Rheological properties of cold and hot filled model cream cheese

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ABSTRACT

A new model for producing cold filled cream cheese was developed. Fresh milk was fermented to pH 4.8 and allowed to drain in a cotton bag over night. The obtained cream cheese base was processed by heating, homogenization, and filling into beakers (hot filled) or alternatively by cooling to 40°C after homogenization and subsequently filled in beakers (cold filled). The rheological properties of hot and cold filled cream cheese were characterized, after two days storage at 4°C, using a penetration test as well as flow curves. Results showed that the peak force of cold filled cream cheese was only ~25% of the hot filled cream cheese, as was the area to peak. The hot filled cream cheese exhibited higher Young's Modulus compared to the cold filled cream cheese as well whereas the latter had a higher initial shear stress and apparent viscosity. Cooling using a scraped surface heat exchanger (SSHE) prior to packaging thus reduced the firmness and modified the texture profile of cream cheese.

INTRODUCTION

Cream cheese is an acid coagulated fresh cheese which is creamy-white, slightly acid-tasting with a mild diacetyl flavour and a smooth consistency. There is a wide variety of cream cheese types with different dry matter and fat content. Full fat cream cheese contains 22%-35% fat, 32-50% dry matter, and 6-10% protein and low fat cream cheese 5-15% fat, 22-32% dry matter and 8-12% protein[1]. The consumption of cream cheese is widespread in North America and Europe (typically in U.K., Germany and France[2]), where it is used as a spread or as an ingredient in cheesecake or in other dessert products

Typically, cream cheese is packaged at temperatures between 65 and 70 °C and cooled in an air tunnel in the final package in order to obtain a desirable structure through maintaining minimal shearing during cooling.

However, from an economic point of view, cooling in an air tunnel has a significant impact on production cost. It is therefore economically interesting to reduce the costs by pre-cooling cream cheese in a heat exchanger as much as the product can tolerate prior to packaging. The effect of pre-cooling on the rheological properties of cream cheese has not been extensively studied. Sanchez *et al.*[3] have looked at the effect of curd cooling rate on double cream cheese. In their study, cream cheese was cooled dynamically to 20ºC or 13ºC in a heat exchanger immediately after homogenization. The consistency and stability of double cream cheese was governed by the extent to which the structure of homogenized curd had been broken down during the dynamic cooling. An increase in curd cooling rate led to a softer cheese with weaker structural organization. At pilot scale, a significant loss of firmness of the final cream cheese has been observed when filling at and/or below 40ºC, with cooling inline after homogenisation[1]. To restore the structure of cream cheese stabilizers can be added to cold filled cream cheese. It has been shown[4] at filling temperatures varying from 20 to 65ºC, that a mix of carrageenan and pectin is well suited for structure reconstruction. During dynamic cooling of cream cheese using a SSHE, carrageenan and pectin interact with proteins and fat globules to affect matrix formation and restore product firmness.

When using rotational rheology on cream cheese, the measuring system will cut a persistent path in the sample. Konkoly *et al*.[5] adopted a Brookfield spiral adapter (Fig.1) to measure the yield stress of commercial cream cheese. As shown in Fig.1 the product is

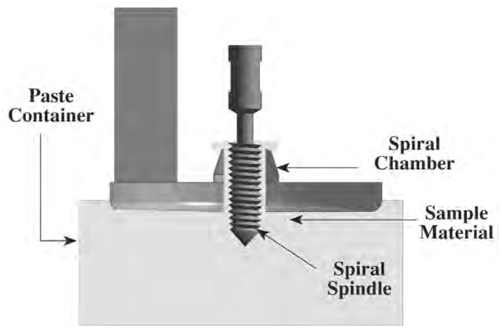

Figure 1. Brookfield spiral adapter cutaway view. The Spiral Adapter has an inner, threaded spindle surrounded by a concentric outer cylinder. The screw is immersed in the sample until the shaft platform rests on the surface of the sample. As the screw rotates at a specified speed, the sample is brought up via the shaft and accumulates in the top of the shaft platform.

continuously transferred to the spiral chamber through the gap between the rotating spindle and the outer cylinder ensuring the material reaches a steady state of flow.

