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COMPOSITION AND MICROSTRUCTURE OF COMMERCIAL FULL-FAT AND LOW-FAT CHEESES

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Abstract

The objective of this study was to analyze the composition of commercial full-fat and low-fat cheeses and to evaluate their microstructure. Commercial cheeses evaluated included full-fat and low-fat Cheddar, Mozzarella, processed, and Swiss cheeses. Cheddar cheeses ranged from 8.2% fat and 51.1% moisture in the 75% low-fat product to 33.2% fat and 35.9% moisture in the full-fat cheese. Mozzarella cheeses ranged in fat from a low of 2.1% to a high of 24% with corresponding moisture content of 56.6 to 45.5% respectively. Fat-free processed cheese had 0.9% fat and 58.7% moisture, while the full-fat cheese had 32.3% fat and 37.4% moisture. Full-fat Swiss cheese had fat and moisture content of 34.8 and 36.7%, respectively. The corresponding values for the low-fat cheese were 27.6 and 40.1%. Total protein content of all cheeses increased with decreasing fat, but the percent increase in protein was less than the percent reduction in fat. The ash content of Cheddar and Swiss also increased with a decrease in fat content. The fat content of cheeses affected the microstructure. Full-fat cheeses for all varieties were characterized by a protein matrix interspersed with fat globules of varying shape and size. Low-fat cheeses had fewer fat globules within the protein matrix, and the globules were usually smaller than in the full-fat cheese. The protein matrix dominated the structure of low-fat cheeses which would explain the firm, rubbery body and texture characteristics.

Key Words: Low-fat cheese, Cheddar cheese, Mozzarella cheese, processed cheese, Swiss cheese, composition, milk fat, microstructure, scanning electron microscopy.

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Introduction

Body and texture are important criteria used to evaluate the quality of hard cheese. According to Bodyfelt *et al.* [5], Cheddar cheese should be firm, smooth, and pliable, and should break down into a smooth, cohesive mass when worked between the thumb and fingers. Milk composition irregularities such as high or low protein or mineral content and improper manufacturing procedures may produce cheese with body and texture defects like weak, corky, rubbery, pasty, etc. [5, 15].

Body and texture, especially of hard cheese, are a reflection of its microstructure. Structurally, cheese is a complex matrix of milk protein, fat, minerals, and other components including water [16, 18]. Cheese variety and composition influence component distribution which in turn largely determines structural characteristics. Hard cheeses such as Cheddar may have up to 39% moisture and at least 50% fat in dry matter (FDM), with the fat globules existing in various shapes and sizes. In this cheese, as in most other hard cheeses, milk protein (mainly casein) is the primary structural material with fat entrapped in the protein matrix.

Mineral content of cheese, calcium in particular, also affects structure [18]. Rate of acid development during the cheese-make process governs the loss of calcium phosphate which in turn determines the size of casein aggregates in cheese. For example, a high-acid cheese such as Cheshire has relatively small protein aggregates whereas a low-acid cheese such as Swiss has larger aggregates. Both these cheeses have distinctly different textures; the former is crumbly and the latter firm and elastic. Low-fat Cheddar cheese made from milk condensed to high solids (22%) has a high mineral content (4.7%) and is extremely firm and crumbly [1].

Milk protein contributes to hardness and milkfat provides smoothness to cheese. The higher the fat content of cheese, the softer the cheese [17], whereas Cheddar cheese made from skim milk is extremely hard and the cheese body does not break down during aging [15]. With increasing consumer interest in low-fat cheese, this structural role of fat bears greater significance as cheese manufacturers attempt to produce low-fat cheese with

Table 1. Commercial cheeses evaluated.

