Effects of composition and storage on the texture of Mozzarella cheese

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Received 29 August 1990; accepted 4 February 1991

Key-words: Pasta filata, rheology, Instron, low fat, moisture, proteolysis.

Summary

Reducing the fat content in part skim Mozzarella cheese below the US legal minimum of 30 % fat in dry matter still resulted in a product with textural and meltability characteristics comparable to those of a full-fat low moisture Mozzarella. Low fat, high moisture cheese was prepared at 32.4 °C and was refrigerated at 4 °C for several weeks. It is apparent that rennet and starter culture enzymes were not completely deactivated during manufacture and that the proteolysis observed at 4 °C was sufficient to break down the dense casein matrix that is ordinarily present in low fat cheese. Texture Profile Analysis revealed that the values for hardness, cohesiveness, gumminess, springiness, and chewiness in the low fat, high moisture cheese were comparable to those in the full-fat, low moisture cheese. Meltability values were also similar. The results could provide greater insight into the effects of fat and moisture on cheese texture and thus aid the development of new reduced-fat cheese products.

1 Introduction

Consumer demand for reduced-fat dairy products has not abated, spurring research on low fat cheese (1). Much of the recent work in this area has involved Cheddar, which, at 4.3 kg per capita, is consumed more than any other cheese variety in the US (2). The consumption of Mozzarella by Americans has doubled to 2.7 kg per capita since 1981, placing it second to Cheddar (2). Part skim Mozzarella cheese, containing 30-45 % fat in dry matter (FDM), has been available for years; the possibility of reducing the fat content even further has not been reported in the literature. Such results could then be applied to other cheese varieties.

Texture and meltability are the most important functional properties of Mozzarella. Chen et al. (3) performed Texture Profile Analyses (TPA) on 11 common varieties of cheese and found that Mozzarella had a comparatively low value for hardness, but the values for cohesiveness, gumminess, springiness, and chewiness were each in the top three. Any research on reducing the fat content of Mozzarella must take these aspects into account.

Low fat cheese tends to be harder or springier than full-fat varieties (4). The length of refrigerated or frozen storage also affects texture. Kindstedt et al. (5) observed large changes in rheological properties of Mozzarella that was vacuum-packaged and stored at 4 °C for 4 wk. Dahlstrom (6) froze Mozzarella samples for 48 wk and found that they exhibited poor cohesiveness and meltability when evaluated immediately after thawing. When the frozen samples were tempered at 4.4 °C after thawing, optimum values of cohesiveness and meltability were exhibited after 21 days. Cervantes et al. (7) froze samples for up to 1 wk, analysed them immediately after thawing, but did not observe textural defects as measured by hardness, cohesiveness, and fibrousness. Cheese samples tempered for 21 days were not significantly different from samples that had never been frozen.

A comprehensive study of the effects of frozen and refrigerated storage on the texture and meltability of Mozzarella cheese is necessary to determine if the full-fat and low fat varieties have comparable properties. TPA and meltability studies were therefore performed on Mozzarella cheese samples containing various fat and moisture levels and stored under different conditions.

2 Materials and methods

2.1 Experimental design

The experiment was set up as a split-plot design where the main effects were fat and moisture and the subeffects were types of storage. Three replicates of each of the following cheeses were produced: low fat, low moisture; low fat, high moisture; high fat, high moisture; high fat, low moisture. Each batch of cheese was then split into appropriate portions for the storage studies. The data were analysed by the Statistical Analysis System-General Linear Models procedure (8). Interactions and differences are described as significant only when $P < 0.05$.

2.2 Cheesemaking

The US Code of Federal Regulations calls for FDM levels of at least 30 %, but less than 45 %, in part skim Mozzarella, and at least 45 % in whole milk (full-fat) Mozzarella. The moisture content in low moisture cheeses must be greater than 45 %, but no more than 52 %, while full-fat Mozzarella must have greater than 52 % moisture, but no more than 60 % (9). The cheeses were made to meet the standards for moisture and fall below those for FDM. No attempt was made to optimize the moisture level.