The objective of the present study was to develop a procedure for manufacturing cold filled cream cheese with addition of stabiliser and to characterize the rheological properties of hot and cold filled cream cheese produced from the same batch. The expected product specifications are shown in Table 1.

Table 1. Expected parameters of cold filled cream cheese specifications

Expected value	
Fermentation time	15h
Yield	25%-30%
pH	4.8
Dry matter	30%
Fat	12%-14%
Protein	10%-12%
Fat in dry matter	40%-50%

MATERIALS AND METHODS

Cream cheese base manufacture

Two trials were carried out. In the first trial 24 L of milk (homogenized, commercial milk, Arla Foods, DK) was pasteurized in a fermentation tank at 85 ºC for 15 seconds. The milk was then inoculated with 0.05% O-type starter culture (CHOOZIT™220, 20 DCU/100 L; Danisco A/S, DK) and fermented at 21ºC until a pH value of 4.8 was achieved. The fermented milk was left to drain in a cotton bag over night. In the second trial, the pasteurization time was in prolonged from 15 sec to 15 min; fermentation temperature was increased from 21 ºC to 24 ºC and a second draining step was added to the procedure. Fermentation time was recorded and expelled whey was collected for yield calculations in both trials.

Production of hot and cold filled cream cheese

Cream cheese base was produced as described for the second trial above. It was heated to 50 ºC in Z-arm blender (Danisco A/S, DK) and blended with 0.8% salt and 0.5% stabiliser (GRINDSTED®BK170, Danisco A/S, DK) for 10min. The mixture was then transferred to the SSHE (Danisco A/S, DK) , heated to 72 ºC and homogenized at 150 bar. This was followed by filling in 150ml beakers (hot filled) or cooling (SSHE) to 40°C after homogenization and subsequently filling in beakers (cold filled). All products were stored at 4 ºC until further analysis.

Chemical analysis

From the cream cheese base produced in each trial, 100g sample were taken for chemical analysis (dry matter, pH, fat and protein content)

Visual observation

A wooden spoon was used for testing texture properties. Comments were given on whey separation (dig a hole in sample with a spoon, leave it on the table, and observe after 1 hour), liquefaction (sample becomes liquid without recovery when mixed with a spoon), stickiness, rigidity, spreadability, firmness, mouthfeel and appearance.

Penetration test

The firmness of cream cheese was determined with a Texture Analyser TA-XT2i (Stable Micro Systems, UK); using 1/2 inch cylindrical probe plunged at 0.2 mm/s for 5mm with load 5kg, at 5 ºC (± 2 ºC). The measurements took place directly in the beaker. To avoid side wall effects, the testing point was in the middle of the sample. The force at peak, area to peak and the initial gradient of the graph were takes as indicators of the texture of the sample. Two measurements were made for both hot and cold filled cream cheeses, each time with a new sample.

Flow curves recording

The measurements were carried out in the cream cheese plastic beakers at 5 ºC (± 2 ºC) using a Brookfield MODEL DV-II+ Viscometer (Struers KEBO A/S Denmark) with a Brookfield spiral adapter (no. 70). The analysis was carried out according to the method used in the study of Konkoly *et al.*[5]. The data was recorded manually

RESULTS

Processing parameters and Chemical analysis results

With the prolonged pasteurization time the yield of cream cheese was increased from 31% to 35% (Table 2), due to a greater amount of denatured whey protein being incorporated into the casein matrix which also increased the water binding capacity of the matrix. The additional draining step led to a higher dry matter (30% which was the target value). Although the fermentation temperature was increased to 24 ºC, there was no influence on the fermentation time. There was a tiny leakage of acidified milk from drainage bag during final production of hot and cold filled cream cheese, which may explain the lower yield (26.3%) compared to 35% in the second trial. The fat and protein content all reached the target level.

Visual observation

Hot filled cream cheese was very firm and brittle (fractured surface), very dry texture and grainy. No liquefaction. Cold filled was slightly shinier and white, slightly sticky, and easier to spread, otherwise good consistency, dull curdled aspect, a bit dry mouthfeel, low liquefaction. They both have low whey separation.

