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# Effects of sodium chloride salting and substitution with potassium chloride on whey expulsion of Cheddar cheese

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## ABSTRACT

A challenge in manufacturing reduced-sodium cheese is that whey expulsion after salting decreases when less salt is applied. Our objectives were (1) to determine whether changing the salting method would increase whey syneresis when making a lower sodium cheese and (2) to better understand factors contributing to salt-induced curd syneresis. Unsalted milled Cheddar curds were salted using different salting intervals (5 or 10 min), different salting levels (20, 25, or 30 g/kg), different numbers of applications when using only 20 g/kg salt (1, 2, or 3 applications), and salting with the equivalent of 30 g/kg NaCl using a 2:1 molar ratio of NaCl and KCl. Whey from these curds was collected every 5 or 10 min until 30 or 40 min after the start of salting, and curds were subsequently pressed for 3 h. Additional trials were conducted in which salted milled Cheddar cheese curd was immersed at 22°C for 6 h in various solutions to determine how milled curd pieces respond to different levels of salt and Ca. The use of 10-min intervals delayed whey syneresis without influencing total whey expulsion or cheese composition after pressing. Lowering the salt level reduced whey expulsion, resulting in cheeses with higher moisture and slightly lower pH. Adding salt faster did not increase whey expulsion in reduced-salt cheese. Partial substitution with KCl restored the extent of whey expulsion. When salted milled curd was immersed in a 30 g/L salt solution, there was a net influx of salt solution into the curd and curd weight increased. When curd was immersed in 60 g/L salt solution, a contraction of curd occurred. Curd shrinkage was more pronounced as the salt solution concentration was increased to 90 and 120 g/L. Increasing the Ca concentration in test solutions (such that both serum and total Ca in the curd increased) also promoted curd contraction, resulting in lower curd moisture and pH and less weight gain by the curd. The proportion of Ca in the curd that was bound to the *para*-casein protein matrix changed with the Ca content of the test solution. Compared with test solutions containing 10 g/L Ca, at low Ca levels (i.e., 1 and 5 g/L) the proportion of bound Ca was lower, whereas at 20 g/L Ca, the proportion of bound Ca was higher. Both Ca and salt concentration influence the physicochemical properties of the protein matrix such that at low concentrations the curd expands, whereas at high concentrations the curd contracts and expels whey.

**Key words:** cheese, syneresis, salt, potassium

## INTRODUCTION

In cheese manufacture, the process of whey being expelled out of curd is called syneresis (Pearse and Mackinlay, 1989). The rate and extent of syneresis strongly affects mechanical handling during the subsequent cheese-making steps, loss of fat and protein in whey, cheese moisture, ongoing acidification, and proteolysis, and therefore strongly influences cheese composition and quality (Daviau et al., 2000; Dejmek and Walstra, 2004; Everard et al., 2008). Generally, salting of cheese curd promotes syneresis and results in a decreased moisture level (Kindstedt et al., 1992; Pastorino et al., 2003a; Agarwal et al., 2008). With this expulsion of whey, up to 50% of the salt added to curd can be lost, depending on the salting level (Grummer et al., 2013). Reduced-salt cheeses exhibit less syneresis after salting (Johnson et al., 2009) (and therefore have lower salt losses) and have high moisture compared with curd salted at the normal level (Schroeder et al., 1988; Fox et al., 2000; Guinee and Fox, 2004).

When dry salt is applied to milled cheese curd, salt dissolves slowly in moisture on the curd surfaces and forms a thin layer of concentrated salt solution. Osmotic pressure produced by this concentration gradient between the curd surface and the interior of the curd particle provides a driving force for salt and water diffusion (Georgakis, 1973; Guerts et al., 1974; Resmini et al., 1974). Sodium and chloride ions and water molecules can respond by diffusing through the serum phase contained within the protein matrix of curd particles to restore equilibrium (Guinee, 2004; Guinee and Fox, 2004). Based upon the chemical environment, this

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can result in a net movement of water from the curd particles, which is observed as whey syneresis.

Protein solubility plays a role in water movement in cheese by promoting protein matrix shrinkage or expansion (Guo and Kindstedt, 1995; Paulson et al., 1998; Pastorino et al., 2003a; McMahon et al., 2009; Fucà et al., 2012). Sodium and other monovalent ions at low concentration can have a salting-in effect, which causes increased protein solubility and expansion of the protein matrix. At high concentration, a salting-out effect reduces protein solubility, resulting in contraction and dehydration of the protein matrix (Guo et al., 1997; Paulson et al., 1998; Guinee and Fox, 2004; McMahon et al., 2005).