The starter culture was CR5, containing 50 % *Streptococcus thermophilus* and 50 % *Lactobacillus bulgaricus*, obtained from Miles Laboratory, Marschall Division, Madison, Wisconsin. The optimum growing temperature is listed as 40-45 °C, with a maximum of 50 °C. The rennet used was single strength #01034, obtained from Chr. Hansen's Laboratory, Milwaukee, Wisconsin. Single herd mixed breed milk was used. The raw milk was warmed to 38 °C, separated in an open DeLaval separator, and standardized with cream or skim milk to the desired fat level before pasteurization at 63 °C for 30 min. Low fat cheese milk was standardized to 1.0 % butterfat. High fat cheese milk was standardized to a range of 3.0-3.7 % butterfat, using 22.5 kg lots per batch of cheese.

High moisture cheese was prepared as follows: A 110 kg batch of milk was heated to 32.4 °C ± 0.5 °C, inoculated with 125 ml of starter culture as provided by the manufacturer and stirred 2 min. The cheese vat was covered 1-1.5 h until the pH dropped 0.1 unit or more, and 4.4 g of rennet was diluted 1:40 in water and added. The milk was stirred for 1 min and allowed to set for 35 min. The curd was cut into 9-10 mm cubes, rested for 15 min, and stirred for 15 min without additional heat. After a 45-60 min hold, half of the whey was drained. After another 30-45 min, the remainder of the whey was removed and the curd was rinsed with 4 l of 33 °C water, ditched, and cut into 8 slabs. After 30 min, the slabs were turned and piled double, and the double slabs were turned every 30 min until the pH dropped to 5.2-5.3. This usually took 1-1.5 h. The slabs were then covered with cheesecloth and iced overnight. The next day, the curd was divided into 8 parts and stretched by hand for about 7 min in 70-80 °C water. The stretched cheese was shaped in 224-ml yogurt cups, cooled under running water, then removed from the cups, brined 2 h in 23 % brine, wiped dry, and packaged individually in vacuum sealed pouches for storage studies.

Low moisture cheese was prepared following the above procedure until 15 min after the curd was cut, when cooking and stirring were started. The temperature was raised to 45.9 °C within 1 h; this temperature was selected as being the highest for cooking curd to induce dryness without completely inactivating the starter culture and retarding further pH development. Half of the whey was drained, and the remainder was drained 45 min later. The curd was rinsed with 4 l of 40 °C water, the circulator temperature was reduced to 40 °C, and the curd was covered with 40 °C water for 30 min. After draining, the curd was handled the same way as in the high moisture procedure, with the exception that the desired pH usually occurred about an hour earlier.

2.3 Analyses

Samples were designated as low fat if they contained less than 25 % FDM; high fat cheeses contained more than 42 %. Cheeses containing less than 52.0 % moisture were designated as low moisture; high moisture samples contained more. Samples were analysed on the last day of storage. Samples designated as fresh were stored at 4 °C for 1 wk before analysis, while samples designated as refrigerated were stored at 4 °C for 6 wk. Frozen samples were stored at –20 °C for 8 wk and then tempered at 4 °C for 3 wk.

TPA were performed on fresh, refrigerated and previously frozen samples in the following way. The cheese sample was removed from the refrigerator and allowed to come to room temperature (1-2 h). The cheese was then cut into a 15-16 mm thick slab using a drill press and two wire cutters designed for this use. Cylinders were then cut from the slab randomly using a 15 mm diameter cork borer. A caliper was used to measure each cylinder three times for thickness; the diameter was measured three times each at both the top and bottom of the cylinder. Average values for cylinder height ranged from 14.5 to 15.2 mm, and average diameter was from 14.2 to 14.7 mm. Three to six samples were tested for each replicate.