Cream cheese firmness

The firmness of hot and cold filled cream cheese was strongly influenced by the filling condition (Table 3). The peak force of cold filled cream cheese was only ~25% of the hot filled, as was the energy needed to reach the same amount of deformation. Moreover, the texture profile curve of cold filled cream cheese has a lower initial slope (Young's Modulus).

Table 2. Results from experiments where the parameters for manufacture cream cheese were changed.

		First trial	Second trial	Final hot and cold filled cream cheese
	Process parameters	85 ºC, 15s Ferment at 21 ºC Once draining	85 ºC, 15min Ferment at 24 ºC Twice draining	85 ºC, 15min Ferment at 24 ºC Twice draining
During process	Fermentation time	14h	14h	14h
	Yield	31%	35%	26.3%
Chemical analysis	Dry matter	28.9%	30%	30%
	pH	4.78	4.77	4.76
	protein	10.9%	11.5%	12.3%
	fat	13%	12.5%	12.9%
	Fat in Dry matter	45%	42%	43%

Table 3: Results from penetration test.

	Force at peak (g)	Area (g• s)	Initial gradient
Hot filled	612.9	9110.1	26.1
Cold filled	152.5	2740.3	13.8

Flow curves

Flow curves of hot and cold filled cream cheese are shown in Fig. 2. Similar curves were obtained from a study of Sanchez *et al.*[2].

The shear stress of cold filled cream cheese only changed slightly at lower shear rates (0.34 to 3.39s^{-1}) and afterwards gradually increased at a level of ~600 Pa, indicating a homogeneous structure with higher viscosity than the hot filled cream cheese. It seems that at the initial low shear rate (0.34s^{-1}), the structure of cold filled cream cheese has already started to breakdown. For the hot filled cream cheese, when the shear rate increased to 1.69s^{-1}, the shear stress dramatically increased and subsequently decreased.

This could be caused by initial shearing of lumps (aggregated from smaller particles) followed by structural breakdown and finally constant shearing of smaller particles

Cold filled cream cheese had a higher apparent viscosity compared with hot filled cream cheese (Fig. 3). The apparent viscosity of both hot and cold filled cream cheese decreased with an increasing shear rate which indicated the shear-thinning behaviour of these two cream cheeses produced from the new model.

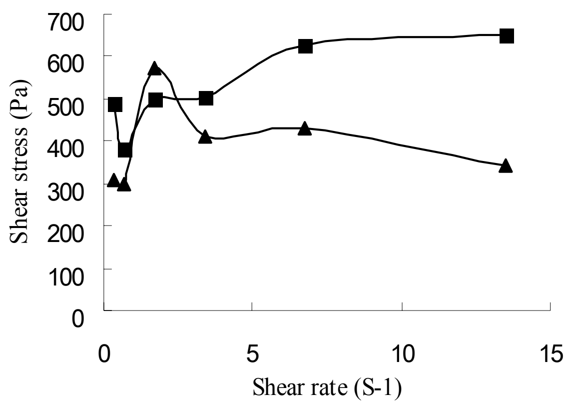

Figure 2. Flow curve of cold filled cream cheese (■) and hot cream cheese (▲). Shear rate ranges from 0.34 to 13. 5s^{-1}. Each line represents the average of two replicates

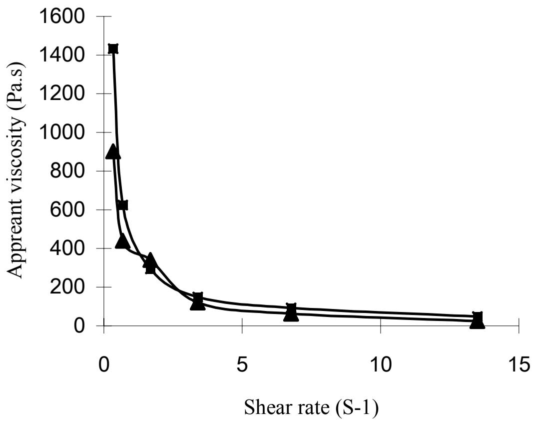

Fig. 3 Change of apparent viscosity of cold filled cream cheese (■) and hot filled cream cheese (▲) with increased shear rate. Shear rate ranges from 0.34 to 13.5s^{-1}**.** Each line represents the average of two replicates.

