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Browning of Mozzarella Cheese During High Temperature Pizza Baking[1]

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ABSTRACT

The objective of this study was to evaluate various properties of low browning Mozzarella cheese. Low moisture, part skim type Mozzarella cheese was made using strains of *Streptococcus* spp. and *Lactobacillus helveticus* that release inappreciable amounts of galactose into the cheese curd and was compared with high browning cheese made using cultures that release galactose into the curd. Cheese composition differed only for galactose content. The browning potentials of the cheeses were significantly different. Pizzas were made using 125 g of each cheese type and evaluated for appearance, texture, and flavor by a consumer panel. Panelists could distinguish between pizza samples based on color of the baked pizza, although no differences or preferences based on any of the other criteria were discernible. Both brown and low browned pizza were acceptable by the panelists, indicating that browning of Mozzarella cheese on pizza was not an undesirable property. (**Key words**: Mozzarella cheese, pizza, browning)

INTRODUCTION

Rapid growth of the pizza industry in the US during the past 20 yr has led to a tremendous increase in consumption and production of Mozzarella cheese. Approximately 30% of the nearly 3 billion kg of cheese produced annually in the US is Mozzarella (7), and >70% of this cheese, or about 600 million kg, is used in the manufacture of pizza (2). Because pizza manufacturers require that melted or cooked Mozzarella cheese behave consistently and have specific functional properties, Mozzarella manufacturers are expected to produce cheese that conforms to customer specifications (4). Stretching, oiling off, melting, and browning are considered by pizza manufacturers to be the most important characteristics (2). Because many pizza manufacturers bake pizza at temperatures ≥260°C, the propensity of the cheese to brown excessively has become a particular concern to the Mozzarella industry. Many Mozzarella manufacturers must deliver cheese that will not brown even when cooked at these high temperatures.

We recently isolated *Streptococcus* spp. and *Lactobacillus helveticus* strains that could be used to make low browning Mozzarella cheese (3). The strains used to make this cheese not only are galactose fermenters, but they also do not release free galactose into the curd, as do most Mozzarella cultures. The cheese made with these cultures that do not release galactose contained less galactose and, based on a predictive test, had less browning potential than the control cheese (made with a galactose-releasing *Streptococcus* sp.).

One objective of this study was to determine whether low browning Mozzarella cheese actually browned less during pizza manufacture at high temperature. Because excessive browning on pizza is frequently considered to be a defect (5), a second objective was to assess consumer acceptability of pizzas made with the low browning rather than high browning cheese.

MATERIALS AND METHODS

Cheese Making

Mozzarella cheese (181 kg of milk per vat) was made as described previously (3) using

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two different starter cultures. Two vats of cheese were made for each of the two culture combinations: *Streptococcus* sp. KK-3 was used for the low browning cheese, and *Streptococcus* sp. KK-4 was used for the high browning cheese. Both *Streptococcus* cultures were combined with *L. helveticus* KK-31 in a 1:1 (vol/vol) ratio. Bulk starter cultures were prepared as described previously (3). The cheese was aged for 14 d before use in pizza manufacture.

Tests for Browning

Browning tests for all batches of Mozzarella cheese were performed using a Hunter Tristimulus Colorimeter (model D25-9; Reston, VA) and based on the procedures described by Johnson and Olson (1) as modified by Mukherjee and Hutkins (3). Duplicate cheese samples were cooked for up to 2 min at 232 or 307°C; each color index was determined five times. Analyses of fat and moisture were performed as described previously (3). Differences in Hunter values and cheese composition were compared by the least significance difference test using the SAS program (6).

Pizza Manufacture

Fifteen pizzas were prepared according to procedures described by West et al. (8). Pizzas (30.5 cm diameter) were prepared using ingredients (crusts and tomato sauce) from institutional suppliers. The Mozzarella cheeses were shredded using a food processor, and 125 g of low browning cheese (pooled from duplicate batches) were spread on one-half of each pizza, and 125 g of high browning cheese (pooled from duplicate batches) were spread on the other half to ensure that temperature, crust, or other variables would not affect browning. Each pizza was baked at 296°C in a Lincoln Impinger III conveyer oven (Lincoln Food Service Products, Inc., Fort Wayne, IN) with a residence time of 2.7 min.

Sensory Evaluation

Sensory analysis was conducted using a consumer panel (50 individuals) composed of mainly staff and students from the College of Agricultural Sciences and Natural Resources at the University of Nebraska-Lincoln. After baking, each pizza was cut into equal pieces (approximately 7 × 7 cm, or 50 cm^2). One piece of pizza with each type of cheese was presented to the panelists in randomized order. Pizza was evaluated using a 15-cm structured scale based on appearance and eating quality. Panelists were asked to state their opinions of the appearance on color (very light to very dark), appearance other than color (very undesirable to very desirable), and overall acceptability. Texture, flavor, and overall acceptance were also evaluated. The sensory data were analyzed by the least significance difference test using the SAS program (6).

RESULTS AND DISCUSSION

Cheese Composition

Few significant differences existed in composition of the low and high browning cheeses aged 14 d. Fat content of the two cheese types (made in duplicate) ranged from 43.12 to 43.89% (dry basis), which is within legal standard requirements for low moisture part skim Mozzarella cheese. Moisture ranged from 41.6 to 42.6%, about 3 to 4% less than the legal requirement (>45%) for low moisture part skim Mozzarella cheese. However, moisture did not differ significantly between the two cheese types. For both cheeses, pH was 5.2. Although salt was not determined, the cheeses were brined for identical times, and differences were not expected. The only significant compositional difference between the low browning and high browning cheeses was that the high browning cheese contained nearly five times more galactose (.61 vs. .13%). Lactose concentrations were low in both cheese types (<.1%). These results are similar to those in a previous report (3) in which cheese made with KK-4 (galactose-releasing) contained five to six times more galactose than cheese made with KK-3 (not galactose-releasing). Because the streptococci and lactobacilli used in these studies were both nonproteolytic (3), we attribute the differences in browning to the residual galactose remaining in the curd.

