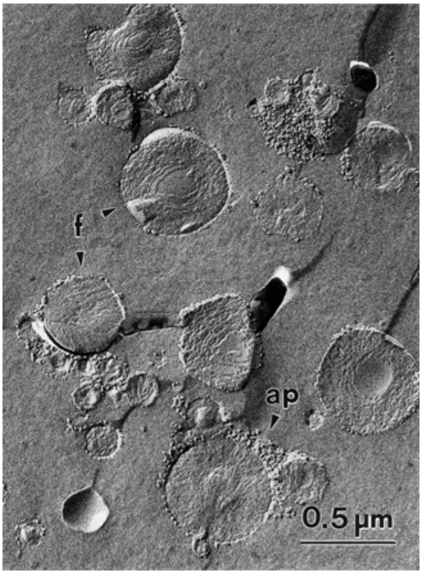

Figure 10.2. Electron micrograph of floccules in a coffee cream after feathering in a hot coffee solution (enlarged compared to Figure 10.1.1); f: fat globules; ap: aggregated protein.

The coffee stability is particularly important for the quality of the product. It is also affected by the coffee brand and concentration, minerals present in the water, brewing conditions, and by temperature (Kessler, 2002). Typical coffee beverages have a pH of about 5.0, which is near the isoelectric range of casein. High temperature ($\geq$70°C), low water hardness, low pH or a high concentration of sulphates accelerate protein coagulation, and hence, fat/protein aggregation. Therefore, it must be ensured that this feathering remains invisible to the naked eye (Buchheim *et al.*, 1986; Hoffmann *et al.*, 1996) (Figure 10.2). The probability of feathering increases with the fat content of the cream. Apart from feathering, floccules of condensed cream may float on the coffee surface when using cream from small polystyrene (PS) portion packs. Considerable loss of water (about 10–15% of cream weight during 4 months) occurs with deep-drawn PS containers, which facilitates the formation of such floccules in coffee.

10.3. Whipping Cream

Whereas the processing of long-life coffee cream is characterized by severe homogenization and heat treatment, traditionally pasteurized (at *ca*. 85°C) whipping cream is produced carefully with little thermal and mechanical input (Figure 10.3). However, the demand for a longer shelf-life has led to a subsequent high-temperature pasteurization (≥110°C) or even UHT heating and additional low-pressure homogenization. The higher thermal load results in more or less cooked flavor. Although the prolonged shelf-life requires efficient steps against irreversible creaming (plug formation), adequate storage stability of the double-pasteurized cream containing 30–35% fat can, however, be achieved without homogenization. The addition of hydrocolloids (particularly fractions of carrageenan), milk constituents (whey proteins and high-melting fat fractions, see Precht *et al.*,1988) and even synthetic emulsifiers (if legally permitted) can slow down creaming during 3 weeks at ≤10°C. The aim of UHT treatment is to produce sterile cream with a shelf-life up to 3 months at about 20°C. Usually, indirect heating at ≥135°C with a short holding time of a few seconds is applied in order to limit the thermally induced physical, chemical and sensory changes. Unchilled storage without serious creaming requires the use of stabilizers (hydrocolloids and/or synthetic emulsifiers), a fat content near the lower limit of 30%, but also a slight reduction in the size of the original fat globules. The homogenization effect must be moderate in order to retain acceptable whipping properties. A compromise between long storage stability and adequate functional attributes is needed. Homogenization and subsequent UHT heating would, however, cause an increase in the content of free fat. Therefore, a down-stream two-stage homogenization of cream at a total pressure of not more than 4 MPa is used frequently.

