Characterization of Particles in Cream Cheese

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ABSTRACT

Cream cheese is used as a spread and as an ingredient in many food applications. A gritty or grainy mouthfeel is an undesirable textural defect that occurs in cream cheese. However, the factors that cause the textural defect are not well understood. The objectives of this study were to isolate and characterize particles from cream cheese and to study the effect of particles on cheese texture. Particles were isolated by washing cream cheese with water first at 25°C and then at 50°C repeatedly 4 to 5 times. The size of these particles was determined using a particle size analyzer. The particles as well as the original cheeses were analyzed for moisture, fat, protein, ash, and lactose. The particle size ranged of 0.04 to 850 μm . It was found that isolated particles were significantly higher in protein content as compared with the whole cheese. To study the effect on the cheese texture, particles were added at 5, 15, and 25% (wt/wt) levels to smooth cream cheese, and a sensory ranking test was done on the samples. Isolated particles were further separated into 2 size classes of 2.5 to 150 μm and $\geq 150 \mu\text{m}$. These particles were then mixed with smooth cream cheese at 16 and 29% (wt/wt), and a sensory test was conducted on these samples. Smooth cream cheese with only 5% (wt/wt) added particles was perceived as significantly grittier than the control sample. This experiment also revealed that the perceived grittiness increased with increase in amount and size of particles.

(Key words: grittiness, cream cheese)

Abbreviation key: SEM = scanning electron microscopy, TEM = transmission electron microscopy.

INTRODUCTION

Cream cheese has soft, rich, mildly acid flavor and a smooth consistency. It is made from cream or from a mixture of cream and milk or skim milk. Traditionally,

cream cheese mix is pasteurized, homogenized, inoculated with lactic culture, and held at 23°C until it attains a pH of approximately 4.6. The curd is heated to 52 to 63°C, and stabilizers, emulsifiers and salt are added. This mixture is homogenized and is packed either cold or hot. In 2000, the production of cream cheese in the United States was about 312 million kg, and per capita consumption was 1.10 kg (IDFA, 2001).

Typical cream cheese has a smooth texture and is somewhat spreadable at refrigerator temperatures. Cream cheese is used as a spread and as an ingredient in baked goods, desserts, and other food products. In these applications, gritty or grainy cheese texture is an undesirable textural defect. Modler et al. (1989) reported the formation of small hard particles when the cheese was heated at 44 to 63°C for 30 min. These small hard particles were detected by sensory evaluation and also by viewing the cheese under a light microscope. According to Kalab et al. (1975), grittiness in cream cheese may be due to the interactions between protein and various ingredients such as stabilizers and other thickening agents. Kalab et al. (1981) observed a corpuscular microstructure in the finished product when the curd was stirred and homogenized during manufacture. Such corpuscular (particulate) structure was seemingly responsible for the spreadability and smoothness of creamed cheeses (Kalab and Modler, 1985).

Several studies have been reported on the microstructure of different kinds of cream cheese (Kalab et al., 1981; Kalab and Modler, 1985; Xiong and Kinsella, 1991; Sanchez et al., 1996). Kalab and Modler (1985) studied the development of microstructure at each individual stage of cream cheese manufacturing from cultured cream (58% fat) and Queso Blanco curd. They found that the microstructure of the cheese was related to the temperature of coagulation; the microstructure was granular, and the grain size decreased from 5 to 0.5 μm with the decrease in coagulation temperature from 98 to $\sim 76.5^\circ\text{C}$. Harwalkar and Kalab (1980, 1981) observed a characteristic core-and-lining ultra structure of the casein matrix in the curd using scanning electron microscopy (SEM) and transmission electron microscopy (TEM) techniques. The nature of this structure depended on the temperature of coagulation.

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Despite these studies, the specific cause of graininess and how to control graininess in cream cheese is not understood well; specifically, the impact of particle size on the perceived grittiness had not been studied. Therefore, the aim of this study was to isolate and characterize the particles in cream cheese and to determine the

Figure 2. Flow diagram for fractionation of the crude particles to Fraction I and II.

1. The cheese was washed with ~800 mL of deionized water first at 25°C. The water was decanted, and then the cheese was washed at 50°C with deionized water. The suspension was then cooled and held overnight at 10°C, and the top fat layer was decanted. These steps (washing at 25 and 50°C) were repeated 4 to 5 times to obtain good isolation of the particles. The suspensions were then vacuum-filtered through Whatman filter no. 42. The particles isolated were called crude particles.