The tests were performed at 22 °C ± 1 °C on an Instron Universal Testing Machine Model 4201 (Instron, Inc., Canton, Massachusetts) equipped with a 500 N compression load cell, a Hewlett-Packard HP-86B computer, and an Instron Model 4200 X-Y strip chart recorder. The Instron Cyclic Foam Compression Test Software was used to control the machine during the test. Crosshead speed was 50 mm per min, dwell time was zero seconds, and compression factor was 75 %. Chart speed was set to 500 mm per min. The force versus time curves were digitized using a digitizing pad and Sigma-scan Software (Jandel Scientific, Corte Madera, California) to give force, crosshead travel and peak area data. These data were then analysed into hardness, springiness, cohesiveness, gumminess and chewiness values according to the methods and definitions used by Bourne (10) and Szczesniak (11).

Fat content was determined by the modified Babcock test (12), moisture was determined by using the forced-draft oven method (13), and meltability was examined by the Schreiber test (14). The latter, which assesses meltability by diameter expansion of a cheese disk at 232 °C, produces consistent results (14). However, it is not a standard procedure for evaluating meltability, and comparisons with results obtained by different researchers may be hampered by factors such as heat transfer and temperature gradients (14).

3 Results and discussion

The moisture, fat, and pH levels in the cheeses are shown in Table 1. The results of the TPA and meltability analyses are shown in Figures 1-4. There were significant effects due to fat content on each of the responses. A reduced level of fat results in higher values of each of the textural responses and lower meltability values. Instron measurements by Emmons et al. (4) demonstrated that low fat Cheddar is firmer than full-fat Cheddar, with more cohesiveness and springiness. His electron micrographs showed that reducing the fat content resulted in fewer fat globules, with more casein being deformed per unit volume. Similar effects are apparently present in the low fat Mozzarella in this study.

There were also significant effects due to moisture content on each of the responses. Reduced moisture levels resulted in greater values for hardness, gumminess, springiness, and chewiness; lower values resulted for cohesiveness and meltability (Figs. 1-4). Water in cheese is either free or bound to the protein since fat, the other major constituent, is hydrophobic (15). Decreasing the moisture in a cheese results in a firmer texture due to alterations in the casein matrix. In addition, water can act as either a lubricant or a plasticizer between the different proteins. Lowering the moisture therefore increases the hardness and springiness, along with gumminess and chewiness, while making the cheese less meltable. The lack of water also causes the cheese to be crumblier, which reduces its cohesiveness.

Combined fat and moisture interactions were significant in hardness, gumminess, chewiness, and meltability. Fat content changed these responses more than moisture content, with a synergistic effect causing the differences to become more pronounced as fat and moisture both decreased. The effects of fat and moisture levels on the cheese texture are in agreement with results on Emmental and other Swiss cheeses (16).

There was a significant effect due to storage on all responses except for cohesiveness, with significant differences between fresh and frozen storage,

Table 1. Average moisture, FDM, total fat, and pH levels in prepared Mozzarella cheeses.

Type of Mozzarella	Moisture (%)	FDM (%)	Total Fat (%)	pH
Low fat, low moisture	51.8	23.1	11.1	5.50
Low fat, high moisture	57.4	22.3	9.5	5.31
High fat, low moisture	47.3	47.6	25.1	5.39
High fat, high moisture	52.2	43.9	21.0	5.23