Cheese	Abbreviation
Cheddar cheeses	
1. Full-fat	C
2. 33% low-fat	C33
3. 50% low fat	C50
4. 75% low-fat	C75
Mozzarella cheeses	
5. Full-fat	M
6. Part-skim, low-moisture	PSLMM
7. Fat-free	FFM
Pasteurized processed cheese slices	
8. Full-fat	P
9. 33% low-fat	P33
10. Fat-free	FFP
Swiss Cheeses	
11. Full-fat	S
12. Part-skim	PSS

texture resembling that of full-fat cheese. Additionally, low-fat hard cheeses such as Cheddar, may have a dull surface appearance due to a reduction in the light scattering properties of fat globules [2].

Natural and processed low-fat cheeses with varying degrees of fat reduction (20% or more) are available commercially but a firm, rubbery body is prevalent [1, 10]. To produce low-fat cheese with a smooth body, an understanding of cheese microstructure and the role of fat is essential.

The microstructure of full-fat cheeses has been extensively studied [9, 10, 11, 12, 24], but information on the structure of low-fat cheese is scarce. The objective of this study was to analyze the composition of commercial low-fat and full-fat cheeses and to evaluate their microstructure.

From the regulatory standpoint, the terms low-fat, reduced-fat, lite, fat-free, etc., have specific definitions. In this paper, the term low-fat will be used to refer to all cheeses with less fat than traditional full-fat cheeses.

Materials and Methods

Cheeses

Twelve different full-fat and low-fat cheeses were obtained from retail stores in Brookings, SD (Table 1). The exact age of the ripened cheeses was not known but the Cheddars C, C33, and C50 were labeled as "mild" and C75 was "sharp". Hence, it could be assumed that the former three were in the same age range. The two Swiss cheeses had no indication of age on the label. Three replicates of the above 12 types of cheeses were evaluated for a total of 36 cheese samples. Different codes were selected for each cheese within each replicate to ensure that each replicate was from a separate batch. Immediately after purchase, a portion of each cheese was fixed for scanning electron microscopy (SEM) as described below and the remaining portion was shredded and stored in glass beakers covered with parafilm® (American Can Co., Greenwich, CT) at 4°C. Composition was determined within a week of purchase.

Composition

Fat content was measured by the Mojonnier method [4], total protein by the macro-Kjeldahl method [3], and ash by heating a 0.5 g sample in a muffle furnace at 100°C for 1 hour, 200°C for 2 hours, and 550°C overnight [7]. Moisture was determined with an Ohaus MB200 moisture balance (Ohaus Corp., Florham Park, NJ) [8]. Melting characteristics of the Mozzarella cheeses were analyzed according to Olson and Price [20]. Ten grams of shredded Mozzarella cheese were placed in the bottom of a 32 mm X 200 mm test tube (Corning Products, Corning, NY), packed down to form a plug of constant dimension, and sealed with a no. 6 rubber stopper. The stopper had an air hole to allow gas to escape. The test tube was cooled in a vertical position at 4°C for 30 minutes, then placed horizontally in an oven at 104°C for 60 minutes. Meltability was measured as the distance in centimeters from the bottom of the horizontal test tube to the point where the cheese had stopped flowing.

Microstructure

Cheese samples were prepared for SEM according to modified methods [11, 24]. Cheese samples were cut into approximately 4 mm cubes and immersed in a 1.4% glutaraldehyde fixative (E. Merck Science, Ft. Washington, PA) for 30 minutes. They were washed in 6 changes of distilled water, 30 seconds each change, freeze-fractured in liquid nitrogen, and defatted with chloroform for 60 minutes; 6 changes of 10 minutes each. Samples were then dehydrated in a graded series of ethanol (30 to 100%) and critical-point dried in a Denton DCP-1 critical-point drying apparatus (Denton Vacuum Inc., Cherry Hill, NJ). All fixation processes were conducted at 20 to 22°C. The dried samples were mounted on aluminum stubs with silver paint (E. Merck Science, Ft. Washington, PA), allowed to dry, and coated with 20 nm gold/palladium for 6 minutes in a Hummer VI sputter coater (Technics Electron Microscopy Systems Inc., Munich, Germany). All prepared, fixed samples were stored in a desiccator at 20°C. Samples were viewed in an ISI Super IIIA scanning electron microscope (International Scientific Instruments Inc., Korea) operated at 15 kV. Photomicrographs were taken on a Type 55 Polaroid® 50 ASA film (Polaroid Corp., Cambridge, MA).