Cheese Browning

Browning of cheese samples was analyzed objectively using the Hunter colorimeter as

TABLE 1. Hunter L*, a*, and b* values for cooked Mozzarella cheese.

Temperature	Time	L*		a*		b*	
		KK-3[1]	KK-4	KK-3	KK-4	KK-3	KK-4
(°C)	(min)						
232	2.0	60.6	58.9	−2.8	−.8	16.8[a]	21.4[b]
307	1.5	56.4[a]	50.0[b]	.2[a]	5.0[b]	19.6	20.0
307	2.0	52.6[a]	38.8[b]	2.8[a]	10.5[b]	20.5[a]	18.0[b]
SE		.90		.58		.61	

[a,b]Means in the same row within each pair with different superscripts differ significantly ($P < .05$).

[1]The KK-3 cheese was made using *Streptococcus* sp. KK-3 and *Lactobacillus helveticus* KK-31, and KK-4 cheese was made using *Streptococcus* sp. KK-3 and *L. helveticus* KK-31.

described previously (3). Previous work in our laboratory (3) demonstrated that the Hunter values L* (a measure of lightness or darkness) and a* (a measure of red to green) were the most relevant indicators of browning. In the present work, average L* values for low galactose samples baked at 232°C for 2.0 min were not significantly ($P > .05$) different from high galactose samples baked at the same temperature and time (Table 1). When the cheeses were baked at a higher temperature (307°C) for 1.5 to 2.0 min, however, differences in L* values were significant ($P < .05$). Cheese made with culture KK-4 had significantly ($P < .05$) lower L* values and were, therefore, darker than cheese made with strain KK-3. The differences in L* values were particularly pronounced at 307°C at the longer cooking time (2 min).

We reported previously (3) that differences in Hunter b* values (a measure of yellow to blue) for cooked cheese made with KK-3 and KK-4 generally were not significant. In the present study, Hunter b* values for low browning KK-3 cheese were significantly ($P < .05$) less than for high browning KK-4 cheese when cooked for 2 min at 232°C but were significantly ($P < .05$) greater at 307°C (Table 1). In contrast, a* values for high browning KK-4 cheese were also significantly ($P < .05$) lower then those for the low browning KK-3 cheese cooked at 307°C (Table 1), but a* values for KK-4 cheese were always greater than for KK-3 cheese.

Sensory Analysis

Sensory analysis results are summarized in Table 2. The only significant parameter was for cheese color; panelists could clearly distinguish between pizzas made with each type of cheese ($P < .05$). Because all of the pizzas were baked in the same oven for the same time and temperature, perceived differences in pizza color and appearance must have been due to the different cheeses and to their respective browning characteristics (Figure 1).

For appearance other than color, means for the low browning sample were not significantly different than for the high browning sample, indicating that appearance based on other cooked cheese characteristics, such as melting or oiling off, were perceived as being very similar for both samples. For overall ac-

TABLE 2. Sensory evaluation of pizza made with low browning and high browning cheeses.[1,2]

Characteristic	KK-3[3]	KK-4
	(cm)	
Color	4.93[a]	9.30[b]
Appearance other than color	9.80	10.54
Overall appearance	9.88	10.63
Texture	8.95	8.86
Flavor	8.91	9.47
Overall acceptability	9.21	9.15

[a,b]Means in the same row with different superscripts differ significantly ($P < .05$).

[1]The color scale ranged from 0 = very light to 15 = very dark; for all other parameters, the scale ranged from 0 = very undesirable to 15 = very desirable.

[2]Values are means of 50 responses.

[3]The KK-3 cheese was made using *Streptococcus* sp. KK-3 and *Lactobacillus helveticus* KK-31, and KK-4 cheese was made using *Streptococcus* sp. KK-3 and *L. helveticus* KK-31.

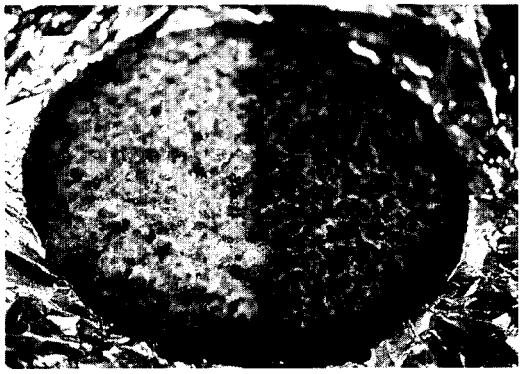

Figure 1. Baked cheese pizza (296°C for 2.7 min) containing low browning (left) and high browning (right) Mozzarella cheeses.

ceptability of appearance, no differences were significant, suggesting that no preference existed toward either low or high browning samples. Importantly, panelists did not perceive the high browning as undesirable, except for a few comments associating high browning with "burnt" color. Means for other cheese characteristics, such as texture, flavor, and overall acceptability, were also not significantly different, indicating that no differences among these attributes were perceived by the panelists.

The browning potential of Mozzarella cheese has become an important quality attribute because of the widespread use of high temperature ovens to bake pizzas. Many pizza manufacturers specify to cheese manufacturers that the cheese have little browning potential. We have demonstrated that low browning cultures can be used to make Mozzarella cheese that browns significantly less than conventional cheese even when it is cooked at nearly 300°C. Although taste panelists could clearly distinguish between pizzas made with low and high browning cheeses, no preferences for low browning cheese were expressed. However, personal preferences may exist that explain the lack of overall preference differences in this study.

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