Improvement of storage stability and foaming properties of cream by addition of carrageenan and milk constituents

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Abstract. The increasing automation in the dairy industry and the longer guaranteed shelf life of the packed products of cream lead to a loss in the quality of liquid and whipped cream associated with the formation of irreversible plugs, too long whipping times and high degrees of liquid separation of the whipped product. In test series 0.015% carrageenan, 0.25% protein-fat as the dry matter (whey proteins with high-melting milk fat fractions) or a combination of both were added to homogenized and unhomogenized, pasteurized or ultra-high temperature treated (UHT) cream from the winter and summer feeding period (fat content: 30%). The creaming behaviour after storage at 7 or 20°C was characterized by determining the fat content in different layers of a cream package. In cream samples without additives unstirrable layers had been formed after 2–7 weeks, in particular during the long storage times of UHT cream without cooling. A desired (i.e. low) degree of creaming of the liquid cream as well as little separation in the whipped product could be achieved for all samples only by means of a combination of carrageenan and protein-fat powder. Of the rather varying carrageenan fractions examined, a combination of similar proportions of kappa- and iota-carrageenan has proved to be particularly effective without excessively increasing viscosity.

Introduction

The increasingly longer guaranteed shelf lives of packed cream products and highly automatic processing associated with increasing stress for the milk fat globules, because of more intense heat and mechanical treatment and, further, by the number of pumping processes during milk collection, lead to a loss in the quality of whipping cream. Although microbiological problems arising during longer distribution times can easily be overcome by ultra-high temperature treatment (UHT), the latter aggravates physical problems such as creaming in liquid cream or drainage in whipped cream. However, both phenomena are quality criteria of particularly high relevance to the consumer. Further, whipping cream which is too viscous is rejected, in particular, because it sometimes takes too long to whip the cream or because the increase in volume of the whipped product (overrun) is too low.

Creaming or separation of the fat globules occurs since the density of the suspended globules is lower than that of the surrounding milk plasma. Due to the high stress exerted upon the fat globules during production, damage to the globule membrane is almost unavoidable. As a result liquid fat fractions escape, which accelerates creaming because of globule agglomerations associated with the formation of partly irreversible fat plugs on the surface of cream in small packages.

Besides the homogeneous consistency of the liquid cream product, the physical properties of the whipped product are also of importance. Whilst a minimum increase in volume of 80% is achieved in most cases, whipping times are frequently too long and, in particular, foam stability is unsatisfactory. As a
result, excessive drainage of liquid is often observed, even if the product has been left standing only for a shorter time.

Since, according to Stoke’s law, the diameter of the fat globule plays a decisive role in creaming, it has been attempted to reduce the degree of creaming by homogenization, thereby reducing the size of the fat globules. On the other hand, even mild homogenization can impair the whipping properties (1–3).

The literature often reports on the emulsion-stabilizing influence of hydrocolloids (4–6) as well as of proteins (7,8) in dairy-food processing. Therefore, in this paper particular attention has been paid to investigations on homogenized and unhomogenized pasteurized or UHT cream to which carrageenan and small amounts of milk constituents had been added, i.e. whey proteins and fractions of milk fat. All studies on the quality of liquid whipping cream and whipped cream were based on different feeding conditions for the cows (summer and winter). Little is known of the influence of carrageenan on cream which has been subjected to one of the currently used processing methods. Although a number of reports on the influence of carrageenan added to cream have been published (9–11), neither the influence of carrageenan additives combined with protein–fat additions, which is of interest here, nor the effect of individual carrageenan fractions such as kappa-, iota- and lambda-carrageenan have been dealt with.

Addition of the hydrocolloid carrageenan, belonging to the polysaccharides, is admitted in a great number of foodstuffs without assuming nutritional disadvantages (12).