Statistical analysis

Composition and melting data were analyzed by analysis of variance using the General Linear Model procedure [22]. Means were separated by Fisher's (protected) LSD at $P < 0.05$ level for all data [23].

Results and Discussion

Composition of cheeses

Various descriptors were observed on the labels of the commercial cheeses e.g., 1/3 less-fat, 50% less-fat,

Table 2. Composition of commercial cheeses (components are given in per cent)[1].

Cheese[2]	Fat	Moisture	Total protein	Ash	FDM[3]	MNFS[4]
Cheddar cheese:						
1. C	33.2[a]	35.9[a]	23.6[a]	3.2[a]	51.8[a]	53.7[a]
2. C33	19.8[b]	44.7[b]	29.7[b]	3.9[b]	35.8[b]	55.7[a]
3. C50	13.2[c]	47.5[c]	32.5[c]	4.3[c]	25.1[c]	54.7[a]
4. C75	8.2[d]	51.1[d]	34.6[d]	4.9[d]	16.8[d]	55.7[a]
Mozzarella cheese						
5. M	24.0[a]	45.5[a]	23.8[a]	3.6[a]	44.0[a]	59.9[a]
6. PSLMM	22.5[b]	46.4[a]	27.0[a]	3.1[a]	42.0[a]	59.9[a]
7. FFM	2.1[c]	56.6[b]	33.5[b]	3.6[a]	4.8[b]	57.8[a]
Pasteurized cheese						
8. P	32.3[a]	37.4[a]	20.5[a]	6.1[a]	51.6[a]	55.2[a]
9. P33	15.2[b]	45.6[b]	23.3[b]	5.7[b]	27.9[b]	53.8[a]
10. FFP	0.9[c]	58.7[c]	23.8[b]	6.6[c]	2.2[c]	59.2[b]
Swiss Cheese						
11. S	34.8[a]	36.7[a]	25.2[a]	2.8[a]	55.0[a]	56.3[a]
12. PSS	27.6[b]	40.1[a]	28.3[b]	3.2[a]	46.1[b]	55.4[a]

[a,b,c,d] Means in columns within cheese types with unlike superscripts differ ($P < 0.05$).
[1] Mean of three replicates. [2] See Table 1 for explanation of cheese symbols.
[3] FDM = Fat-in-dry-matter. [4] MNFS = Moisture-in-non-fat-substance.

part-skim low-moisture, fat-free, and non-fat. With new labeling regulations being implemented in the U.S., these descriptors will change to reflect the fat and calorie content of cheeses in a standardized manner. Fat descriptors under the new laws will include the terms low-fat, reduced-fat, light, fat-free etc. [19]. Composition of full-fat and low-fat cheeses is shown in Table 2.

