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Effect of various high-pressure treatments on the properties of reduced-fat Cheddar cheese

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ABSTRACT

A major problem with reduced-fat cheese is the difficulty in attaining the characteristic flavor and texture of typical full-fat versions. Some previous studies have suggested that high hydrostatic pressure (HHP) can accelerate the ripening of full-fat cheeses. Our objective was to investigate the effect of HHP on reduced-fat (~7.3% fat) Cheddar cheese, with the goal of improving its flavor and texture. We used a central composite rotatable design with response surface methodology to study the effect of pressure and holding time on the rheological, physical, chemical, and microbial characteristics of reduced-fat Cheddar cheese. A 2-level factorial experimental design was chosen to study the effects of the independent variables (pressure and holding time). Pressures were varied from around 50 to 400 MPa and holding times ranged from 2.5 to 19.5 min. High pressure was applied 1 wk after cheese manufacture, and analyses were performed at 2 wk, and 1, 3, and 6 mo. The insoluble calcium content as a percentage of total Ca in cheeses were not affected by pressure treatment. Pressure applications ≥225 MPa resulted in softer cheese texture during ripening. Pressures ≥225 MPa increased melt, and resulted in higher maximum loss tangent values at 2 wk. Pressure treatment had a greater effect on cheese microbial and textural properties than holding time. High-pressure-treated cheeses also had higher pH values than the control. We did not observe any significant difference in rates of proteolysis between treatments. In conclusion, holding times of around 5 min and pressures of ≥225 MPa could potentially be used to improve the excessively firm texture of reduced-fat cheese.

Key words: high-pressure processing, reduced-fat cheese, insoluble calcium phosphate, cheese functionality

INTRODUCTION

Cheese flavor development is a complex and time-consuming process that is not fully understood. Proteolysis is one of the most important steps in cheese ripening (McSweeney and Sousa, 2000; Sousa et al., 2001). Several methods have been developed to improve cheese flavor development, such as addition of adjunct cultures, using modified starters, increased storage temperatures, and the addition of exogenous enzymes (Law, 2001). Previous studies indicated that the application of high hydrostatic pressure (**HHP**) to cheese can have a positive effect on cheese ripening, probably as a result of increased starter lysis and the breakage, and only partial reforming, of bonds in the protein matrix (Yokohama et al., 1992; Messens et al., 1997). Yokohama et al. (1992) claimed that HHP treatment of young cheese at 50 MPa for 72 h gave comparable proteolysis rates and flavor development to 6-mo-old conventionally aged Cheddar cheese. Later, O'Reilly et al. (2000) and Saldo et al. (2002) applied similar conditions (50 MPa for 72 h) to Cheddar and goat milk cheeses, respectively, but the increase in the proteolysis was not as significant as the rates suggested by Yokohama et al. (1992). An increase in the proteolysis rate of Camembert cheese (Reps et al., 1998) was observed upon the application of 50 MPa for 4 h. Nevertheless, HHP treatment did not have any significant influence on the proteolysis of Gouda cheese (Reps et al., 1998; Messens et al., 1999). Other authors have studied the use of higher pressures for shorter times. Saldo et al. (2003) treated goat milk cheese at 400 MPa for 5 min and reported that HHP-treated cheese had twice the levels of total free amino acids compared with untreated cheese. However, this HHP treatment (400 MPa for 5 min) decreased lipolysis in this cheese, which was considered an unfavorable effect for goat cheese (Saldo et al., 2003).

Reducing the fat content of cheese significantly changes starter activity, starter lysis, flavor development, flavor release, and texture (Bryant et al., 1995; Carunchia Whetstine et al., 2006). High hydrostatic pressure treatment (100–500 MPa) of half-fat (~15%) Cheddar cheese for 2 h resulted in softer cheese texture and increased meltability (Johnston et al., 2002). It was

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also reported that half-fat Cheddar cheese treated at 200 MPa exhibited the closest textural properties to the full-fat control. On the other hand, the application of 400 MPa for 5 min to reduced-fat Mozzarella cheese did not influence its rheological properties (Sheehan et al., 2005).

Conflicting results have emerged from the various HHP studies; one issue is the different process conditions used. We therefore wanted to explore a wide range of pressures and times to see if we could determine some suitable conditions to improve the quality of reduced-fat Cheddar cheese. We are not aware of any studies on the use of HHP to improve the properties of cheese around this fat level (~7%). The objective of this study was to determine the effect of pressure and holding time on the texture and characteristics of reduced-fat Cheddar cheese.