Materials and methods

Initial cream

Cream from summer and winter seasons (fat content 30% each) was pasteurized in a plate heat exchanger at 100°C and 40 s holding time. Another batch of cream was indirectly UHT treated at 140°C and 5 s holding time. The pasteurized and UHT creams were stored for 2 and 7 weeks respectively, at storage temperatures of 7 and 20°C. The pasteurized cream samples stored at 20°C served exclusively as controls for the UHT samples.

Carrageenan and protein–fat additions

The blend consisting of carrageenan fractions and the protein–fat powder were from Messrs Petco, Ganderkesee. The protein–fat powder was made up from a spray-dried mixture of ultra-filtered whey (lactalbumin and lactoglobulin) and a hard-fat fraction. The ratio of whey protein to fat is given later in the text. Individual carrageenan fractions were from Messrs Fluka (kappa- and iota-carrageenan) as well as from Denmark from the Copenhagen Pectin Factory Ltd (lambda-carrageenan). The additives were mixed with skim milk (10°C) using an Ultra-Turrax homogenizer and the cream samples with this skim milk blend standardized to a constant fat content of 30%. Preliminary tests have shown that in varying samples direct incorporation of the additives in cream using the Turrax homogenizer led partly to destabilization phenomena of the fat...
Addition of carrageenan and milk constituents to cream

globule membrane causing additional measurable proportions of free fat in cream and leading, hence, to more pronounced creaming phenomena.

Chemical fat characterization

Composition of fat. Gas chromatographic analysis of fatty acids (GC 439, Packard) followed extraction of the methyl esters by interesterification. Column: fused silica capillary column, length 50 m, i.d. 0.25 mm, coated with SIL88; carrier gas: 2 ml/min H₂, split: 1:50; by-pass gas: 30 ml/min N₂; temperatures: detector and injector 255°C; temperature program: 50–225°C at 5°C/min, then isothermal. Calibration was made using a test blend consisting of the methyl esters of the main fatty acids, the composition being adjusted to the milk fat.

Iodine number. Determination (Wijs) was according to the IDF Standard no. 8 (13).

Physical fat and plug characterization

Measurement of the degree of creaming. For assessment of the degree of creaming two different methods were used. In the experiments with protein–fat powder as well as carrageenan blends, consisting of kappa-, iota and lambda-carrageenan, a vessel of the same total filling height as in commercial cream cups was used. By means of a canula, adjustable to the sample depth desired in the individual case, the required sample quantity was carefully sucked off under vacuum. In the experiments with the individual fractions of carrageenan the cream was stored in cylindrical metal insets using the same filling height as in commercial cream cups, rapidly frozen at −40°C at the end of storage time, cut into slices and their fat content determined. A similar method was used in the studies on creaming by Fink and Kessler (14). Determination of the fat content was made according to Gerber (15). Yield and dropping points were determined using the dropping point apparatus according to Ubbelohde (16). Determination of plug firmness was performed using a jelly tester from Messrs Stevens (UK). The data obtained with it are non-dimensional and only relative values.

Viscosity of the liquid cream using a capillary viscosimeter. The measuring arrangement consisted of a fine glass tube and a vessel with a lower and upper mark connected to it. The tempered cream was allowed to flow off the filled vessel through a glass tube and the time was measured during which the miniscus of the liquid fell from the upper to the lower mark.

Sensory evaluation

Sensory evaluation was carried out by trained panelists according to the five-score valuation scheme of the German Society of Agriculture (‘Deutsche Landwirtschaftsgesellschaft’, DLG) (17), the test criterion being ‘appearance’. Scores of 5 were given if all quality requirements were satisfied, scores of 4 were associated with negligible deviations from the quality standard, scores of 3 with
slight defects, scores of 2 with marked defects, scores of 1 with severe defects and scores of 0 with too large variations from the quality standard.

**Physical properties of the whipped cream**

**Whipping time.** According to the method of Mohr and Koenen (18) 100 ml of cream (5°C) was whipped in a standardized cup using two rotating cylindrical wire baskets (900 r.p.m.) and the time up to the final point of whipping (max. watt capacity of the whipping machine) measured (15).