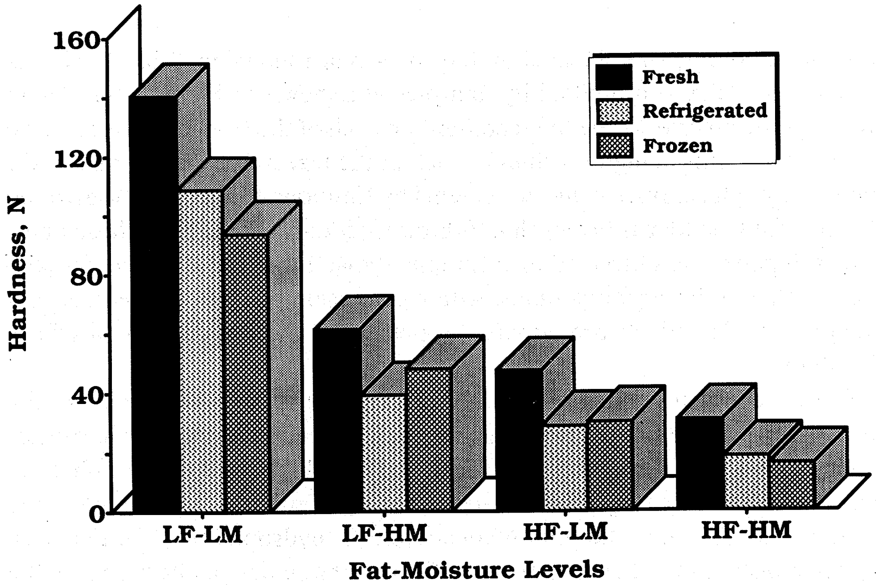

Fig. 1. Effects of fat, moisture, and type of storage on Mozzarella hardness. LF = low fat, LM = low moisture, HF = high fat, HM = high moisture.

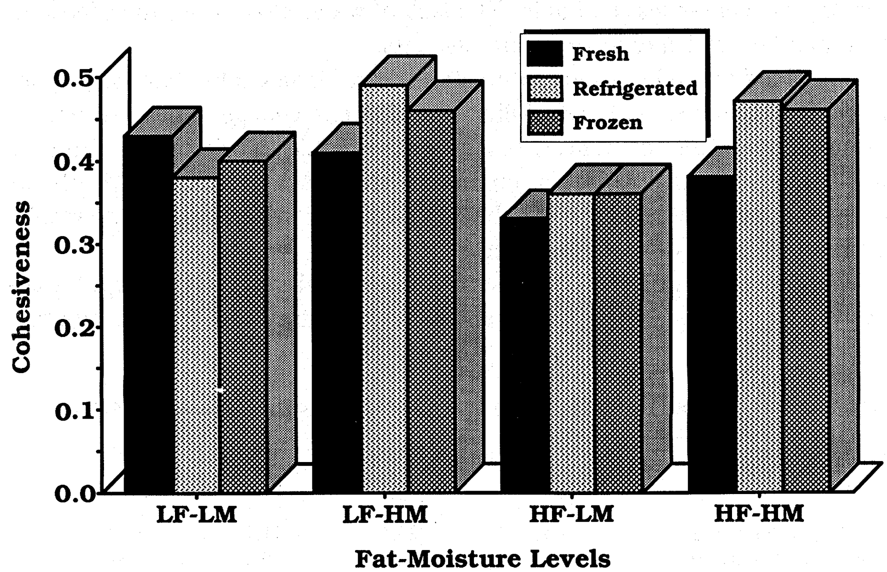

Fig. 2. Effects of fat, moisture, and type of storage on Mozzarella cohesiveness.

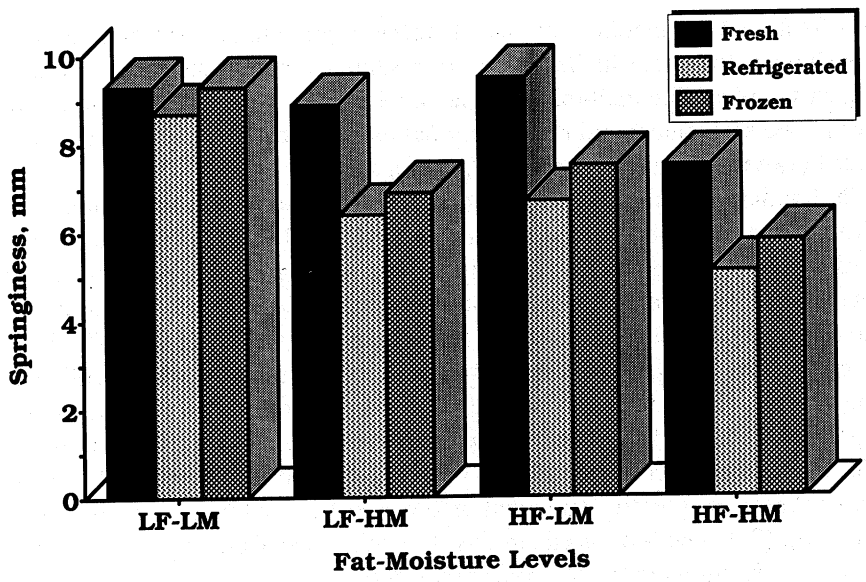

Fig. 3. Effects of fat, moisture, and type of storage on Mozzarella springiness.