DISCUSSION

Cream cheese base is a concentrated acidified milk gel mainly composed of a casein matrix associated with denatured whey protein, with embedded fat globules and water. Applying a relatively high pasteurization temperature (~80ºC) will cause a stiffer cheese base, increased cheese yield and less syneresis[6]. A longer pasteurization time (from 15 seconds to 15 minutes) increased the yield in the present study from 31% to 35%. The more intensive heating leads to a greater amount of denatured whey protein attached to the casein micelles through hydrophobic interactions and intermolecular disulphide bonds[7], as a consequence, form filamentous strands on the surface of casein micelles[8]. This ensures an earlier gelation, a denser network structure and less syneresis[6].

An increase in incubation temperature (from 21 ºC to 24 ºC) had an influence on whey separation during draining, presumably due to the formation of a coarser microstructure and larger pores which resulted in a significant increase in permeability of acid milk gel. The fermentation time was not decreased by increasing the fermentation temperature, maybe due to the optimum temperature of the applied starter cultures being in the vicinity of 21 to 23 ºC. The higher temperature, however, appeared to positively affect the draining step, so 24 ºC was chosen as the final fermentation temperature.

When cheese base is heated, it becomes more liquid. The hydrogen bonding decreases and electrostatic repulsion increases with increasing temperature, leading to relaxation of protein-protein bonds and a change to a more liquid-like character[10]. The stabilizer (carrageenan with additional pectin) was added at 50 ºC to the molten cream cheese. This will cause formation of new bonds between carrageenan, pectin and the milk protein matrix, but these bonds will be broken rapidly after heating to 72 ºC and homogenization. The result is disintegration of protein aggregates and a uniform distribution of fat globules. Carrageenans will at this temperature be present on the coil form in cream cheese. With a decrease of temperature, which induces the formation of helices carrageenans start to form a network and interact with the protein matrix. Additionally, pectin will bind water, which may enhance the interaction between the helical form of carrageenan and the protein. Moreover, homogenization will decrease the size of the protein clusters allowing more helices to link. Without any disruption in the system (hot filled), a more compact and stronger gel network will thus be formed and the observed bump in shear stress caused by the need to break the linked network.

If the gel is too warm and therefore still weak when it is subjected to a high shear (e.g. cooling in the SSHE) the structure can be damaged. Loss of firmness of cream cheese filled at temperatures below 50ºC has been found earlier by Liot[5], and a faster cooling rate, involved with mechanical stress, has been shown to soften the texture of double cream cheese[3]. Possibly phase separation occurs in cold filled cream cheese. During cooling in a SSHE, shear breaks the already formed gel into smaller particles.

When the temperature approaches 40 ºC, carrageenan may be present on both coil and helical form in the cream cheese system. Although a certain amount of helices can be assumed to already have interacted with protein clusters, some of these linkages may be disrupted by the applied shearing. Hence, the carrageenan which has not been linked to protein clusters may form a gel prior to the build-up of sufficient protein-carrageenan interactions[11] that subsequently form the continuous phase in cream cheese. Thus, when cooling from 40 ºC to 4 ºC, protein particles will rebuild to a lesser degree in cold filled compared to hot filled cream cheese, and will be dispersed in a hydrocolloid continuous phase. This may then result in a weaker and softer gel but also increase the viscosity of the final product, as has been indicated by the results from the present study.

CONCLUSION

Cold filled cream cheese, cooled to 40°C by SSHE before filling, was successfully produced according to a novel pilot scale procedure. The cooling step reduces the firmness and also modifies the texture profile of cream cheese.

The methods used for analysis of the rheological properties of hot and cold filled cream cheese should be further optimized. For instance, the distance of penetration might be increased in order to gather more information. Moreover, measuring both the up- and downsweep when obtaining flow curves would aid in more precisely characterizing the flow behaviour of cream cheeses.

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