

OUR INDUSTRY TODAY

Manufacture of Low Fat Mozzarella Cheese Using Exopolysaccharide-Producing Starter Cultures¹

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ABSTRACT

Exopolysaccharide-producing starter cultures, consisting of single strains of *Streptococcus thermophilus* MR-1C and *Lactobacillus delbrueckii* ssp. *bulgaricus* MR-1R, were used to make three trials of low fat (6% fat) Mozzarella cheese. Our aim was to determine whether observations made using small [10-kg (22-lb) capacity] vats with manual stretching of curd could be replicated using pilot-scale [454-kg (1000-lb) capacity] double-O vats with mechanical stirring and stretching of the curd. A control cheese was made using *S. thermophilus* TA061 and *Lactobacillus helveticus* LH100 as starter cultures that did not produce exopolysaccharides. Cheese was measured for moisture content and meltability at d 1. Cheese made with the exopolysaccharide-producing starter cultures had 2% higher moisture contents and exhibited slightly higher meltability. Because of changes in the procedure to manufacture low fat cheese that were necessary when the mechanized vats were used, the cheeses made in the double-O vats were slightly lower in moisture than cheeses previously made in the hand-stirred laboratory-scale vats.

(**Key words:** Mozzarella cheese, low fat, exopolysaccharide, mechanized vat)

Abbreviation key: EPS = exopolysaccharide-producing.

INTRODUCTION

Because of its continued popularity, Mozzarella cheese has been targeted for the low fat and nonfat

cheese market. The pizza industry has played a major role in the increased production of Mozzarella cheese; therefore, the majority of Mozzarella cheese produced must have functional properties that are suitable for pizza production. For use on pizza, Mozzarella cheese should exhibit good shredding, melting, and stretching properties and be free of off-flavors or textural defects (6).

The removal of fat in low fat Mozzarella cheese can result in cheese that is low in moisture, giving the cheese poor melting and stretching properties (8). There are various strategies that have been used to increase moisture content of lower fat Mozzarella cheeses. Merrill et al. (9) used higher pasteurization conditions (175°F for 29 s) to denature some of the whey proteins and increase the water-holding capacity of the cheese curd. They also used preacidification of the milk to pH 6.0 to shorten the manufacturing time, cut the curd into larger pieces than normal, and minimized stirring to reduce curd syneresis. Such modifications are effective on a laboratory scale but are not always suitable for practical application by cheese manufacturers. The use of fat replacers has also been suggested; McMahon et al. (7) reported on how microparticulated ingredients can be used to increase cheese moisture content. Another approach (14) is to take advantage of the natural properties of some strains of cheese starter cultures to retain more moisture in the cheese.

Exopolysaccharide-producing (EPS) lactic acid bacteria (commonly called ropy or slime-producing cultures) have been used in fermented dairy products, such as yogurt and buttermilk, to improve product rheology and slow syneresis by binding free water (1, 3, 4, 5). We have used EPS strains of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* to produce low fat Mozzarella cheese in small-scale, manually-stirred vats (14). Unlike ropy cultures, which release the polysaccharides into the surrounding medium, the EPS cultures that are suitable for cheese making maintain the polysaccharide around the bacterial cells. This capsule of hydrated polysaccharide effectively increases the size of the bacteria up to 5 μ m in diameter. Thus,

Received June 3, 1997.

Accepted September 8, 1997.

¹Contribution Number 5074 of the Utah Agriculture Experiment Station. Approved by the director. Mention of companies or products does not constitute endorsement by Utah State University, Utah Agricultural Experiment Station, or Weber State University over similar products not mentioned.

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the polysaccharide coat not only retains moisture, but the increased cell size may also block some of the fusion of the protein matrix that takes place during cooking and stretching (14). Cheese made in the small manually-stirred vats using the EPS cultures retained 3% more moisture (61% versus 58%, respectively) than a control cheese made using non-EPS cultures; the cheese made using EPS cultures also had improved meltability (14).

The object of this study was to determine whether increased moisture percentages in cheese could still be obtained using the EPS starter cultures when the manufacturing procedure (9, 10, 14) for making lower fat Mozzarella cheese was scaled up to represent commercial practice. Instead of using the small 22-lb (10 kg) vats with manual stirring and manual stretching of the curd, cheese was made in 1000-lb (454-kg) double-O vats with mechanical stirring of curd and mechanical stretching of the curd. We also wanted to know how changes made during scale-up of the cheese-making procedure affected the moisture content and meltability of the cheese.

MATERIALS AND METHODS

Starter Cultures

Starter cultures from the Department of Microbiology culture bank at Weber State University (Ogden, UT) were grown separately in Sure Set XL[®] internal pH-controlled medium (Waterford Foods, Millville, UT). Cultures were grown at 42°C (108°F) to a pH of 4.4 1 d prior to cheese making and kept at 6°C (43°F) until used. The streptococci and lactobacilli used as starters were added separately to the milk in each vat. The milk in vat 1 was inoculated with 2.0 L (4.4 lb) each of the non-EPS *S. thermophilus* TA061 and *L. helveticus* LH100. The milk in vat 2 was inoculated with 3.0 L (6.6 lb) each of the EPS *S. thermophilus* MR-1C and *L. delbrueckii* ssp. *bulgaricus* MR-1R. Amounts of starter cultures were selected to provide similar manufacturing times between the vats.