The crude particles were further separated into 2 size classes 1) 2.5 to 150 μm and 2) ≥150 μm using filters (Figure 2). This was accomplished by making the slurry of the isolated particles with deionized water and filtering it through a USA standard testing sieve (no. 100; Fisher Scientific Co., Texas) with a mesh size of 150 μm. The particles were washed continuously with water to get good separation. The retained particles (Fraction I) were ≥150 μm. The filtrate, which consisted of particles <150 μm, was refiltered using Whatman filter no. 42. The retained particles were called Fraction II.

Analysis of Cheese and Particles

The cheese and the particles were analyzed for TS (990.20), fat (989.04), protein (991.20), and ash (935.42) using standard methods (AOAC, 2000). Lactose was determined by difference for the pilot scale cheese and particles and by enzymatic kit (Kleyn and Trout, 1984) in case of commercial cheeses and particles isolated from them.

The protein profile of the cheese and the particles were determined using a 15% SDS-PAGE gel with a thickness of 0.75 mm. Samples were prepared according to the method described by Gores (1993). The samples were prepared in reducing (mercaptoethanol was used for breaking the disulphide bonds in the protein) and

denaturing (SDS was used for complete unfolding of the native protein structure) conditions, and 20 μL of prepared sample (protein concentration of 0.5 mg/mL) was loaded per well. Electrophoresis of gels was carried out at 80 V for 15 min and at 120 V for the rest of the time. The time for mini gels was 90 to 120 min. Gels were stained for 14 to 16 h using Brilliant blue R concentrate (Sigma Chemical Co., St. Louis, MO) and destained for 2 to 3 h with continuous gentle shaking. Different fractions of the proteins were quantified using imaging densitometer (model GS-700; Bio-Rad, Hercules, CA) and molecular analyst software (version 2.1; Bio-Rad).

The size distribution of the particles in suspension was estimated using a fluid module of Coulter LS230 particle size analyzer (Coulter Corp., Miami, FL). Particle size analysis was carried out on Fraction I as well as on Fraction II. Particle size was measured at obscuration value ≥8% and polarization intensity differential scattering value between 45 and 55%. The pump was run at 40% speed, and the test run length was 60 s.

Scanning electron microscopy was done on gritty cheese manufactured at pilot scale and on the commercial smooth cheese. Cheese samples put in a petri dish (approximately 1 × 1 × 10 mm) were fixed in 2% glutaraldehyde solution for 1 h at room temperature (22°C). The glutaraldehyde solution was then changed, and the samples were stored in new glutaraldehyde solution for 2 d at 4°C. After refrigerated storage, the samples were processed according to McManus et al. (1993). Samples were transferred to liquid nitrogen and cryofractured perpendicular to their long axis. They were then dehydrated in a graded ethanol series followed by fat extraction with Freon 113 (Electron Microscopy Sciences, Fort Washington, PA). After overnight storage in Freon 113 at 4°C, the samples were rehydrated by reversing the graded ethanol series and washed with a 0.1 M sodium cacodylate buffer (pH 7.2) (Acros, NJ). The samples were then postfixed for 2 h with a solution containing 1% OsO₄ (Electron Microscopy Sciences) and 1.5% K₄Fe(CN)₆·3H₂O (Acros). This solution was replaced by a 2% tannic acid (Acros) solution in cacodylate buffer, and the samples were left for 3 h at room temperature. The tannic acid solution was then replaced with the mentioned solution of osmium tetroxide and potassium ferrocyanate, and samples were left for 4 h. This solution was later replaced with an aqueous solution of 1% hydroquinone (Acros), and samples were left overnight. After the heavy metal impregnation, the samples were washed with distilled water, dehydrated in a graded ethanol series, and critical-point dried in a LADD critical-point drier (LADD Research Industries, Inc., Burlington, VT) using liquid CO₂. The samples were sputter-coated using a sputter coater (model Kurt J. Lesker 108;

Table 1. Gross composition (mean $\pm$ SD) on DM basis for the cheeses (moisture content = 55%; $P < 0.05$).