**Overrun.** The foam volume of the whipped cream was determined in standardized cups by means of a measuring stick and related to the 100 ml initial volume of the liquid cream (15).

**Firmness.** The time (in s) that a standardized 130-g stamp needs to penetrate 3 cm deep into the whipped cream was measured (15).

**Serum separation.** The quantity of liquid (in ml) that in 1 or 2 h at 18°C drips off a square block (edge length 6 cm) of the whipped cream foam of the sample obtained from 100 ml cream was measured (15).

**Results**

A 0.015% carrageenan blend (kappa-, iota- and lambda-carrageenan) was added to samples of cream (30% fat) before pasteurization or UHT treatment. To other samples of cream a 0.25% fat–protein powder which consisted of a combination of whey proteins and milk fat fraction (yield point: 38.4°C; dropping point: 38.8°C) was admixed. The fat/protein ratio was 78:22% when the powder was added alone and 55:45% when the powder was combined with carrageenan. In order to characterize fat separation the fat contents in pasteurized cream (storage at 7°C) and UHT cream (storage at 20°C) have been analysed after 2 and 7 weeks of storage and samples from seven layers of different depths in the cups were taken. The studies with cream were made under varying conditions of feeding, i.e. summer and winter cream were used. Here the iodine number for winter fat (29.2) differed considerably from that for summer fat (39.1). Figure 1 shows the proportion of fatty acid in the milk fat from both feeding periods, which were determined by gas chromatography, as well as the fatty acid distribution of the high-melting milk fat fractions used.

Table 1 summarizes the fat content in seven different layers of varying depths in the cups containing cream with the above-mentioned different additives. It was found that in samples without additives the fat content of winter and summer cream samples of pasteurized and, in particular, of UHT cream was particularly high in the top layer, whilst fat globules were hardly still present in both bottom layers. Here an irreversible cream plug exhibiting a thickness of up to 3 cm (UHT) and which was absolutely unstirrable had formed each time. Adding protein–fat powder alone gave markedly better results; also adding carrageenan exclusively reduced the degree of creaming, which we call improved
Addition of carrageenan and milk constituents to cream

Fig. 1. Main fatty acids (w%) of the different milk fats from barn (winter) and pasture (summer) feeding periods as well as from the high-melting milk fat fraction (protein–fat powder).

Table I. Creaming (fat content in %) in different layers of pasteurized and UHT cream

<table>
<thead>
<tr>
<th>Additives</th>
<th>Depth of layer (cm)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Pasteurized summer cream (storage: 2 weeks at 7°C)</td>
<td>No addition</td>
<td>48.1</td>
<td>49.4</td>
<td>44.3</td>
<td>34.7</td>
<td>27.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Protein/fat/carrageenan</td>
<td>32.4</td>
<td>32.7</td>
<td>32.1</td>
<td>32.4</td>
<td>31.6</td>
<td>29.4</td>
<td>19.3</td>
</tr>
<tr>
<td></td>
<td>Protein/fat</td>
<td>36.2</td>
<td>35.8</td>
<td>34.7</td>
<td>34.1</td>
<td>33.9</td>
<td>33.6</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Carrageenan</td>
<td>38.8</td>
<td>37.9</td>
<td>36.4</td>
<td>34.6</td>
<td>33.7</td>
<td>28.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Pasteurized winter cream (storage: 2 weeks at 7°C)</td>
<td>No addition</td>
<td>55.1</td>
<td>53.7</td>
<td>50.1</td>
<td>34.7</td>
<td>14.4</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Protein/fat/carrageenan</td>
<td>30.7</td>
<td>30.4</td>
<td>30.0</td>
<td>30.0</td>
<td>29.9</td>
<td>29.9</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Protein/fat</td>
<td>36.9</td>
<td>37.2</td>
<td>35.2</td>
<td>34.7</td>
<td>34.3</td>
<td>31.0</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Carrageenan</td>
<td>30.8</td>
<td>31.4</td>
<td>31.0</td>
<td>31.2</td>
<td>30.9</td>
<td>27.2</td>
<td>27.5</td>
</tr>
<tr>
<td>UHT summer cream (storage: 7 weeks at 20°C)</td>
<td>No addition</td>
<td>86.3</td>
<td>69.0</td>
<td>46.0</td>
<td>4.0</td>
<td>2.3</td>
<td>1.7</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Protein/fat</td>
<td>43.4</td>
<td>41.4</td>
<td>41.4</td>
<td>40.7</td>
<td>40.7</td>
<td>2.0</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Carrageenan</td>
<td>59.1</td>
<td>54.2</td>
<td>51.1</td>
<td>44.5</td>
<td>0.8</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