Cheese Manufacture

Skim milk was pasteurized at 80°C (175.5°F) for 29 s and cooled to 13°C (55°F) in the G. H. Richardson Dairy Products Laboratory at Utah State University, Logan. Three replicates of low fat Mozzarella cheese were made using two 1000-lb capacity, open top, vertical-blade double-O vats (Damrow DEC International, Fond DuLac, WI). Each vat was filled with 363 kg (800 lb) of pasteurized skim milk, which was then standardized to 0.6% fat using pasteurized

cream of known fat content. Standardized milk was preacidified to pH 6.3 using acetic acid diluted 1:10 (vol/vol) with distilled water to prevent localized precipitation, and the milk was then heated to 34°C (93°F). After inoculation, the cultures were allowed to ripen for 10 min. Ripened milk was clotted at 34°C (93°F) using 27.2 ml (1 oz) of double-strength Chymax[®] (Pfizer, Inc., Milwaukee, WI) diluted in 270 ml (10 oz) of distilled water.

Curd was cut 25 min after rennet addition using a medium cut speed for 8 to 10 revolutions of the knives. After this cutting regimen, the knives were reversed and set on low speed to provide healing time for the curd. After 15 min of slow agitation, the speed was gradually increased to a high speed over a 15-min period. The curd was then heated to a cooking temperature of 39°C (102°F) over a 10-min period with continued agitation. When a curd pH of 5.4 was reached, the whey was completely drained from the vat, and the curd was moved to the side of the vat. The curd was then salted [1.0% (wt/wt) salt in each vat] and stirred manually. After salting, the curd pH had decreased to 5.2, and the curd was then run through an Alfa-Laval Cooker/Stretcher (Tetra-Pak, Greenwood, IN). The water used for curd stretching had 5% salt added and was maintained at 82°C (180°F). As the cheese emerged from the cooker-stretcher, it was put in 4 × 15 × 4 in (10 × 38 × 10 cm) stainless steel molds and cooled in an ice bath for 1 h. Blocks of cheese were vacuum-packaged and stored at 4°C (40°F).

Cheese Analysis

After 1 d of storage, cheese was analyzed for composition and meltability. Moisture content was measured using a vacuum oven method (15). Meltability was determined using the tube test method (13) with an oven temperature of 110°C (230°F) for 1 h. Fat content was measured using a modified Babcock method (2), and pH was measured using a glass electrode. Differences between moisture content and meltability of cheeses made using EPS and non-EPS cultures were analyzed using Student's *t* test. Significance was declared at $P \leq 0.05$, and tendencies were declared at $0.10 > P > 0.05$.

RESULTS AND DISCUSSION

All cheese had percentages of fat (6.2 to 6.3%) as required for low fat cheese. They also had comparable manufacturing times (180 ± 5 min) and had d 1 pH of 5.22 ± 0.03 . Use of the EPS starter cultures for making cheese significantly increased cheese moisture and had tended to increase cheese meltability (Table 1).

TABLE 1. Mean moisture contents, pH, meltability, and manufacturing time (from cut to stretching) for three replicates of low fat Mozzarella cheese made with exopolysaccharide-producing (EPS) starter cultures and non-EPS starter cultures.

Starter culture	Moisture contents		pH		Meltability		Manufacturing time	
	— (%) —				— (cm) —		— (min) —	
	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE
EPS	57.1	0.35	5.22	0.02	10.6	0.5	183	2
Non-EPS	55.3	0.15	5.22	0.01	9.5	0.1	177	3

Compared with the 3% elevation of moisture content observed when cheese was made in 10-kg (22-lb) vats (14) with manual stirring, the increase in moisture for cheese made using EPS cultures in the 454-kg (1000-lb) double-O vats was only 2%. All of the cheeses made in the double-O vats (with the EPS on non-EPS cultures) were lower in moisture than cheeses made in the smaller vats. This result was expected because the curd was stirred only intermittently in the small vats, and it was relatively simple to keep the curd particles separated. However, the larger volume of curd in the double-O vats made it more difficult to keep the curd suspended in the whey, and more vigorous and constant agitation was required to keep the curd from matting together on the bottom of the vat.

Another problem that was encountered when the experiments were scaled up from 10-kg (22-lb) batches to 363-kg (800-lb) batches was the effect of preacidification of the milk on the properties of the curd. Previously (9, 10, 14), we had preacidified the milk to pH 6.0 when making lower fat Mozzarella cheeses. In preliminary cheese-making trials in the double-O vats, however, it was observed that, if the milk was preacidified to pH 6.0, the curd became quite sticky and would adhere to the agitator blades as the curd was being stirred. The same effect was observed for milk preacidified to pH 6.1 or 6.2.