The whipping of pasteurized cream containing ≥30% fat is possible only after adequate cooling since the transformation of the original o/w emulsion into a stable foam requires that part of the fat is solid. The initial stage of

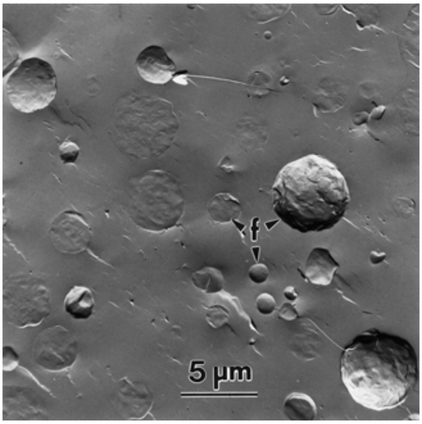

Figure 10.3. Electron micrograph of fluid whipping cream; f: fat globules.

whipping involves stabilization of the trapped air bubbles by a temporary interfacial film of soluble whey proteins and β-casein. On mechanical treatment, fat globules increasingly loose at least segments of their natural membrane, thereby exposing strongly hydrophobic surface areas of pure fat. Subsequently, these partly destabilized fat globules adsorb at the air/serum interface of the air bubbles (Figure 10.4). The leakage of liquid fat from mechanically stressed and deformed fat globules supports globule agglomeration and partial coalescence. These agglomerates also interact with the air bubbles and may form bridges between them. The above, highly dynamic and concurrent processes also apply on the whole to low-homogenized UHT whipping cream containing about 30% fat. Details of the interactions and processes during whipping are described by Anderson *et al*. (1987), Anderson and Brooker (1988), Buchheim (1991), Buchheim and Dejmek (1997) and Smith *et al*. (1999).

The whipping properties of creams are assessed by whipping time, increase in volume (expressed as overrun), foam firmness and by subsequent serum leakage. Comparative studies require standardized temperature, whipping and other handling conditions. Most test whipping devices are modifications of that described originally in 1937 by Mohr and Baur (see Hoffmann, 2003). Whipping of a typical cream increases the volume by 80–125% by inclusion of ambient air. UHT-treated creams can also be aerated by means of suitable propellants (e.g., N_2O), resulting in a volume increase in the range of about 300–500%. These convenience products are filled into sterilized aluminium or tin-plate cans. Compared with regular whipped cream, clearly more fat globules adsorb at the air interfaces, and,

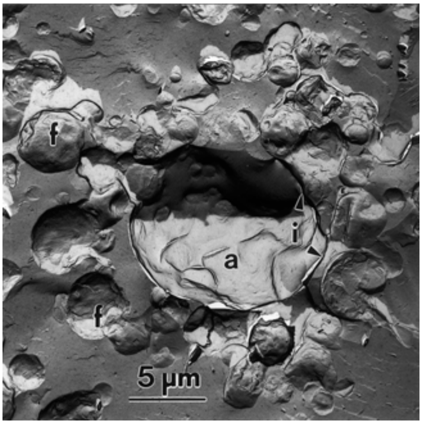

Figure 10.4. Electron micrograph of whipped cream; a: air cell; f: fat globules; i: interfacial layer.

simultaneously, agglomeration of fat globules is reduced substantially, which results in an impaired network formation between the air bubbles. Due to the different foaming process, aerosol creams develop only soft foams with low stability (Buchheim, 1991).

Whipping cream ranks among premium food products and is consumed for its pure flavor. High-quality raw milk is essential for this product. Raw milk and separated cream must be handled carefully to minimize damage to the natural fat globule membrane. Excessive agitation and pumping should be avoided. The flow velocity should not exceed the critical shear rate, which can be calculated (Kessler, 2002). Incorporated air bubbles increase the risk of damaged fat globules or can act as centres for fat globule aggregation and subsequent coalescence. During crystallization, fat globules are most sensitive to mechanical treatment. As a result of the partial or complete loss of the protective membrane, both indigenous and bacterial lipases catalyse the hydrolysis of exposed fat to fatty acids, imparting rancid taints (Kosinski, 1996). When raw cream is homogenized without being subjected immediately to high-temperature pasteurization, indigenous milk lipoprotein lipase penetrates the secondary membrane of fat globules (which has higher interfacial tension than native membrane) and hydrolyzes triglycerides to free fatty acids within a few minutes, resulting in intense rancidity (Walstra *et al.*, 1999).