Sample	Fat	Protein	Lactose	Ash
		(%)		
Pilot plant gritty cheese	73.9 $\pm$ 0.16	19.3 $\pm$ 0.48	5.3 $\pm$ 0.35	1.5 $\pm$ 0.03
Commercial gritty cheese	74.4	14.9 $\pm$ 0.07	3.82 $\pm$ 0.10	2.1 $\pm$ 0.03
Commercial smooth cheese	69.3 $\pm$ 0.70	12.7 $\pm$ 0.12	7.2 $\pm$ 1.16	2.8 $\pm$ 0.29

Clairton, PA) for 40 s with platinum, for an approximate thickness of 4 nm.

Samples were viewed in a field emission scanning electron microscope (model S-4000T FESEM; Hitachi Scientific Instruments, Mountain View, CA) operated at 3 kV. Images from each sample, at 1500 $\times$ magnification, from 2 fields were recorded digitally using Spectrum 2.0 software (The Dindima Group Pty. Ltd., Ringwood, Victoria, Australia). Fields were randomly selected from areas of the sample that exhibited planes of fracture of good quality.

Effect of Particles on Grittiness

The effect of particles on the perceived grittiness of cream cheese was studied using sensory evaluation. A 15-member untrained panel was used for 2 different sensory ranking tests. In the first test, samples were prepared by the addition of the particles at 0, 5, 15, and 25% (wt/wt) levels to smooth cream cheese, and the panel was asked to rank them on the scale of 1 (most gritty) to 4 (least gritty). In the second ranking test, Fraction 1 (i.e., $\geq 150 \mu\text{m}$) and Fraction 2 ($< 150 \mu\text{m}$) were added separately at 3 different levels (i.e., no particles [0 g], 1 g of particles in 5 g of smooth cream cheese [16%], and 2 g of particles in 5 g of smooth cream cheese [29%]). The panelists were asked to rank the sample from 1 (most gritty) to 5 (least gritty).

All of the experiments were carried out in duplicate, and analyses were done in triplicate. The results represent the mean values for all of the samples. Statistical analyses were done using Minitab (version 13.1) software program at 95% level of confidence.

RESULTS AND DISCUSSION

The gross compositions of all 3 types of cheeses used in this study are presented in Table 1. The protein

content of the commercial cheeses was significantly lower ($P < 0.05$) than the cheese manufactured at a pilot scale. This may be explained by the presence of salt (no maximum limit indicated in the standard of identity), stabilizers, and emulsifiers (1.8% on DM basis maximum allowed) in the commercial cheeses, which contributed approximately 4.5 to 5% on DM basis. Particles were separated using the method described earlier from the pilot scale cheese as well as commercial gritty cheese. The gross compositions of the particles isolated from both types of cheeses are shown in Table 2.

It was also found that protein content in the isolated particles (from pilot scale cheese and commercial gritty cheese) was significantly higher ($P < 0.05$) than the respective cream cheese samples. Modler et al. (1989) reported that the gritty particles were composed of compacted protein. Our findings about the particle composition help us confirm those findings. There was no significant difference ($P > 0.05$) in the fat content of the particles and the cheeses. The differences in the ash and lactose content between the particles and the cheeses might have been due to the washing procedure used for the separation of the particles. It was also found that there were no significant differences ($P > 0.05$) in the composition of the particles separated from the pilot scale cheeses as well as the commercially obtained gritty cheese. Thus, we were able to establish the similarity in composition of the particles in the pilot scale cheese and commercially made cheese.

The cheese and the particles isolated from them were analyzed for its protein profile using 15% SDS-PAGE gels. The photograph of the gel obtained is shown in Figure 3 and the distribution is presented in Tables 3 and 4.

The main differences or contrasts between the commercial and the pilot scale gritty cheese was that κ -casein was significantly higher ($P < 0.05$) in pilot scale

Table 2. Gross composition (mean $\pm$ SD) for the particles separated from the gritty pilot plant cheese and that obtained commercially ($P < 0.05$).