When milk is coagulated at its normal pH of 6.6 to 6.7, there is a time delay after the initial aggregation and before the casein micelles start to fuse together. This delay allows for the surface of the curd particles to heal, and a thin skin is formed (12) that acts as a semi-permeable membrane controlling movement of components (e.g., water, lactose, and lactic acid) in and out of the curd particles. At a milk pH of 6.0, the process of casein micelle destabilization (initiated by renneting of the milk) has been accelerated to the extent that casein micelle fusion is actively taking place when the curd is cut (10). Consequently, with the agitation required to prevent curd settling in the double-O vats, the low fat curd particles do not heal

or form a nonadhesive skin; instead, they stick to each other and the agitator blades. By preacidification only to pH 6.3, the problem was sufficiently reduced (provided constant agitation was maintained) to allow the low fat cheese to be manufactured without excessive sticking of the curd to the agitator blades or the bottom of the vat.

Although substantial technological differences occurred, the same overall effect on elevation of cheese moisture content was observed when cheese was made using the EPS cultures in small, manually-stirred vats as when the cheese was made using the mechanized equipment. When cheese was manufactured in the double-O vats, constant agitation of the curd was required after cutting to prevent the curd from sticking to the knives and to the bottom of the vat. This constant agitation would have caused more moisture to be lost from the cheese curd than occurred in the 10-kg (22-lb) vats where stirring was minimal. Also, the milk used in the double-O vats was preacidified only to a pH 6.3, rather than to pH 6.0 for cheese made in the 10-kg (22-lb) vats, which increased the time until draining. By scaling up from 10-kg (22 lb) to 363-kg (800 lb), a longer time would be required to drain the larger volume of whey (this situation would be even further exacerbated when making cheese from for example, 40,000 lb of milk). Consequently, the overall manufacturing time was 30 min longer when cheese was made in the double-O vats than that required when cheese was made in the small manually-stirred vats.

When making cheese in the small vats, we had observed (14) a strong correlation between manufacturing time and cheese moisture. By shortening the manufacturing time, more moisture could be retained in the cheese. Given the extended manufacturing times when cheese was made in the double-O vats (compared with the hand-stirred vats), we expected more syneresis of whey from the curd and a cheese with a slightly lower moisture content. However, the elevation of cheese moisture obtained when the EPS cultures are used appears to be independent of overall

moisture content. This result suggests that EPS cultures could be used by a cheese manufacturer to increase cheese moisture content, regardless of the moisture content of the cheese being made using non-EPS starter cultures.

When cheese was made in the 10-kg (22-lb) vats, a 14% increase in cheese meltability was observed when the EPS cultures were used. With the double-O vats, the increase in meltability with use of the EPS cultures was 12% which probably reflects a 2% rather than 3% increase in moisture content. The influence of moisture content of cheese on meltability was also demonstrated by the lower meltability (mean = 10.1 cm) of the cheeses manufactured in the double-O vats than that of the cheeses made in the 10-kg (22-lb) vats (mean = 11.3 cm).

A concern that may be raised about using EPS cultures for cheese making is that the polysaccharide produced by the cultures may be partially lost in the whey rather than being retained in the cheese curd. If a ropy or slime-producing culture is used as suggested by Nauth and Hayashi (11), the loss may be a problem because the polysaccharide produced by the culture is released from the bacterial cells into the surrounding media. However, for *S. thermophilus* MR-1C and *L. delbrueckii* ssp. *bulgaricus* MR-1R, the polysaccharide is maintained as a capsule around the bacterial cells, and only minute amounts of polysaccharide could be recovered from a cell-free extract of the starter cultures (Debra Low and Jeffrey Broadbent, 1997, unpublished data). Furthermore, no visual differences were observed in viscosity or in the appearance of the whey produced using either the EPS or non-EPS starter cultures. Using *S. thermophilus* MR-1C or *L. delbrueckii* ssp. *bulgaricus* MR-1R in the cheese making therefore, would not be expected to cause problems in whey processing.

CONCLUSIONS

Scaling up the size of the cheese manufacturing process using 454-kg (1000-lb) capacity double-O vats required that some changes be made to the small-scale manufacturing procedure for lower fat Mozzarella cheese to avoid sticking of the curd to the agitator blades. Although the procedure used did not exactly duplicate how cheese is made in large 22,727-kg (50,000-lb) capacity vats, it provided a

useful step up from the 10-kg (22-lb) capacity vats for testing the efficacy of using EPS cultures to increase cheese moisture content. Using a starter culture that formed an exopolysaccharide capsule allowed a low fat Mozzarella cheese to be manufactured that had a 2% higher moisture content (and better meltability) than a corresponding low fat cheese made using non-EPS starter cultures. The EPS cultures provided a simple method, apart from changing manufacturing procedures and times, for increasing moisture in Mozzarella cheese making.

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