Active extracellular bacterial lipases and proteinases of *Pseudomonas* spp. and most other Gram-negative psychrotrophs may be present even in UHT cream if refrigerated raw milk had been stored for a prolonged period. They can contribute to rancid and tallowy flavors, and also to bitty cream or serious physical changes such as gelation (Castberg, 1992; Driessen and van den Berg, 1992; Houlihan, 1992; Kosinski, 1996).

Flavor defects in cream may occur not only during manufacture but also during transport or storage until the best-before date. UHT whipping cream, with its long shelf-life at ambient temperature, is particularly susceptible to off-flavors. Hence, adequate packaging materials must be chosen. Protection against oxygen and/or light is most important as they may induce oxidation of unsaturated fatty acids, leading to flavor deterioration. Paper cartons with a coating of polyethylene and an aluminium foil laminated to the inner carton layer are often used. Appropriate filling conditions should also be selected to minimize the oxygen content of the package and the cream. However, a certain level of residual oxygen may be beneficial as the UHT process exposes free sulphydryl groups and causes the release of hydrogen sulphide from β-lactoglobulin, thus creating the typical cooked flavor. During storage, oxidation of these groups occurs and most of the cooked flavor disappears. A balanced antioxidative/oxidative action of sulphur groups and oxygen will probably help to ensure cream products of good taste and odor (Eyer *et al.*, 1996).

An important factor for the physical stability of cream is the temperature of the cream during transport and storage. Even a brief warming to $\geq 30°C$ supports creaming during subsequent storage at 20°C and may lead to a distinct thickening after cooling before whipping. Continuous cooling during the whole shelf-life delays creaming, avoids destabilization phenomena and sensory changes, and results in increased foam volume, but a longer whipping time (Hoffmann, 1999).

10.4. Cream Liqueurs

Cream liqueurs combine the flavor of alcoholic drinks with the texture of cream in products with a shelf-life of several years at ambient temperature. During that period, the liqueur must be resistant to both microbiological and physical changes. The microbiological safety is guaranteed by a sufficient concentration of alcohol ($\geq 14\%$) together with a high sugar content (about 19%). Avoiding serious phase separation is the more demanding challenge. This can be achieved by optimal composition and processing. The addition of sodium caseinate (*ca.* 3%), trisodium citrate (*ca.* 0.2%) and possibly low molecular-weight emulsifiers like monoglycerides (*ca.* 0.1%) stabilizes the o/w emulsion of the added cream (e.g., 16% of 48% fat cream) in the liqueur. In the final product, more than 98% of the fat globules should have a diameter $<0.8\,\mu m$, resulting in clearly enhanced viscosity, creaminess and whitening power (Banks and Muir, 1988). The typical volume-mean diameter of about $0.2\,\mu m$ is, by far, the smallest of all dairy

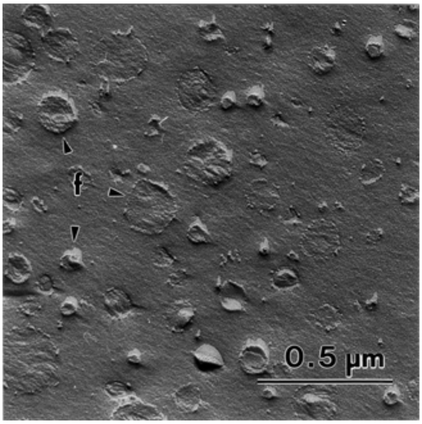

Figure 10.5. Electron micrograph of cream liqueur; f: fat globules.