Particles separated from	Fat	Protein	Lactose	Ash
		(%)		
Pilot scale cheese	72.6 $\pm$ 2.12	22.6 $\pm$ 1.55	4.3 $\pm$ 0.65	0.4 $\pm$ 0.03
Commercial gritty cheese	73.8 $\pm$ 0.77	22.2 $\pm$ 0.19	2.72 $\pm$ 0.10	0.3 $\pm$ 0.03

Figure 3. 15% SDS-PAGE gel for the cheeses as well as particles. Lane 1: Commercial gritty cheese, lane 2: commercial smooth cheese, lanes 3 and 4: pilot scale gritty cheeses, lane 5: gritty particles separated from commercial gritty cheese, lanes 6 and 7: gritty particles separated from pilot scale cheeses.

cheese than in commercial gritty cheese. Gritty cheeses (commercial and pilot scale) were significantly higher ($P < 0.05$) in α - and β -casein fractions as compared with the smooth commercial cheese. There was no significant difference ($P > 0.05$) between the different fractions of protein in the pilot scale cheese and the particles isolated from it. However, the casein fractions (α , β , and κ) were higher, whereas the whey fractions (α -lactalbumin and α -lactoglobulin) were lower in particles as compared with the cheeses. Particles occurring in the commercial gritty cheese were significantly lower ($P < 0.05$) in whey protein fractions, i.e., α -lactoglobulin and β -lactalbumin as compared with the particles occurring in the pilot scale cheese. It was observed (Figure 3, Tables 3 and 4) that the amount of β -lactoglobulin retained in the particles as compared with α -lactalbumin

were higher. This may be due to the interaction of κ -casein and β -lactoglobulin (as reported in the literature earlier) during heating (cooking) of the curd; thus, β -lactoglobulin is more retained in the particles as compared with α -lactalbumin.

Kalab and Modler (1985) reported the size of the particles as approximately 50 μm , whereas Modler et al. (1989) reported that particles ranged from 10 to 100 μm using SEM and fluorescence microscopy techniques, respectively. The particle size distribution for the particles isolated from the pilot scale cheeses and commercial gritty cheese is shown in Figure 4. The size distribution ranged from 0.04 to 850 μm for both the samples, and the mean diameters were 239 and 154 μm for particles from pilot scale and commercial gritty cheeses, respectively. The mean particle size in the commercial

Table 3. Quantification (mean $\pm$ SD) using densitometer for the major fractions of protein in different cheese samples from eluted on 15% SDS-PAGE gels.

Sample	α -Casein	β -Casein	κ -Casein	β -Lactoglobulin	α -Lactalbumin
	(%)				
Commercial gritty cheese	41.7 $\pm$ 0.67	30.9 $\pm$ 2.19	9.8 $\pm$ 0.04	9.6 $\pm$ 0.02	1.9 $\pm$ 0.08
Commercial smooth cheese	29.3 $\pm$ 0.47	25.2 $\pm$ 0.72	11.1 $\pm$ 0.51	12.3 $\pm$ 0.40	3.9 $\pm$ 0.51
Pilot scale gritty cheese (I)	36.2 $\pm$ 2.64	27.9 $\pm$ 0.04	11.1 $\pm$ 0.04	9.7 $\pm$ 0.311	2.7 $\pm$ 0.59
Pilot scale gritty cheese (II)	37.6 $\pm$ 3.07	29.4 $\pm$ 0.44	11.3 $\pm$ 0.39	9.4 $\pm$ 0.61	2.5 $\pm$ 0.87
Milk ¹	38.6	28.4	10.1	9.8	3.7

¹Walstra and Jenness (1984).

Table 4. Quantification (mean $\pm$ SD) using densitometer for the major fractions of protein for the particles eluted on 15% SDS-PAGE gels.

Particles isolated from	α -Casein	β -Casein	κ -Casein	β -Lactoglobulin	α -Lactalbumin
	(%)				
Commercial gritty cheese	35.5 $\pm$ 0.74	32.3 $\pm$ 1.23	11.1 $\pm$ 0.83	8.1 $\pm$ 0.21	1.3 $\pm$ 0.02
Pilot scale gritty cheese (I) ¹	36.8 $\pm$ 1.65	31.1 $\pm$ 1.60	10.1 $\pm$ 0.25	8.6 $\pm$ 0.80	1.5 $\pm$ 0.12
Pilot scale gritty cheese (II)	34.6 $\pm$ 1.78	29.2 $\pm$ 0.80	12.2 $\pm$ 0.41	9.0 $\pm$ 0.68	2.1 $\pm$ 0.13

¹Fractions I and II are the replicates of the cheeses and the particles isolated from them.