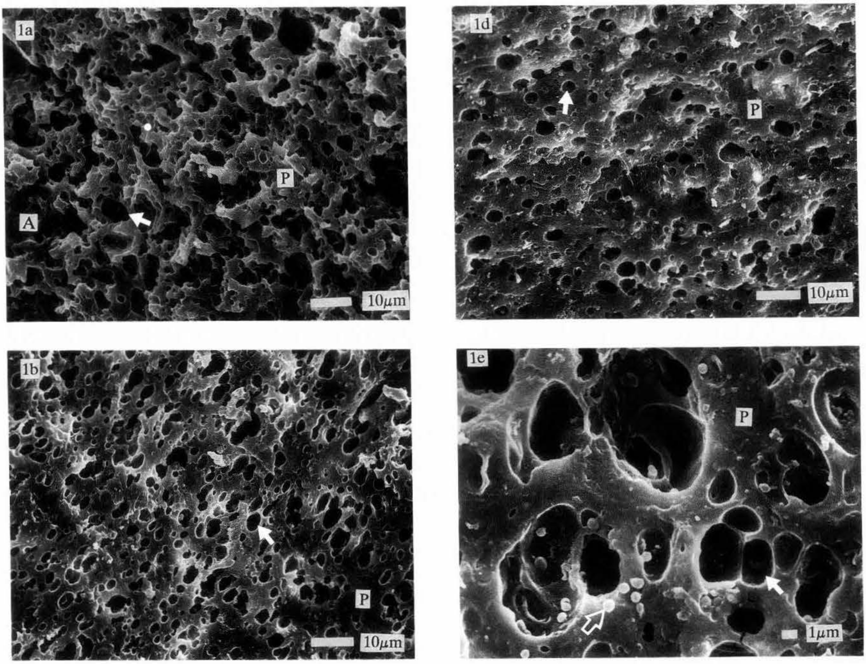
Cheddar cheese. Fat content of low-fat Cheddar cheeses ranged from 8.2 to 19.8%. Compared with C, which had 33.2% fat, this represented a fat reduction of 74.4% for C75 and 40.3% for C33 on an actual fat basis. The C50 cheese had a 60.2% reduction in fat. On a FDM basis, the respective reductions in fat for C33, C50, and C75 were 38.7, 57.0, and 70.5%.

The moisture content of these cheeses increased with decreasing fat content and ranged from 35.9% for C to 51.1% for C75, reflecting up to a 42% increase in C75 over C. The reduction in fat was also compensated for by an increase in protein and ash; C33, C50, and C75 reflected a 25.9, 37.7, and 46.6% increase in protein, and 21.9, 34.4, and 53.1% increase in ash, respectively. This increase in protein was similar to the increase in moisture for each cheese. Consequently, the moisture-in-non-fat-substance (MNFS) values for these cheeses were similar ($P > 0.05$). Lawrence *et al.* [18] have suggested that a good quality Cheddar cheese should have a MNFS value of 52 to 56%. The higher the MNFS value, the faster the flavor development, but flavor quality will decline rapidly after attaining the peak. The MNFS value for all Cheddar cheeses was within the desirable range of 52 to 56%.

Mozzarella cheese. Mozzarella cheese samples, which had no specific percent fat reduction descriptors on the label, ranged in fat from 2.1% for the FFM cheese to 24.0% for the M cheese. On an actual fat basis, PSLMM cheese had 6.5% less fat than the M cheese, whereas on a dry matter basis, fat reduction was 3.8%. Cheese moisture and protein increased significantly in the FFM cheese ($P < 0.05$) but not in PSLMM cheese. The ash content of the three cheeses did not differ ($P > 0.05$). The MNFS values for the Mozzarella cheeses were higher ($P < 0.05$) than those for the Cheddars but did not differ ($P > 0.05$) between the three Mozzarella cheeses.

Processed cheese. The P cheese met legal standards for moisture and FDM. The P33 cheese had a 52.8% fat reduction on an actual fat basis and 45.6% on FDM, whereas the FFP cheese had a 97.4% reduction in fat on an actual basis and 96% on FDM. A 13% increase in protein and 22% increase in moisture were observed in P33 over that in P. Total protein in FFP was similar ($P > 0.05$) to that in P33, but the former had higher moisture and ash, perhaps due to use of additional emulsifiers in FFP. The MNFS in P and P33 were similar but FFP had a significantly higher value ($P < 0.05$) due to the extra moisture required for body.

Swiss cheese. The PSS cheese did not have a specific percent fat reduction value on the label. Actual fat reduction in this cheese was 20.7% (16.3% on FDM basis). Total protein in PSS was significantly higher ($P < 0.05$) than in S, but moisture, ash, and MNFS were not different ($P > 0.05$).