creaming stability. However, only a combination of carrageenan and protein–fat powder yielded the best results, leading to an almost constant fat content within all layers in a cup.

When comparing pasteurized summer and winter cream without additives a higher degree of creaming and more plug formation were found in cream from...
the winter feeding period. Besides analysing the fat content the firmness of the plugs was examined by using a jelly-tester. Further, assessment of the appearance of the creams has been done according to the principles of DLG (17). Both the values obtained with the jelly-tester and those from sensory tests were closely correlated with the results shown in Table I.

For quality assessment of the whipped product, whipping time, increase in volume (overrun) and drainage after 1 and 2 h were taken into account. Here drainage or separation of liquid from the whipped cream shown in Figure 2 can be considered as one of the most important quality criteria for the assessment of the physical properties of whipped cream. Generally it can be observed that the degree of separation is markedly higher in whipped cream without additives from summer milk (pasture feeding) compared with whipped winter cream (barn feeding). For cream without additives, from both feeding periods, the degree of serum separation was not acceptable. A stable cream foam obtained from 100 ml of liquid cream should maximally secrete 1 ml of liquid after 2 h at 18°C (17,19). It is striking that contrary to pasteurized cream (summer cream) addition of just carrageenan to UHT cream apparently yields very good results (below 1 ml). A similarly good whipped cream stability of all samples was only achieved with a combination of carrageenan and protein–fat powder. Compared with storage at 7°C, storage of the pasteurized winter cream at 20°C caused a slightly reduced separation of liquid, in summer cream samples an increased separation.

Fig. 2. Separation of liquid from the whipped cream after 2 h as a function of feeding and storage conditions (temperatures) as well as of additives. Measurement after 2 (pasteurized cream) and 7 weeks (UHT cream). Storage of cream at 7 and 20°C followed by whipped cream production. (Cream temperature on measurement 5°C, room temperature 18°C.)
Additional experiments showed that the positive influence of the protein–fat powder on drainage of the whipped product is mainly due to the hard fat fraction. Thus additions of 0.2% hard fat fraction alone and of 0.1% whey protein alone reduced drainage after 2 h by 30 and 16%, respectively. It should be noted in this context that casein would not be expected to cause greater improvements than whey proteins because the casein micelles do not form an integral part at the air–serum interface of the bubbles (30).

Figure 3 shows the whipping times as a function of feeding conditions, storage temperatures, and the different additives. Prolonged whipping times were associated with pasture feeding as well as with lower storage temperature, and were mostly also observed with UHT samples compared with pasteurized samples (except summer cream without and with carrageenan addition). Apart from the prolonged whipping times for UHT summer cream with protein–fat powder the differences resulting from additions were minor for all samples.

All values for the increase in volume were between 105 and 150%, ranging, hence, far above the required minimum of 80% (17) and could, therefore, be regarded as sufficiently high.