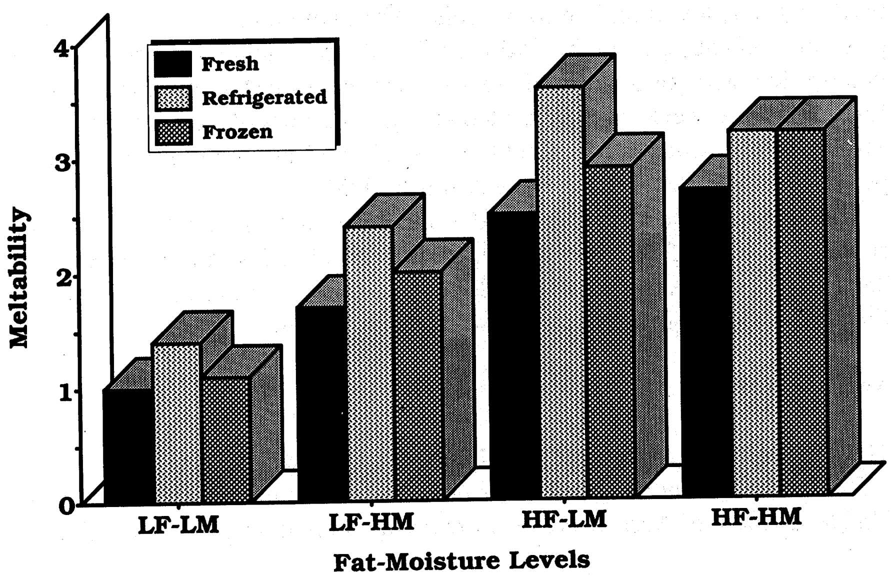

Fig. 4. Effects of fat, moisture, and type of storage on Mozzarella meltability.

and fresh and refrigerated storage. Hardness, gumminess, springiness, and chewiness values were higher in the fresh samples than in the refrigerated or frozen samples. The meltability values were higher in samples that were not fresh. The springiness and meltability data also reflected a significant difference between refrigerated and frozen storage.

Preliminary electrophoretic analyses of low fat, high moisture samples indicated that casein continued to be broken down during storage, accompanied by increases in the number and amounts of bands representing casein fragments. The primary target for proteolysis in cheeses made with rennet is the α_{s1}-casein, with the initial cleavage yielding α_{s1}-I and α_{s1}-II (17). The level of proteolysis in Mozzarella is known to be comparatively low (18,19), but DiMatteo et al. found that almost all of the α_{s1} is broken down into α_{s1}-I and α_{s1}-II (19). This indicates that some rennet activity survives the process of Mozzarella manufacture (20). It has been argued that the rheological properties of cheese are greatly dependent on the moisture content and on the cleavage of α_{s1} (21). The Mozzarella in this study was clearly undergoing proteolysis at 4 °C, resulting in the observed textural changes.

The results indicate that all of the low fat, low moisture Mozzarella cheeses examined in this study are too hard and not meltable enough to be considered comparable to full-fat Mozzarella. However, when refrigerated for 6 wk, the low fat, high moisture cheese does have textural properties similar to those of fresh high fat, low moisture Mozzarella. The proteolysis presumably taking place at 4 °C causes some breakdown of its dense casein structure, resulting in a product with more desirable textural and melting characteristics. Therefore, with a few weeks of refrigerated storage, it is possible to produce a Mozzarella cheese which is comparable texturally and in meltability to an unripened Mozzarella containing twice as much FDM.

The State of Wisconsin specifies that a cheese can be labeled as low fat if it contains at least 33 % less fat than traditional varieties, and no more than 25 % additional moisture (1). The low fat, high moisture cheese prepared in this study would come under this low fat classification.

Acknowledgement

The authors thank Dr John G. Phillips for the statistical design.

Reference to firm or brand name does not constitute endorsement by the US Department of Agriculture over others of a similar nature not mentioned.

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