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Low-sodium Cheddar cheese: Effect of fortification of cheese milk with ultrafiltration retentate and high-hydrostatic pressure treatment of cheese

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ABSTRACT

Low-sodium cheeses often exhibit an acidic flavor due to excessive acid production during the manufacturing and the initial stage of ripening, which is caused by ongoing starter culture activity facilitated by the low salt-in-moisture levels. We proposed that this excessive starter-induced acidity could be prevented by the fortification of cheese milk with ultrafiltration (UF) retentates (to increase curd buffering), and by decreasing microbial activity using the application of high-hydrostatic pressure (HHP) treatment (that is, to reduce residual starter numbers). Camel chymosin was also used as a coagulant to help reduce bitterness development (a common defect in low-sodium cheeses). Three types of low-Na (0.8% NaCl) Cheddar cheeses were manufactured: non-UF fortified, no HHP applied (L-Na); UF-fortified (cheese milk total solids = 17.2 ± 0.6%), no HHP applied (L-Na-UF); and UF-fortified, HHP-treated (L-Na-UF-HHP; 500 MPa for 3 min applied at 1 d post-cheese manufacture). Regular salt (2% NaCl) non-UF fortified, non-HHP treated (R-Na) cheese was also manufactured for comparison purposes. Analysis was performed at 4 d, 2 wk, and 1, 3, and 6 mo after cheese manufacture. Cheese functionality during ripening was assessed using texture profile analysis and dynamic low-amplitude oscillatory rheology. Sensory Spectrum and quantitative descriptive analysis was conducted with 9 trained panelists to evaluate texture and flavor attributes using a 15-point scale. At 4 d and 2 wk of ripening, L-Na-UF-HHP cheese had ~2 and ~4.5 log lower starter culture numbers, respectively, than all other cheeses. Retentate fortification of cheese milk and HHP treatment resulted in low-Na cheeses having similar insoluble calcium concentrations and pH values compared with R-Na cheese during ripening. The L-Na-UF cheese exhibited significantly higher hardness values (measured by texture profile analysis) compared with L-Na cheese until 1 mo of ripening; however, after 1 mo, all low-Na cheeses exhibited similar hardness values, which were significantly lower than R-Na cheese. Pressure treatment significantly increased maximum loss tangent (meltability) from rheology testing and decreased melt temperature. Sensory results indicated only very slight bitterness (<2.5 out of 15-point scale) was detected in all cheeses during the 6 mo of ripening. The L-Na-UF-HHP cheese did not significantly differ in bitterness and acidity from R-Na cheese during ripening. Pressures treatment of cheese at 500 MPa and cheese milk retentate fortification could be used to improve the quality of low-Na cheese.

Key words: high-pressure processing, milk retentate, low sodium cheese

INTRODUCTION

Concerns over a possible relationship between dietary sodium intake and cardiovascular disease have led to an effort to reduce salt in processed foods (US Department of Health and Human Services, 2005), although the long-term health effects of high salt consumption have yet to be conclusively demonstrated (Taylor et al., 2011). Reducing salt in cheese is challenging because salt assists manufacturers in controlling various important cheese parameters, including final moisture content, microbial activity, survival of the starter bacteria, and residual enzymatic activity (Johnson et al., 2009). Salt content of cheese also directly influences flavor and texture, with reduced-salt cheeses often reported to be softer, bitter, acidic, and pasty (Guinee, 2004). In addition, salt also has an indirect effect on flavor of cheese through its influence on chymosin activity; decreasing the NaCl levels in cheese facilitates chymosin action on β-CN, and thus the production of hydrophobic peptides from the C-terminal of β-CN (e.g., β-CN f193–209), which are extremely bitter (Kelly et al., 1996).

Several previous studies have investigated the effect of reducing the sodium content and partial or complete replacement of sodium with other salts on the quality of Cheddar cheese. Lindsay et al. (1982) studied Cheddar cheese manufactured with either NaCl or a 1:1 blend of NaCl and KCl at various final salt levels