In order to exhaust further technological possibilities, we have studied the influence of homogenization of the cream, which is frequently applied in practice. The aim of homogenization is to limit the extent of creaming during the time of distribution. It is well known that more intense homogenization leads to increased clustering of cream associated with a partly unacceptable high increase

Fig. 3. Whipping times as a function of feeding and storage conditions and additives. Measurement after 2 (pasteurized cream) and 7 weeks (UHT cream). Storage of cream at 7 and 20°C followed by whipped cream production. (Cream temperature on measurement 5°C, room temperature 18°C.)
Fig. 4. The effect of a two-stage homogenization process (2.5 + 1.5 MPa) and of additives on creaming of whipping UHT cream (barn feeding). Fat contents in layers of different depth in a cream cup. (Initial fat content 30%, 7-week storage time, storage temperature 7°C.)

in viscosity. First, homogenization was performed in two stages with pressures of 7/0.7, 7/2, 2.5/1.5 MPa. The initial pressure of 7 MPa used caused a high increase in viscosity of ≤700% in a number of experiments, so the experiments were continued with a two-stage homogenization at 2.5/1.5 MPa and a homogenization temperature of 70°C. Figure 4 shows the fat contents in seven layers, each 1 cm thick, of a UHT cream cup as a function of the additions made, homogenization being either not applied or before or after UHT treatment. Without additives and without homogenization a 7-week storage at 7°C led to extremely high fat contents in the top layers, whereas a 2.5/1.5 homogenization reduced creaming markedly. Best results were obtained by adding carrageenan and protein-fat powder. Further, homogenization after UHT treatment slightly reduced the degree of creaming.

While in the experiments without homogenization agreement was obtained between the course of creaming and assessment of plugs, this was no longer the case with the homogenized samples. Sensory assessment of appearance (plugs) generally yielded worse results for homogenized cream compared with unhomogenized cream, although the course of creaming showed a more uniform cream in terms of the fat content in all layers. In Table II the quality criteria according to DLG test conditions for appearance (plug) are given: five scores for best assessment, etc. Accordingly, the unhomogenized UHT cream without additives was scored higher (by 2–4 scores), although the fat content gradation in the layers of homogenized UHT cream was less good (Figure 4). This result was attributable to the existence of a top layer, 1–2 mm thick, in the
Addition of carrageenan and milk constituents to cream

Table II. Plug firmness, sensory assessment and viscosity of UHT winter cream after 6 weeks

<table>
<thead>
<tr>
<th>Additives</th>
<th>Storage temperature: 7°C</th>
<th>Storage temperature: 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jelly (units)</td>
<td>Sensory viscosity¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UHT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No addition</td>
<td>70</td>
<td>3–4</td>
</tr>
<tr>
<td>Carrageenan</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Protein/fat/carrageenan</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UHT + 2.5/1.5 homogenization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No addition</td>
<td>81</td>
<td>0</td>
</tr>
<tr>
<td>Carrageenan</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Protein/fat/carrageenan</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>2.5/1.5 homogenization + UHT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No addition</td>
<td>7</td>
<td>1–2</td>
</tr>
<tr>
<td>Protein/fat/carrageenan</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

¹Capillary viscosity standardized to 100 for base trial.
²Sample clumpy.

homogenized sample, which was, though thin, slightly furry and no longer stirrable in the highly viscous cream below it.

These results obtained with homogenization are also to be seen in connection with the physical properties of the whipped UHT cream. Table III shows that the homogenized samples had inacceptably long whipping times. Further all homogenized samples had a markedly higher degree of drainage. Only addition of the combination of protein–fat powder/carrageenan reduced separation to an extent which was still considered acceptable.

Having achieved essential improvements in the quality of liquid and whipped cream by adding carrageenan, further experiments were aimed at elucidating the stabilizing influence of individual carrageenan fractions. It was intended to use the lowest possible carrageenan additions, which, on the one hand, still allow detection of an effect and, on the other hand, do not completely stop creaming associated with an inacceptably high increase in viscosity, so that it would have been impossible to differentiate between the fractions. Figure 5 shows creaming on the basis of the fat contents in the different layers of a 30% pasteurized initial cream (winter feeding), to which 0.008 and 0.015% kappa-, iota- and lambda-carrageenan has been added. It is, in particular, the fat content in the bottom layers which shows that the lowest degree of creaming is achieved by adding kappa-carrageenan. Higher doses caused very similar fat content gradients.