products (Buchheim and Dejmek, 1997) (Figure 10.5). This is achieved by multiple high-pressure homogenization. Banks and Muir (1988) recommended the addition of alcohol after homogenization resulting in the formation of fewer large fat globules. Compared to unhomogenized cream, the total fat surface area increases by a factor of about 20 (up to *ca*. 40 m^2/g fat) in cream liqueurs. Therefore, sodium caseinate is dissolved first in hot water before adding the cream, sugar, citrate and a complementary emulsifier (if necessary). No other protein than sodium caseinate is able to provide the required long-term emulsion stability. O'Kennedy *et al*. (2001) isolated special fractions of commercial sodium caseinate (soluble in high concentrations of ethanol), which keep a constant viscosity of cream liqueur during storage. Trisodium citrate, a useful stabilizer for several dairy products, such as evaporated milk or sterilized coffee cream, complexes the Ca^{2+} and concurrently increases the pH. In cream liqueur, trisodium citrate prevents the interaction between sodium caseinate and available calcium. Otherwise, gelation and syneresis during storage would occur. If a cream liqueur with a substantially higher alcohol content than 14% is produced (e.g., 19%), a second addition of alcohol after homogenization of cream (and other ingredients) is required in order to produce a stable emulsion. The manufacture of cream liqueurs ends with filling into brown glass bottles to prevent light-induced off-flavor. Very occasionally, during long-term storage, the formation of a non-redispersible cream or fat plug in the neck of the bottle may occur (Dickinson *et al*., 1989). The fatty solid-like cohesive structure of this plug points to unfavorable ambient temperatures, possibly accompanied by excessive mechanical agitation. The formation of neck-plug may be similar in origin to the thickening of whipping cream after warming for a short period ($\geq$30°C) and subsequent cooling.

10.5. Cultured Cream

Cultured or sour(ed) creams find various applications as valuable additives for dishes and in refining sauces and dressings. They are manufactured in many countries and their fat content generally ranges from 10 to more than 40%. The production is largely equivalent to that of other fermented milk products (Puhan, 1988). It starts with standardization of the fat content and may include the addition of skim milk concentrate or skim milk powder, milk protein and hydrocolloids (e.g., gelatin or starch), if legally permitted. These ingredients improve texture and prevent syneresis of the final product. Adequate processing conditions and a higher fat content reduce the need for supplementation. The homogenization pressure required for cream decreases with increasing fat content. Homogenization after high-temperature

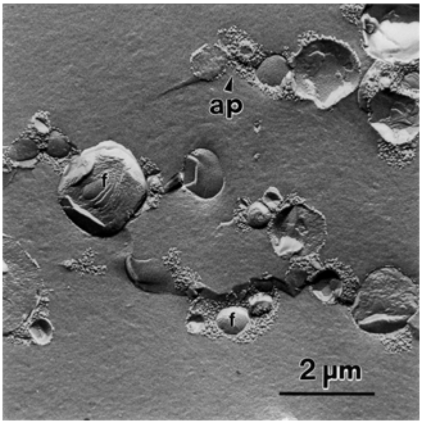

Figure 10.6. Electron micrograph of cultured cream (10% fat); f: fat globules; ap: aggregated protein.

pasteurization results in better consistency compared to up-stream treatment. The fat globules participate directly in the following fermentation process and are integrated into the developed network (Buchheim and Dejmek, 1997) (Figure 10.6). Normally, the use of mesophilic lactic acid bacteria results in a long fermentation time (14–24 h). Chemical acidification (e.g., by glucono-δ-lactone, lactic acid) is uncommon. Typical cultured cream products should be uniform (without creaming), creamy and viscous with a slightly acidic, mild "cheesy" or "buttery" flavor. Cultured creams may also develop a nearly plastic consistency as a result of modified composition and/or appropriate production and may be used as low-fat spreads (o/w type).

Bibliography

Anderson, M., Brooker, B.E. 1988. Dairy foams. In: *Advances in Food Emulsions and Foams* (E. Dickinson, G. Stainsby, eds.), pp. 221–256, Elsevier Applied Science, London,.

Anderson, M., Brooker, B.E., Needs, E.C. 1987. The role of proteins in the stabilization/destabilization of dairy foams. In: *Food Emulsions and Foams* (E. Dickinson, ed.), pp. 100–109, Royal Society of Chemistry, London.

Banks, W., Muir, D.D. 1988. Stability of alcohol-containing emulsions. In: *Advances in Food Emulsions and Foams* (E. Dickinson, G. Stainsby, eds.), pp. 257–283, Elsevier Applied Science, London.