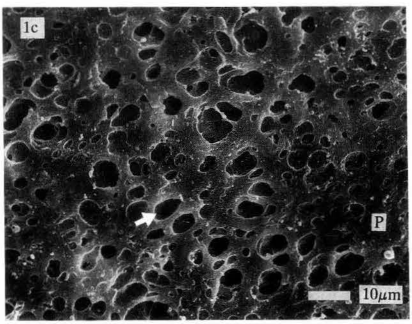


Figure 1. Micrographs of **Cheddar cheeses**: **a)** full-fat (A = aggregated fat globules); **b)** 33% low-fat; **c)** 50% low-fat; **d)** 75% low-fat; and **e)** 33% low-fat (at high magnification showing bacteria, white open arrow). White arrow in each micrograph points to void representing fat globule. P = protein matrix.

Cheese microstructure

When studying the microstructure of cheese it is necessary to extract fat with a solvent such as acetone or chloroform prior to critical point drying [12, 24]. If fat is not extracted, the cheese protein matrix may be obscured and charging may be observed and cause artifacts [13]. In typical scanning electron micrographs of cheese, the protein matrix is visible with evenly distributed open spaces of various shapes and sizes which represent fat globules. Hence, the higher the fat content of cheese, the larger the number of open spaces [11, 12].

Scanning electron micrographs of cheeses evaluated in this study are shown in Figures 1 to 4. All micrographs shown, except Figure 1e, have the same magnification. Within each cheese variety, fat content had a distinct influence on cheese microstructure. Full-fat Cheddar cheese typically had a smooth surfaced protein matrix which appeared to be layered, thereby producing a three-dimensional effect (Figure 1a). A large number of fat globules were evenly distributed within this protein matrix. The fat globule size and shape was variable, producing a "sponge-like" structure. Similar structural characteristics of Cheddar cheese have been reported by others [9, 10, 12, 24, 25].

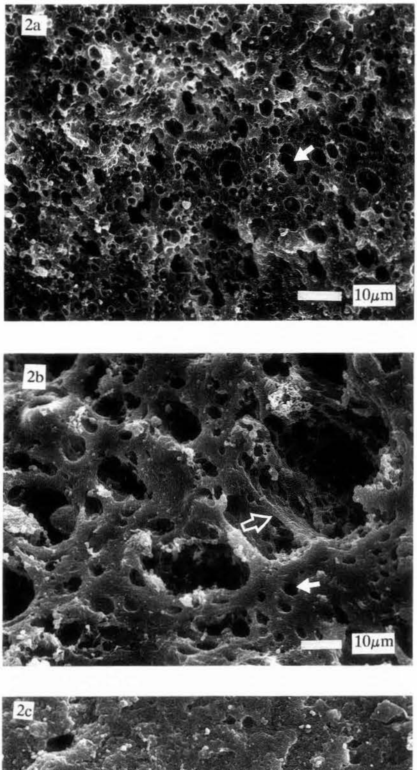


Figure 2. Micrographs of: **a**) full-fat; **b**) part-skim low-moisture (white open arrow points at fibrous protein network indicating stretching); and **c**) fat-free **Mozzarella cheeses**. White arrow in each figure points to void representing fat globule.

As cheese fat content decreased (C33, C50, and C75), the number of fat globules dispersed within the protein matrix also decreased (Figures 1b, c, d). At higher magnifications, bacteria were visible in C33 usually in or near fat globule cavities (Figure 1e). Fat globule shape and size were more uniform in the low-fat Cheddars than in full-fat cheese. Unlike in C, the protein matrix in C33, C50, and C75 was not layered but was flat. The protein matrix in C75, which was manufactured with a protein-based fat substitute, had a rough appearance with residual material (Figure 1d). As the fat content of cheese decreased, the protein matrix became more dense.

It has been commonly observed that low-fat Cheddar cheese has a rubbery, firm body which does not improve with age [1, 21]. These defects become more severe as fat content is further reduced. The body and texture defects of low-fat hard cheese appear to be related to two characteristic features: high moisture and dominating protein matrix. The latter accounts for the firm texture in cheeses that are naturally low in fat e.g., Sapsago which is made from skim milk and has approximately 49% moisture but is extremely hard [15].