As to separation characterizing the foam stability of the whipped product best results were again obtained with kappa-carrageenan (Figure 6). Although additions of iota- and lambda-carrageenan also allowed marked improvements in quality, the values for drainage were still too high after 2 h. On the other hand, viscosity measurements have shown that compared with cream without additives, addition of 0.008% individual carrageenan fractions led to increases of 36.1 (kappa), 5.2 (iota) and 20.6% (lambda); addition of 0.015% even caused increases of 83.2, 7.1 and 16.1% respectively.

499
Table III. Physical properties of UHT winter cream after 7 weeks

<table>
<thead>
<tr>
<th>Additives</th>
<th>Storage temperature: 7°C</th>
<th></th>
<th>Storage temperature: 20°C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whip time (s)</td>
<td>Overrun (%)</td>
<td>Firmness (s)</td>
<td>Serum separation 1 h</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------</td>
<td>-------------</td>
<td>---------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>UHT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No addition</td>
<td>124</td>
<td>135</td>
<td>&gt;12</td>
<td>2.5</td>
</tr>
<tr>
<td>Carrageenan</td>
<td>126</td>
<td>155</td>
<td>&gt;12</td>
<td>1.0</td>
</tr>
<tr>
<td>Protein/fat/carrageenan</td>
<td>123</td>
<td>150</td>
<td>&gt;12</td>
<td>0.0</td>
</tr>
<tr>
<td>UHT + 2.5/1.5 homogenization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No addition</td>
<td>195</td>
<td>145</td>
<td>&gt;12</td>
<td>6.2</td>
</tr>
<tr>
<td>Carrageenan</td>
<td>202</td>
<td>150</td>
<td>&gt;12</td>
<td>3.0</td>
</tr>
<tr>
<td>Protein/fat/carrageenan</td>
<td>290</td>
<td>150</td>
<td>&gt;12</td>
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<tr>
<td>2.5/1.5 homogenization + UHT</td>
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<td>No addition</td>
<td>189</td>
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<td>&gt;12</td>
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<td>Protein/fat/carrageenan</td>
<td>233</td>
<td>175</td>
<td>&gt;12</td>
<td>0.0</td>
</tr>
</tbody>
</table>

–, Illegal values (clumpy).
Addition of carrageenan and milk constituents to cream

Fig. 5. Creaming of pasteurized cream (barn feeding) as a function of individual carrageenan fractions (addition of 0.008 and 0.015%). Fat contents in layers of different depth in a cream cup. (Initial fat content 30%, 2-week storage time, storage temperature 7°C.)

Fig. 6. Separation of liquid from whipped cream (pasteurized, barn feeding) after 1 and 2 h as a function of individual carrageenan fractions (addition of 0.008 and 0.015%). (2-week storage time, storage temperature 7°C, cream temperature on measurement 5°C, room temperature 18°C.)
The extreme increases in viscosity by adding kappa-carrageenan alone are unacceptable. Therefore, further studies will be aimed at elucidating whether combinations of kappa- and iota-carrageenan, causing only a moderate increase in viscosity, altogether allow the flow properties of cream to be improved.

From the course of the fat gradients of the varying combinations in Figure 7 it can be seen that, with total carrageenan additions of 0.01% each, again addition of kappa-carrageenan alone caused the lowest degree of creaming, and that all combinations of kappa- and iota-carrageenan yielded better results than the exclusive addition of iota-carrageenan (compare eighth layer).