Figure 4. Particle size distribution (on volume percentage bases) for the particles separated from commercial gritty cheese and from pilot scale cheese. **Figure 5.** Particle size distribution (on volume percentage bases) for Fraction I (a) and Fraction II (b).

Figure 6. SEM of commercial smooth cheese at a lower magnification. Void spaces (v) result from the moisture extraction.

Figure 8. Details for the microstructure for the commercial smooth cheese. Light arrow points to the void created by the extraction of fat and void spaces (v) from the moisture extraction.

sample was lower than the pilot scale cheeses. This result might have been due to mechanical stirring of the curd at a high speed or homogenization of the curd, which may help in reducing the average particle size of commercial cream cheese. The particle size distribution for Fraction I and Fraction II is shown in Figure 5. The distribution ranged from 1 to 850 μm for Fraction I, with a mean diameter of 322 μm , whereas the distribution for Fraction II ranged from 0.04 to 250 μm , with a mean particle size diameter of 79 μm . These fractions were later used for the sensory analysis. Fraction I particles were filtered using the 150- μm mesh filter. Smaller particles might have attached to the larger size particles and, thus, were retained. Some of the larger-sized particles may be able to pass through the filter because

of their irregular shape and, thus, ended up in Fraction II, which may help to explain the overlapping of the 2 fractions.

Scanning electron microscopy revealed that the smooth cheese had relatively uniform protein matrices (Figure 6), where void space created by moisture extraction is shown by 'v' in the figure. It was found that the cheese consisted of fat globules uniformly dispersed in protein matrix. In contrast, the gritty sample had a coarse structure with compacted protein, which was visible even at lower magnification (Figures 7 and 8). These particles ('p' as represented in the figure) were looked at in greater detail as shown in Figure 9. The particles seem to be embedded in the protein matrix. This matrix seems to be similar to the protein matrix observed in smooth cheese, where fat globules were uniformly dispersed throughout the network. The particle shapes varied from being elongated, near spherical, to irregular (Figures 10 and 11).

Figure 7. SEM micrograph for gritty cheese manufactured at pilot scale. Light arrow points to the compacted protein.

Effect of Particles on the Grittiness of Cheese

In the first sensory experiment, where a 15-member panel was asked to rank the samples from most gritty (rank 1) to least gritty (rank 4), the sample with 25% of the gritty particles added was perceived as the most gritty, and the ranks follow the linear pattern with decrease in the amount of particles added. The results of this study are shown in Figure 12. Interestingly, smooth cream cheese with particles added only at the 5% level was perceived as gritty. In another ranking test (where size as well as amount of particles was varied), panelists were asked to rank the samples from most gritty (rank 1) to least gritty (rank 5). The results

Figure 9. Details of the morphology of the compact particles (p) present in the gritty cheese. Void spaces (v) result from the moisture extraction, and light arrow points to the void created by the extraction of fat.

of this set of experiments are shown in Figure 13. Results show that size and amount of the particles added had a significant effect on the perceived grittiness in

Figure 10. Details for the microstructure for the commercial smooth cheese. Light arrow points to the void created by the extraction of fat and dark arrow towards the microorganism.

the cheese. As the size and amount of particles increased, the mean ranks for perceived grittiness decreased. This shows that the cheese was perceived to be grittier with an increase in amount and size of the particles, which further indicates a low threshold (<5%) for significant grainy perception.

CONCLUSIONS

A method for the isolation of particles from cream cheese was developed. The particles had significantly higher protein concentration compared with the source cheeses. The particles isolated for the pilot scale gritty cheeses were almost identical to the particles isolated from the commercial gritty cheese in their composition,

Figure 11. Detail of the compact particle (p) present in the gritty cheese made at pilot scale.

Figure 12. Average ranks for the samples with added particles (5, 15, and 25%), where 4 = least gritty and 1 = most gritty.

Figure 13. Average ranks for the samples with added particles (16 and 29%; fraction1 and fraction2), where 5 = least gritty and 1 = most gritty.

protein profile, and sizes. Perceived grittiness of cream cheese increases with greater amounts and larger size of the added particles. Subsequent work may be done to get a more detailed understanding of the factors that influence the formation of the particles that contribute to grittiness or graininess and to evaluate conditions that would reduce the perceived grittiness by studying the effects of different processing parameters on grittiness in cream cheese.

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