The microstructure of full-fat Cheddar cheese has been described as an open and fibrous protein matrix with aggregated fat globules [25]. Milk fat which has a low melting point disrupts the hardness of the protein matrix and provides for the typical smooth texture of Cheddar cheese. In addition, the fat globule membrane may also have an emulsifying effect [26] and contribute to texture. With a decrease in cheese fat content, fat globule aggregation is reduced; hence the protein matrix is not as open as in full-fat cheese and the cheese is firm and rubbery.

It has been suggested that the texture of low-fat Cheddar cheese may be improved by increasing the MNFS value [10]. While an increase in moisture softens a cheese, it does not provide for the smoothness and creaminess of fat and affects the keeping quality due to excessive bacterial growth [1]. Fat substitutes have been used with some success but in an informal sensory evaluation it was observed that the texture of C75 resembled that of C in that the former was not rubbery or corky; however, it was extremely crumbly.

The protein matrix of the M cheese (Figure 2a) was not as open as that of C and resembled that of C33 (Figure 1b). Fat globules were smaller and more uniform in size and shape. Fat globules in PSLMM were larger (Figure 2b), and a large variability in size and shape of these globules was observed. Unlike in M, the protein matrix in this cheese appeared to be fibrous and less compact, perhaps indicating that it is a stretched cheese [11]. There was no indication of stretching in M. The FFM cheese was dominated by a dense rough-surfaced protein matrix interspersed with a few small fat globules. The compact nature of the protein matrix suggested that this cheese was not stretched. The meltability of this cheese was significantly lower ($P < 0.05$) than that of M and PSLMM (Table 3). Meltability is the ability of cheese particles to coalesce into a uniform continuous layer of melted cheese and depends on the FDM [14].

Microstructure of processed cheeses is shown in Figures 3a, b, and c. Processed cheese is made from heated blends of natural cheese, such as Cheddar, mixed with emulsifying salts [15]. Full-fat processed cheese, P, consisted of a flat protein matrix in which fat globules were evenly distributed. Unlike in Cheddar cheese, fat globules in processed cheese were of uniform spherical shape ranging in diameter from 2 to 20 μm (Figure 3a). This structure is typical in an emulsified cheese [6, 24]. In P33, the protein matrix appeared rough (Figure 3b), but due to emulsification salts, the fat globules remained uniform in shape and there were a larger number of small fat globules. Undissolved emulsifying salts or use of excessive emulsifiers may be evident in the micrographs and appear as needle-shaped cracks in the protein matrix (Figures 3b, c). A severe case of this was apparent in FFP (Figure 3c). This 0.9% fat cheese exhibited a dense, rough protein matrix with cracks which in some instances appeared as wide open spaces. Only a few fat globules were visible and they were much smaller than fat globules in the other two cheeses. Irregularly shaped particles, perhaps residues of emulsifiers and stabilizers, were also evident. When high concentrations of emulsifying salts are used, salts such as sodium citrate may not dissolve completely and their needle-shaped crystals are washed out during the cheese fixation steps [6]. Needle-shaped void spaces are left behind in the protein matrix. Crystals of emulsifier salt were not evident in P (Figure 3a).

Part-skim Swiss had a 20% fat reduction over the full-fat cheese (16.3% on FDM), and marked differences in microstructure between the two cheeses were apparent (Figure 4a, b). As in full-fat Cheddar, full-fat Swiss displayed an open, layered protein matrix with irregularly shaped fat globules of varying size. In this cheese aggregation of fat globules was observed also, producing a sponge-like structure (Figure 4a). The protein matrix in PSS was more compact with fewer and smaller fat globules dispersed (Figure 4b). Fat globule aggregation was not as extensive as in the full-fat Swiss.

Conclusions

Low-fat natural and processed cheeses are generally characterized as firm and rubbery. The protein matrix of low-fat cheese dominated the microstructure of these cheeses and was not broken up by fat to the extent that it was in full-fat cheese for all varieties studied. The greater the fat reduction, the larger the influence of protein on cheese structure. Fat globule aggregation was less extensive in the low-fat cheeses. These differences in microstructure due to fat content may help explain the body and texture characteristics of low-fat cheese. To produce a low-fat cheese with acceptable body and texture, the important structural role of fat needs to be mimicked.