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(1.25, 1.5, and 1.75%). Cheeses made with NaCl and KCl blends received lower overall acceptability scores and exhibited higher bitterness and lipolysis compared with the cheeses made with NaCl alone (at the same total salt level). Grummer et al. (2013) investigated the partial (60%) replacement of NaCl with KCl with and without flavor enhancers. They reported that low-Na cheeses made with NaCl and KCl blends were well liked by the sensory panelists and were comparable to the control cheese (which contained only NaCl). However, the type of flavor enhancers used either positively or negatively affected the quality of reduced-NaCl cheese. However, unintended consequences may occur for a sizable subpopulation in the United States if KCl is used widely and at high levels, especially because the K content of foods is not generally provided in label information. Adverse cardiac effects (arrhythmias) can result from hyperkalemia, which is a markedly elevated serum level of K in individuals whose urinary K excretion is impaired by a medical condition, drug therapy, or both; instances of life-threatening hyperkalemia have been reported (IOM, 2005). Kosikowski (1983) used a different approach rather than replacing Na, by fortifying cheese milk with UF retentate for the manufacture of reduced-salt (~1%) Cheddar cheese. Control cheese (1% NaCl, with no UF retentate fortification) was acidic, bitter, pasty, and lacked typical Cheddar cheese flavor, whereas cheeses fortified with UF retentate exhibited good to excellent quality, probably due at least partially to their higher pH values.

Application of high-hydrostatic pressure (**HHP**) processing to cheese influences microflora levels, acid development, proteolysis, and protein-protein interactions (Martinez-Rodriguez et al., 2012). Ozturk et al. (2013b) investigated the effect of HHP on regular- (5.3%), reduced- (2.5%), low- (1.9%), and no-NaCl (0.2%) added Cheddar cheeses. One week after manufacture, cheeses were subjected to HHP of ~405 MPa for 3 min. No significant differences were noted in proteolysis, pH values, or sensory profiles of cheeses made with the same NaCl levels. It is known that the effects of HHP on cheese primarily depend on the pressure and time treatment and the age of the cheese when the HHP treatment is applied (Juan et al., 2007). Juan et al. (2007) reported that cheeses that were HHP treated at 1 d had higher pH values than nontreated cheeses, whereas cheeses that were HHP treated at 15 d did not exhibit any pH differences compared with nontreated cheese. This was probably because most lactose was fermented by 15 d of ripening. Previous studies indicated that pressures >400 MPa resulted in lower levels of lactic acid and proteolysis (via decreased residual activity of chymosin and bacterial proteinases; Malone et al., 2003; Juan et al., 2007).

It is generally agreed that the activity of residual coagulant plays a major role in bitterness development in cheese (Guinee and Fox, 2004; Grant, 2011). A novel type of coagulant (i.e., fermentation-produced camel chymosin) that had less residual proteolytic activity in cheese was successfully used to decrease bitterness in low-fat (Govindasamy-Lucey et al., 2010) and low-sodium cheeses (Grant, 2011; Moller et al., 2013). Therefore, we hypothesized that a further reduction in the activity of residual coagulant due to HHP treatment could assist in the production of good-quality low-sodium Cheddar cheese. In the current study, we wanted to investigate a combination of approaches involving cheese milk fortification with UF retentate, along with HHP treatment of cheese, on the properties of low-sodium Cheddar cheeses manufactured with fermentation produced camel chymosin.

MATERIALS AND METHODS

UF of Milk

Raw whole milk was obtained from the University of Wisconsin-Madison dairy plant on 2 d before cheesemaking. Low-concentration-factor UF was performed on whole milk to approximately 27.5% TS (7.7% CN). The low-concentration-factor UF was performed at less than 7°C, by recirculation through a UF unit (modified APV North America Inc., Tonawanda, NY) fitted with 4 spiral-wound, polyethersulfone membranes (model ST3B4338, Synder Filtration, Vacaville, CA). Each membrane had a molecular weight cut-off of 10,000 Da and the total membrane area was 32.8 m^2. The retentates were then stored overnight at 4°C and blended to the specified CN content (4%) and CN-to-fat ratio the following morning to give standardized cheese milks.

Cheese Manufacture

Licensed Wisconsin cheesemakers manufactured 5 independent batches of milled-curd Cheddar cheeses at the University of Wisconsin-Madison dairy processing plant. On each cheesemaking day, 4 square, jacketed stainless steel open cheese vats (Stoelting LV60, Kiel, WI), with a maximum capacity of 272 kg of milk, were used to manufacture 2 salt-in-moisture (**S/M**) level cheeses. Cheese milk (12.4 ± 1.5% TS, 2.4 ± 0.3% CN, 3.7 ± 0.5% fat) in 2 vats were fortified with UF retentate (27.5 ± 1.5% TS, 7.7 ± 0.3% CN, 11.6 ± 0.5% fat) to give blended cheese milk (17.2 ± 0.6% TS, 4.0 ± 0.1% CN, 6.5 ± 0.2% fat). For 2 unfortified vats, 227 kg of cheese milk was used, whereas the 2 UF-fortified cheeses were manufactured with 125 kg of cheese milk. This was done to produce similar final curd weights