MATERIALS AND METHODS

Cheese Manufacture

A licensed Wisconsin cheesemaker manufactured 2 independent batches of reduced-fat, milled-curd Cheddar cheeses at the University of Wisconsin-Madison Dairy Plant over a period of 1 yr. Skim milk (0.45 ± 0.15% fat) was pasteurized at 73°C for 19 s, cooled to 32.2°C, and preacidified to pH 6.50 with 25% citric acid solution. The milk was inoculated with a mesophilic mixed-strain starter culture consisting of *Lactococcus lactis* ssp. *cremoris* and *Lactococcus lactis* ssp. *lactis* (LL50; DSM Foods, JH Heerlen, the Netherlands), and starter adjunct *Lactobacillus helveticus* (LH-32; Chr. Hansen Inc., Milwaukee, WI) at the rate of 381 and 9.5 g per 1,672 kg of milk, respectively. Cheese milk was ripened at 33.3°C for 30 min. Annatto (Cheese Color 2×; Chr. Hansen Inc.) was added as colorant right after starter culture addition at the rate 105 mL per 1,672 kg of milk. Double-strength chymosin [Chy-Max Extra; 600 international milk clotting units (IMCU)/mL; Chr. Hansen Inc.] was added at the rate of 142 g per 1,672 kg of milk. The coagulum was cut with 1.9-cm knives and the curd was given a 10-min healing time before cooking. The temperature of the curd-whey mixture was raised from approximately 32 to 34.5°C over 15 min. The curd was held at 34.5°C for 15 min before draining the whey. Curd slabs were cheddared, stacked 2 high, and milled at a pH of approximately 5.9. The curd was rinsed with cold water (~20 L) for 15 s after milling. The curd was salted at the rate of 6.3 kg per 1,672 kg of milk and was packed in 11-kg Wilson-style hoops (35 × 28 × 13 cm) and pressed at ambient temperature until the pH reached about 5.4 (~2 h); then, cheese blocks were vacuum packaged and aged at 7°C.

HHP Treatment

Cheeses were HHP treated 1 wk after manufacture. The conditions used are given in Table 1. The commercial high-pressure unit (Avure Ultra 215 L; Avure Technologies Inc., Kent, WA) has a volume of 215 L and can process up to 150 kg of product per cycle, depending on product size and packaging. The HHP unit can reach pressures of up to 600 MPa, and a complete compression/decompression cycle takes 4 to 5 min, excluding holding time. The machine reached 48 MPa in around 6 s and approximately 400 MPa in around 100 s. Water was used as the pressure-transfer medium. The water temperature of the holding tank of the HHP unit was between 7 to 11°C. An untreated cheese block was used as a control for each trial.

Sampling and Composition Analyses

In several cheese blocks, we observed acid spot defect occurring before the pressure treatment (possibly reflecting localized regions where citric acid was added). After realizing that the data we obtained from these regions were not representative of the remainder of the cheese block, we decided to avoid sampling from these regions. The data received from these regions were excluded in our calculations/results.

The cheese milk was analyzed for fat (Mojonnier method; AOAC International, 2000), protein (total percentage N × 6.38, Kjeldahl method; AOAC International, 2000), casein (AOAC International, 2000), lactose (AOAC International, 2000), TS (Green and Park, 1980), total Ca (Park, 2000), and insoluble calcium (**INSOL Ca**) by the acid-base titration method (Lucey et al., 1993; Hassan et al., 2004). Unacidified milk was used to generate rennet whey (Lucey et al., 1993), which was analyzed for total soluble Ca (Park, 2000). The cheeses were analyzed at 1 mo for moisture (Marshall, 1992), fat (AOAC International, 2000), pH using a pH electrode (Sam Gray gold electrode; Nelson-Jameson Inc., Marshfield, WI; Marshall, 1992), protein by the Kjeldahl method (AOAC International, 2000), and salt by the chloride electrode method (model 926; Corning Glass Works, Medfield, MA; Johnson and Olson, 1985); lactose/galactose and lactic acid contents were analyzed enzymatically (Boehringer Mannheim, 1997; Severn et al., 1986) and total Ca content was determined (Park, 2000). Proteolysis was monitored with water-soluble N and 12% TCA-soluble N (Kuchroo and Fox, 1982). The INSOL Ca contents in cheeses were measured at time points of 2 wk and 1, 3, and 6 mo. Acid-base titrations of the cheeses were performed as described by Lucey et al. (1993). The INSOL Ca contents in cheeses were calcu-