Figure 8 also presents relatively good results for the foam stability of the whipped product obtained with the combined additives. In measuring capillary viscosity addition of the blends of 0.002% kappa + 0.008% iota, 0.004% kappa + 0.006% iota, 0.006% kappa + 0.004% iota, 0.008% kappa + 0.002% iota, 0.01% kappa and 0.01% iota caused increases in viscosity by 19, 19.4, 36.2, 47.6, 94.4 and 27.6% compared with pure cream. Hence, it is shown that a combination of kappa- and iota-carrageenan increases viscosity to a markedly lesser extent than adding exclusively kappa- and partly even iota-carrageenan. The relatively good results relating to creaming stability and separation obtained with a combination of 0.005% kappa- and 0.005% lambda-carrageenan...
Addition of carrageenan and milk constituents to cream

Fig. 8. Separation of liquid from whipped cream (pasteurized, barn feeding) after 1 and 2 h as a function of varying combinations of carrageenan fractions. (2-week storage time, storage temperature 7°C, cream temperature on measurement 5°C, room temperature 18°C.)

presented in Figures 7 and 8, however, caused an unacceptable high increase in viscosity of 64.4%. The increases in viscosity measured using the carrageenan combinations are, considering their absolute level, altogether not completely comparable to the results obtained for cream using individual carrageenan fractions, as in this case another winter cream had been used.

Discussion

Our earlier electron microscopic investigations showed (20,21) that, with cooled cream, tensions inside the fat globules are caused because crystalline fat is more dense than liquid fat. The fat globule membranes are often not able to withstand the resulting pressure even without any mechanical stress. As a result fat which remains liquid also at low temperatures flows out causing agglomerations that can lead to cream plugs inside the cups. Such a plug cannot be restirred, i.e. separation is no more reversible. With the particularly ‘hard’ palmitic-acid-rich and oleic-acid-poor (Figure 1) fat globules in winter cream, crystallization processes are more pronounced, associated with damage of the fat globule membrane (destabilization). The simultaneously occurring increase in free fat leads to agglomerations of the globules and, hence, to more severe creaming in winter cream compared with summer cream.
These studies as well as earlier investigations (20,22–24) have shown that, independent of the feeding conditions, it is, without using additives, not possible to produce a cream stable for weeks, not separating out, and exhibiting, in addition, good physical properties as a whipped product.

Further, it was shown that addition of carrageenan has to be considered as the most important stabilizing measure. However, if it is intended, independent of the respective fat composition, to completely avoid plug formation in liquid cream without increasing viscosity too much and more severe syneresis processes in the whipped cream, the combined addition of protein–fat powder and carrageenan is indispensable. This is particularly true for the long storage times required for UHT cream partly associated with high storage temperatures. Our studies are in agreement with the results of Kieseker and Zadow (1,25), who found the most satisfactory reduction in fat separation of homogenized UHT cream by using lecithin–carrageenan additions.

An important property of carrageenan of being able to form a stable cream with little tendency towards creaming is its capability of forming complexes with casein (4,26). Here a weak gel state reducing creaming can form without excessively increasing the viscosity of cream (27). As a result of these interactions additions of ~0.008–0.015% suffice already to reduce creaming to a considerable extent. On the other hand, the observed reduction in drainage in the whipped cream product may, besides additional stiffening of the foam lamellae, partly be attributed to the water-binding property of carrageenan.

Selection of appropriate carrageenan fractions is of importance. Carrageenan consists of a blend of polysaccharides with D-galactose, 3,6-anhydro-D-galactose residues and sulphate ester groups, the main fractions kappa-, iota- and lambda-carrageenan differing in the position of the sulphate ester groups in the molecule and the 3–6 anhydrogalactose content (27). Kappa-carrageenan is hot dissolvable, 65°C being necessary for its complete dissolution. On cooling kappa-carrageenan gels in the presence of potassium ions. Lambda-carrageenan is cold dissolvable, does not gel (4) and can only be used as a thickener. Iota-carrageenan is easier to dissolve than kappa-carrageenan and forms thixotropic gels (5). Our experiments showed that kappa-carrageenan is more effective in stabilizing the liquid cream than the other fractions. According to Snoeren (4) this is due to its electrostatic interaction with casein, kappa-casein being mainly involved in this interaction. The addition of kappa-carrageenan may lead to the formation of a thixotropic network in the cream as a consequence of the interaction with casein, as found in milk chocolate (4,28,29).