Calcium content of the cheese curd also affects the extent of whey syneresis after salting. Paulson et al. (1998) reported that salting can stop whey syneresis if the curd has a low Ca content. We have also observed that adding $CaCl_2$ as part of the salting can promote syneresis but only when the curd has been manufactured to have a low Ca content (unpublished data). Likewise, injecting Ca into a low-Ca cheese causes shrinkage of the cheese block with concomitant syneresis (Pastorino et al., 2003b). In contrast, adding Ca to milk before cheese manufacture can reduce syneresis of cheese curd (Fagan et al., 2007; Geng et al., 2011). At high Ca levels, cheese develops a more cross-linked, rigid, and less hydrated protein network (Pastorino et al., 2003b; McMahon et al., 2005).

It has been suggested that partial replacement of NaCl with KCl can be used to produce reduced-sodium Cheddar cheese without adversely affecting cheese quality (Lindsay et al., 1982; Fitzgerald and Buckley, 1985; Grummer et al., 2013). Our objective was to determine whether changing the salting method would increase whey syneresis after salting when making a lower sodium cheese. To better understand the factors contributing to salt-induced curd syneresis, a curd immersion test was used to study contraction of the milled curds as influenced by salt and calcium levels.

## MATERIALS AND METHODS

### *Curd Salting*

Unsalted milled Cheddar cheese curd (410 to 420 g/kg moisture, pH 5.4) was obtained from Aggie Creamery (Utah State University, Logan) and divided into 3-kg batches (in the first of 3 trials, 1.5-kg batches were used). Each experiment was conducted in triplicate with fresh curd obtained on separate days for each replicate. Cheese curds were manufactured following the method of Rogers et al. (2010) and milled at pH 5.4.

Curd (34°C) was placed in a plastic container (with lid) and salted using sodium chloride (TFC H.G. Blending salt; Morton Salt Inc., Chicago, IL) and potassium chloride (J. T. Baker, Phillipsburg, NJ) as described in Table 1. The blending salt used is recommended by the manufacturer for salting of Cheddar cheese curd because of its uniform particle size, cubical shape, and the addition of a water-soluble anticaking agent. Whey was collected periodically for about 30 min and the curd reweighed. Curd was then placed in an 18.5-cm-diameter, round, porous plastic hoop. Hoops were placed in a vertical press and pressed at 100 kPa for 3 h at room temperature (~20°C). After pressing, the cheese sample was collected for chemical analysis.

### *Curd Immersion*

A "whey" stock solution for curd immersion tests was prepared from whey that was collected during the cheddaring stage of cheese manufacture after curd pH had decreased to $<6.1$. It was then heated to 72°C for 15 s, cooled to 4°C, 0.2 g/L sodium azide added, and the whey stored at 4°C. Before use it was diluted 1:1 with deionized water (to prevent precipitation of calcium phosphate when additional calcium was added) and then sodium chloride (Morton Salt Inc.) and calcium chloride (J. T. Baker) were added to prepare the test solutions. Salted Cheddar cheese curd (405 g/kg moisture, pH 5.4) and unsalted Cheddar cheese curd (409 g/kg moisture, pH 5.3) were obtained from Aggie Creamery and tested for response to various Ca and Na levels, respectively.

***Different Salt Levels.*** Pieces of unsalted milled Cheddar curd (~100 g) were accurately weighed, placed into plastic container that were filled with 300 g of test solutions containing 30, 60, 90, or 120 g/L NaCl, supplemented with 6 g/L Ca [we had previously found that levels of 5 to 11 g/L Ca in this test solution maintain the insoluble Ca to solids ratio (**Insol Ca/solids**) in cheese curd], adjusted with NaOH to 5.4 (i.e., the pH of salted curd), and then sealed and kept at 22°C. After storing for 6 h, the curd was removed and excess moisture was removed by rolling the curd over a paper tissue; then, the curd was reweighed and tested for moisture, pH, and salt. Adjusted weight change (**AWC**) of curd was calculated as total weight change minus calculated weight of NaCl that had diffused into cheese.

***Different Ca Levels.*** Aliquots of 100 g ± 0.3 g of salted milled curd were accurately weighed and then immersed in 300 g of test solutions per liter containing 15 g of NaCl (to reduce the diffusion of sodium between cheese serum and test solutions), and 1, 5, 10, or 20 g of Ca (added as $CaCl_2$) with pH adjusted with NaOH

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