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Investigating the properties of high-pressure-treated, reduced-sodium, low-moisture, part-skim Mozzarella cheese during refrigerated storage

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ABSTRACT

We proposed that the performance and sensory properties of reduced-Na, low-moisture, part-skim (LMPS) Mozzarella cheese could be extended by the application of high hydrostatic pressure (HHP) to cheese postmanufacture and thereby decrease microbial and enzymatic activity. Fermentation-produced camel chymosin was also used as a coagulant to help reduce proteolysis during storage. Average composition of the LMPS Mozzarella cheeses was 48.6 ± 0.6% moisture, 22.5 ± 0.4% fat, 24.5 ± 0.6% protein, and 1.0 ± 0.1% NaCl. Blocks of cheeses were divided into 3 groups randomly after manufacture and stored at approximately 4°C for 20 wk. The control group was not HHP treated. Two weeks after manufacture, 2 groups of cheese samples were treated with HHP at 500 or 600 MPa for 3 min and then returned to storage at approximately 4°C. Analysis was performed during 20 wk of storage after cheese manufacture. Texture profile analysis (TPA) and dynamic low-amplitude oscillatory rheology were used to monitor cheese functionality. Quantitative descriptive analysis was conducted with 9 trained panelists using a 15-point scale to evaluate texture and flavor attributes of unmelted cheese as well as cheeses melted on pizzas. Pressure treatments at 500 and 600 MPa resulted in approximately 1 and 2 log reduction in the numbers of starter culture, respectively, compared with the control when measured 1 d after HHP treatment. Starter numbers continued to decrease in all cheeses over the 20 wk of storage, but the decrease was larger in the HHP-treated cheeses. Even though the initial numbers of nonstarter lactic acid bacteria were the same in all cheeses, the numbers of these bacteria increased faster in the control cheeses. High-pressure treatment of LMPS Mozzarella cheese resulted in an initial (1 d after HHP treatment) increase in pH, but by 2 wk after HHP treatment there was no statistical difference in pH values between control and HHP-treated samples. Immediately after treatment, HHP-treated cheeses exhibited significantly lower TPA and sensory (unmelted) hardness. However, by 14 wk after pressure treatment, the 600-MPa HHP-treated cheese had significantly higher TPA compared with control or 500-MPa HHP-treated cheeses. Sensory panels also indicated that by 14 wk after HHP treatment, the 600-MPa treated samples were significantly firmer than the control or 500-MPa treated cheeses. Compared with control cheese, cheeses treated at 600 or 500 MPa exhibited lower water-soluble nitrogen values at 6 and 10 wk after pressure treatment, respectively. By 10 wk after pressure treatment, the levels of intact α_{S1}-casein were significantly higher in all HHP-treated cheeses compared with the control. Pizza sensory panels indicated that 600-MPa treated cheese was significantly chewier and exhibited lower blister quantity and higher strand thickness compared with control cheeses. High hydrostatic pressure treatment of low-Na, LMPS Mozzarella cheese could result in the extension of its desired baking characteristics when the cheese is stored at refrigerated temperature.
Key words: high pressure, reduced sodium, camel chymosin, Mozzarella

INTRODUCTION

Low-moisture, part-skim (**LMPS**) Mozzarella cheese is mostly consumed as an ingredient on pizza. Desired performance properties of traditional LMPS Mozzarella cheese are acceptable (optimal) for only a relatively short time period (e.g., 3–4 wk) when stored under refrigeration conditions (~4°C; Kindstedt, 1993). During longer storage, cheese becomes soft and pasty due to casein hydrolysis. Aged cheese becomes excessively fluid when melted. Heat treatment during the cooking and stretching process decreases, but does not eliminate, residual chymosin activity during cheese storage. High cooking temperatures result in higher levels of intact α_{S1}-CN in cheese during ripening (Feeney et al.,

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2002; Lucey et al., 2003). Previous studies suggested that cheese firmness and stretchability were related to the level of intact α_{S1}-CN (Creamer, 1976; De Jong, 1976). Moynihan et al. (2014) investigated the effect of fermentation-produced bovine and camel chymosin on LMPS Mozzarella cheese functionality. They reported that cheeses manufactured with camel chymosin exhibited reduced levels of primary proteolysis compared with cheeses manufactured with calf chymosin. Cheeses made with camel chymosin also maintained desirable unmelted and melted characteristics during 84 d of refrigerated storage.