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Figure 3. Micrographs of **pasteurized processed cheese slices**: **a**) full-fat (arrow points to fat globule indicating proper emulsification; **b**) 33% low-fat (note compact protein network, P; white open arrow indicates void left by emulsifier salt crystals due to use of high concentrations of emulsifier; and white arrow points at void representing fat globule; and **c**) fat-free (white open arrow points at crack due to emulsifier salts; and white arrow shows pin-holes representing fat globules).

Table 3. Melting characteristics of commercial Mozzarella cheeses[1].

Cheese[2]	Melting characteristics (cm)
M	10.0[a]
PSLMM	10.9[a]
FFM	6.7[b]

[a,b]Means in columns with unlike superscripts differ ($P < 0.05$). [1]Mean of three replicates. [2]M = Full-fat, PSLMM = Part-skim low-moisture, and FFM = Fat-free, Mozzarella type.

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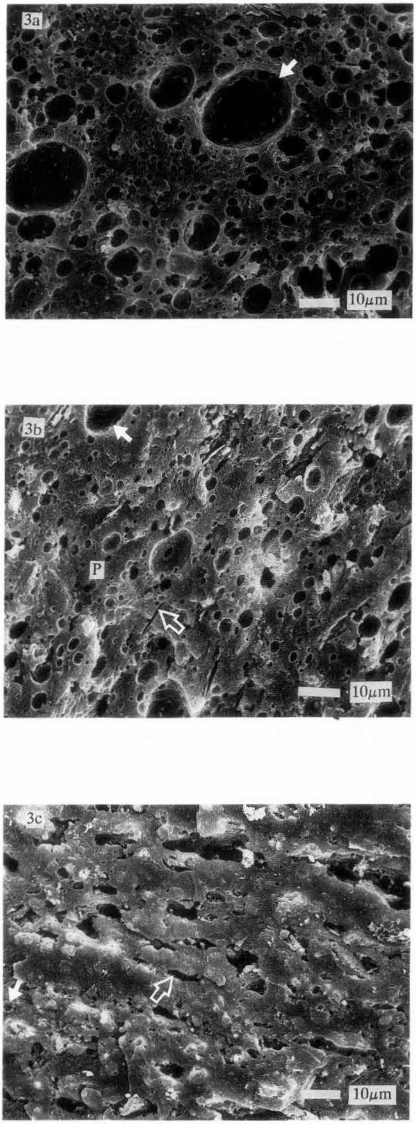

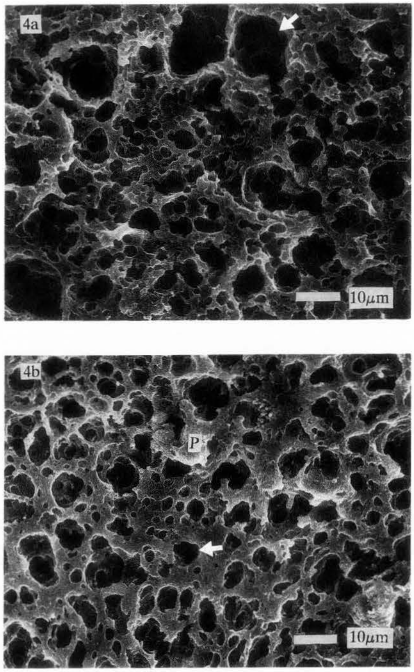

Figure 4. Micrographs of **Swiss cheeses**: **a**) full-fat (white arrow points at aggregated fat globule); and **b**) part-skim (white arrow points at void representing fat globule; note compact protein network, P).