An increase in viscosity impedes separation of the fat globules. This is certainly true for the lambda-fraction exhibiting exclusively a thickening effect which can be interpreted in terms of polymer-induced (depletion) flocculation. On the other hand, electrostatic bonds lead to the formation of a three-dimensional network by adhesive points (29), which, according to Snoeren (4), can be ascribed to coil/double helix transitions of free tails or loops of carrageenan molecules which are adsorbed on the casein particles. Such a network retards the rising of the fat globules. However, network formation is restricted to kappa- and iota-carrageenan. Our studies have shown that addition
of 0.01% kappa-carrageenan alone increases viscosity too much, but that a blend of 0.004–0.006% kappa- and 0.006–0.004% iota-carrageenan leads to markedly lower degrees of viscosity and, simultaneously, only to a slightly reduced creaming stability. Here, there may exist still better possibilities of optimization, the more so since also lambda-carrageenan exhibits, in spite of lacking gel formation properties, stabilizing abilities as a thickener and kappa-carrageenan fractions of different molecular weight might possibly be used to achieve further improvements. According to Snoeren (4) the chain length of kappa-carrageenan plays an important role in milk or cream reactivity.

It is of importance that the lowest possible carrageenan dose is used. General and uncontrolled usage of hydrocolloids can, in particular, lead to a sensorially worse quality rejected by the consumer; in this case defects in flavour (gluey and cardboard flavour) and in consistency (too creamy) can be expected in liquid cream and in whipped cream on mouth-feeling (tough, swelling). However, addition of selected combinations of carrageenan fractions associated with usage of low proportions of whey proteins (~0.08–0.1%) and high-melting milk fat fractions (~0.1–0.2%) allow the proportion of hydrocolloids to be kept at a low level (~0.01–0.02%) and an excessive increase in viscosity to be avoided.

The effect of the whey proteins, i.e. improvement in quality, can be explained by the fact that added proteins are adsorbed on damaged fat globules forming a kind of protecting zone that prevents agglomeration of fat globules. Under an electron microscope, we have often observed this kind of repair mechanism when we examined cooled and harder mechanically treated cream at 4–6°C (21,22). In the whipped product the stabilizing effect of whey proteins is completely different. When air enters the cream by whipping, small bubbles are formed that are stabilized by a thin coating of whey proteins (30). Adding proteins leads to further stabilization. The next step in the formation of ready-whipped cream is an exchange of fat globules with the whey proteins from the foam-lamellas (30,32). Fat globules adsorb to air bubbles (7,31,32) and the combining substance is free fat from destroyed fat globules having the function of fat bridges. From addition of higher melting fractions to this fat a better stabilization can be expected while too soft free fat rather produces a foam-destroying effect. This also explains the tendency toward increased separation in whipped summer cream with its relatively soft fat.

The homogenization experiments have shown that higher increases in viscosity resulting from clustering of the fat globules can be hardly avoided. Further extremely long whipping times are to be expected. Single-stage homogenization would have an unfavourable effect, because it contributes, in a particular manner, to the formation of fat globule clusters. If homogenization is to be applied, then a two-stage homogenization with low pressures should be chosen, by which these clusters are dispersed (25). However, homogenization always leads, at least partly, to formation of a clean oil-serum interface which rapidly adsorbs surface active proteins from the serum (33). Firm bonding of casein particles to the fat globules (34,35) prevents formation of highly hydrophobic fat globule surfaces during whipping and, hence, their incorporation into the air-serum interface. This leads to long whipping times. As
reported also by Fink and Kessler (36) homogenization following UHT treatment improves the creaming stability compared with reverse handling of cream.

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References


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