Several other methods have been investigated to improve performance shelf life of Mozzarella cheese. Bertola et al. (1996) reported that the viscoelastic and sensory properties of Mozzarella cheese could be maintained using frozen storage, although not all researchers agree that freezing produces high-quality cheese (Dahlstrom, 1978; Oberg et al., 1992). Cervantes et al. (1983) reported that the freezing–thawing cycle was a critical parameter affecting the quality of frozen LMPS Mozzarella during storage. However, frozen storage results in extra costs for cheese manufacturers, such as investment in freezing equipment, maintenance costs, and—most important—energy costs. Some manufacturers use individual quick freezing technology for pizza cheese to prevent deterioration of the cheese properties during storage.

High hydrostatic pressure (**HHP**) processing has become popular in the food industry to extend product shelf life and quality. The number of commercial HHP units has dramatically increased over the past 20 yr; correspondingly, the cost of HHP has become more feasible for industrial processing of foods and beverages (Bermúdez-Aguirre and Barbosa-Cánovas, 2011). Textural, rheological, and sensory characteristics of cheeses can be modified with HHP depending on the magnitude of the pressure or holding time treatment (Malone et al., 2003; Ozturk et al., 2013a). Malone et al. (2003) reported that the activity of major glycolytic and proteolytic enzymes (including residual chymosin) was reduced or inhibited with pressures ≥500 MPa, suggesting that HHP could be useful tool to arrest cheese ripening. For example, Evert-Arriagada et al. (2014) reported that 500-MPa HHP treatment of starter-free fresh cheese increased shelf life from 7 to 8 d to 19 to 21 d.

There is a current trend in the food industry to reduce sodium in processed foods (Johnson et al., 2009); some overseas markets also prefer reduced-sodium cheeses. Salt (NaCl) influences the conformation of caseins, final moisture content of cheese, hydration of protein network, as well as microbial and enzymatic activity in cheese (Cervantes et al., 1983; Guinee, 2004). Grant (2011) reported that decreasing the NaCl content of Cheddar cheese caused quality defects, such as soft and pasty texture, lower meltability, and development of off-flavor. These types of defects could be a major quality problem for reduced-Na LMPS Mozzarella cheese, where shredability, meltability, and a clean background flavor are important attributes for its end use (i.e., pizza).

Low-moisture, part-skim Mozzarella cheese generally requires a short aging period at refrigeration temperature (4°C) to attain the desired melt and stretch characteristics when baked on a pizza. Solubilization of Ca associated with the casein in cheese occurs during this time, which results in the physical changes necessary for LMPS Mozzarella cheese to attain the desired machinability and bake characteristics (Johnson and Lucey, 2006). After the desired characteristics are reached, minimizing biochemical changes in the cheese matrix may help extend the shelf life of LMPS Mozzarella cheese. Therefore, we hypothesized that reduced-Na LMPS Mozzarella cheese could be stored at refrigeration temperature (4°C) without loss in quality attributes for more than the normal period of 4 to 6 wk if these cheeses were HHP treated at pressures ≥500 MPa for 3 min.

MATERIALS AND METHODS

Cheese Manufacture

Two licensed Wisconsin cheese makers manufactured 5 batches of reduced-Na LMPS Mozzarella cheeses at the University of Wisconsin–Madison Dairy Plant over a period of 5 wk. Milk was received at the dairy plant 1 d before cheese manufacture. On each manufacturing date, 3 batches of cheese were made in cheese vats sized to hold 272 kg of milk to obtain the required amount of cheese curd. All 3 batches were manufactured with the same make procedure, starter, rennet, and milk supply. Partially skimmed (2.55 ± 0.05% fat) milk was pasteurized at 73°C for 19 s, cooled to 33.3°C, and inoculated with a direct-vat-set thermophilic culture (a blend of *Streptococcus thermophilus* and *Lactobacillus helveticus*; Tempo 303, DSM Food Specialties Cultures USA Inc., Waukesha, WI) at a rate of 23 g/272 kg of milk. Fermentation-produced camel chymosin (Chymax M, Chr. Hansen, Milwaukee, WI) was added to the milk at a rate of 10 g/272 kg of milk 45 min after starter addition. The coagula were cut on firmness (subjectively evaluated by the cheesemaker; pH ~6.5) with 1.9-cm knives about 45 min after chymosin was added. After cutting, the curd was given a 10-min heal time (no stirring), and then the curd and whey were stirred as the temperature of the vats was increased to 41°C over