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Discussion with Reviewers

H.D. Goff: You have clearly shown that protein plays an increasingly dominant role in the structure of low-fat cheeses, which is detrimental to their texture, and you suggest that the structural role of fat needs to be mimicked in these cheeses in order to return the texture and structure closer to its original. Figure 1d illustrates the structure of a 75% lower fat Cheddar cheese in which a protein-based fat substitute has been added to improve its texture. Yet the fat substitute appears to be indiscernible in the structure of the cheese. Was the fat substitute successful in modifying the texture of the cheese? How could the microstructure be modified to mimick the structural role of fat if protein-based substitutes are unsuccessful?

Authors: Based on sensory evaluation of this cheese, the substitute was unable to fully mimick the structure of full-fat cheese. On the one hand, C75 did not have the rubberiness of a low-fat cheese but on the other hand it was crumbly and mealy. Modifying the microstructure of low-fat cheese without the use of substitutes is the subject of an ongoing research project and involves a careful balance between fat and MNFS.

P.S. Kindstedt: According to your experimental design, you analyzed 3 samples of each cheese type for a total of 36 cheeses. I assume, therefore, that scanning electron micrographs were obtained from all 36 cheeses. Are the micrographs shown in Figures 1-4 representative of all 3 cheeses within each cheese type or were there any notable differences among the 3 samples of the same cheese type?

Authors: Microstructure shown in Figures 1-4 is indeed representative of all three replicates within each cheese type.

P.S. Kindstedt: The full fat Swiss cheese displayed exceptionally large fat globule aggregates. Was this typical of all 3 of the full-fat Swiss samples? Could you comment on the origin of such advanced aggregation? For example, could it be related to the high cooking temperatures used during the manufacture of Swiss, which might promote greater fluidity, mobility, and aggregation of fat globules during cooking, as occurs in Mozzarella cheese during high temperature stretching?

Authors: The large fat aggregates in Swiss cheese, typical in all three replicates, have been attributed to the high cooking temperature and agitation employed in Swiss cheese making. It has been suggested that fat globules become fragile and lose their initial structure and give large aggregates [Rousseau M, Gallo C Le. (1990). Etude de la structure de l'Emmental au cours de la fabrication, par la technique de microscopie électronique à balayage (Scanning electron microscopic study of the structure of Emmental cheese during manufacture). Lait **70**, 55-66.).

P.S. Kindstedt: You correctly note that the full-fat Mozzarella sample shown in Figure 2a does not exhibit an oriented fibrous microstructure or longitudinal columns or "tunnels" which are typically found in stretched Mozzarella and which appear quite evident in the part-skim Mozzarella (Figure 2b). In addition, the distribution of fat throughout the protein matrix is much more uniform than one normally finds in stretched Mozzarella. Did the other two full fat Mozzarella cheeses that you examined also appear to be "unstretched", and did these unstretched cheeses show any indication of curd granule junctions, as might be expected in this type of Mozzarella?

Authors: All full-fat Mozzarella cheeses appeared to be "unstretched" but curd granule junctions were not evident.

C.J. Oberg: Why does the full-fat cheese protein matrix appear to be layered while the reduced fat cheese does not? Could it be related to fracture or shearing planes during sample preparation?

Authors: The layering effect was probably because of the large amount of fat present in the full-fat cheese (at least 50% FDM in Cheddar). When fat was extracted it left behind cavities some of which were large due to aggregation of the fat globules.

C.J. Oberg: Why are fat globules so much bigger in 50% reduced-fat Cheddar as compared to the full-fat and 33% reduced-fat Cheddar in Figure 1?

Authors: As mentioned earlier, fat globules in full-fat cheese are aggregated and hence provide a three dimensional effect in micrographs. In reality therefore, the fat globules in full-fat cheese are larger than in the low-fat cheeses. When a large number of fields are examined of the 33% and 50% reduced-fat cheeses, it would seem that the fat globule size does vary, hence it may not be appropriate to state that one cheese has larger globules than another. However, micrographs do clearly indicate that as the fat content is reduced, fat distribution is also reduced due to which the protein matrix becomes denser.