Buchheim, W., Falk, G., Hinz, A. 1986. Ultrastructural aspects and physico-chemical properties of UHT-treated coffee cream. *Food Microstruct*. **5**, 181–192.

Buchheim, W. 1991. Mikrostruktur von aufschlagbaren Emulsionen (Microstructure of whippable emulsions). *Kieler Milchwirtschaftl. Forsch.ber*. **43**, 247–272.

Buchheim, W., Dejmek, P. 1997. Milk and dairy-type emulsions. In: *Food Emulsions*, 3rd edn (S.E. Friberg, K. Larsson, eds.), pp. 235–278, Marcel Dekker, New York.

Castberg, H.B. 1992. Lipase activity. *Bulletin* 271, pp. 18–20, International Dairy Federation, Brussels.

Codex Alimentarius Commission 2003. *Codex standard for creams and prepared creams,* Codex Stan. A-9-1976, Rev. 1-2003., FAO/WHO, Rome.

Dickinson, E., Narhan, S.K., Stainsby, G. 1989. Stability of alcohol-containing emulsions in relation to neck-plug formation in commercial cream liqueurs. *Food Hydrocol.* **3**, 85–100.

Driessen, F.M., van den Berg, M.G. 1992. Microbiological aspects of pasteurized cream. *Bulletin* 271, pp. 4–10, International Dairy Federation, Brussels.

Early, R. 1998. Liquid milk and cream. In: *The Technology of Dairy Products*, 2nd edn (R. Early, ed.), pp. 1–49, Blackie Academic and Professional, London.

Eyer, H.K., Rattray, W., Gallmann, P.U. 1996. The packaging of UHT-treated cream. *Bulletin* 315, pp. 23–24, International Dairy Federation, Brussels.

Hoffmann, W. 1999. Lagerstabilität von H-Schlagsahne (Storage stability of UHT whipping cream). *Kieler Milchwirtschaftl. Forsch.ber*. **51**, 125–136.

Hoffmann, W. 2003. Cream. In: *Encyclopedia of Dairy Scienc*es, Vol. 1 (H. Roginski, J.W. Fuquay, P.F. Fox, eds.), pp. 545–557, Academic Press, London.

Hoffmann, W., Moltzen, B., Buchheim, W. 1996. Photometric measurement of coffee cream stability in hot coffee solutions, *Milchwissenschaft*. **51**, 191–194.

Houlihan, A.V. 1992. Enzymatic activity other than lipase. *Bulletin* 271, pp. 21–25, International Dairy Federation, Brussels.

IDF. 1992. Monograph on the Pasteurization of Cream, *Bulletin* 271, International Dairy Federation, Brussels.

IDF. 1996. UHT-Cream, *Bulletin* 315, International Dairy Federation, Brussels.

Kessler, H.G. 2002. *Food and Bio Process Engineering – Dairy Technology*, pp. 385–424, A. Kessler, München.

Kosinski, E. 1996. Raw material quality. *Bulletin* 315, pp. 12–16, International Dairy Federation, Brussels.

O'Kennedy, B.T., Cribbin, M., Kelly, P.M. 2001. Stability of sodium caseinate to ethanol. *Milchwissenschaft*. **56**, 680–684.

Precht, A., Peters, K.-H., Petersen, J. 1988. Improvement of storage stability and foaming properties of cream by addition of carrageenan and milk constituents. *Food Hydrocoll.* **2**, 491–506.

Puhan, Z. 1988. Results of the questionnaire 1785B "fermented milk". *Bulletin* 227, pp. 138–164, International Dairy Federation, Brussels.

Smith, A. K., Goff, H.D., Kakuda, Y. 1999. Whipped cream structure measured by quantitative stereology. *J. Dairy Sci*. **82**, 1635–1642.

Towler, C. 1994. Developments in cream separation and processing. In: *Modern Dairy Technology*, 2nd edn, Vol. 1 (R.K. Robinson, ed.), pp. 61–106, Chapman and Hall, London.

Walstra, P., Geurts, T.J., Noomen, A., Jellema, A., Boekel, M.A.J.S. van 1999. *Dairy Technology*, Marcel Dekker, New York.