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Compositional Factors Associated with Calcium Lactate Crystallization in Smoked Cheddar Cheese

P. Rajbhandari and P. S. Kindstedt
Department of Nutrition and Food Sciences, University of Vermont, Burlington 05405-0044

ABSTRACT

Previous researchers have observed that surface crystals of calcium lactate sometimes develop on some Cheddar cheese samples but not on other samples produced from the same vat of milk. The causes of within-vat variation in crystallization behavior have not been identified. This study compared the compositions of naturally smoked Cheddar cheese samples that contained surface crystals with those of samples originating from the same vat that were crystal-free. Six pairs of retail samples (crystallized and noncrystallized) produced at the same cheese plant on different days were obtained from a commercial source. Cheese samples were 5 to 6 mo old at the time of collection. They were then stored for an additional 5 to 13 mo at 4°C to ensure that the noncrystallized samples remained crystal-free. Then, the crystalline material was removed and collected from the surfaces of crystallized samples, weighed, and analyzed for total lactic acid, L(+) and D(−) lactic acid, Ca, P, NaCl, moisture, and crude protein. Crystallized and noncrystallized samples were then sectioned into 3 concentric subsamples (0 to 5 mm, 6 to 10 mm, and greater than 10 mm depth from the surface) and analyzed for moisture, NaCl, titratable acidity, L(+) and D(−) lactic acid, pH, and total and water-soluble calcium. The data were analyzed by ANOVA according to a repeated measures design with 2 within-subjects variables. The crystalline material contained 52.1% lactate, 8.1% Ca, 0.17% P, 28.5% water, and 8.9% crude protein on average. Both crystallized and noncrystallized cheese samples contained significant gradients of decreasing moisture from center to surface. Compared with noncrystallized samples, crystallized samples possessed significantly higher moisture, titratable acidity, L(+) lactate, and water soluble calcium, and significantly lower pH and NaCl content. The data suggest that formation of calcium lactate crystals may have been influenced by within-vat variation in salting efficacy in the following manner. Lower salt uptake by some of the cheese curd during salting may have created pockets of higher moisture and thus higher lactose within the final cheese. When cut into retail-sized chunks, the lower salt, higher moisture samples contained more lactic acid and thus lower cheese pH, which shifted calcium from the insoluble to the soluble state. Lactate and soluble calcium contents in these samples became further elevated at the cheese surface because of dehydration during smoking, possibly triggering the formation of calcium lactate crystals.
(**Key words:** Cheddar cheese, calcium lactate, crystal)

Abbreviation key: TA = titratable acidity, **WSC** = water-soluble calcium.

INTRODUCTION

White crystalline deposits that sometimes form on the surface of Cheddar cheese have been identified as calcium lactate crystals, specifically calcium lactate pentahydrate $Ca(CH_3CHOHCOO)_2 \cdot 5H_2O$ (Tuckey et al., 1938; McDowall and McDowell, 1939; Shock et al., 1948; Farrer and Hollberg, 1960). These crystals are assumed to form when calcium and lactate ions exceed their solubility, supersaturate the serum phase of the cheese, and then crystallize at nucleation sites. A continuous migration of calcium and lactate ions to the nucleation sites then cause the sites to grow and eventually become macro crystals (Dybing et al., 1988; Swearingen et al., 2004). The white crystals that form preferentially at the cheese surface are considered quality defects because consumers often confuse them for mold or other spoilage (Chou et al., 2003). Consumer rejection of crystallized cheeses not only results in direct financial loss to the manufacturer but also compromises the manufacturer's reputation for quality in the marketplace (Washam et al., 1982; Swearingen et al., 2004).

Several factors have been shown to favor crystallization including high lactose levels in milk (Pearce et al., 1973); milk concentrated by ultrafiltration without diafiltration (Sutherland and Jameson, 1981); certain starter culture strains (Swearingen et al., 2004); biofilm formation, and contamination of cheese by nonstarter lactic acid bacteria that are able to racemize L(+) lactate

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Corresponding author: Paul S. Kindstedt; e-mail: paul.kindstedt@uvm.edu.

to D(–) lactate (Thomas and Crow, 1983; Johnson et al., 1990a; Somers et al., 2001; Chou et al., 2003); low storage temperature (4.4°C) and loose packaging (Johnson et al., 1990b); and low salt-in-moisture levels (Swearingen et al., 2004). In addition, naturally smoked cheeses may be prone to increased crystallization due to surface dehydration that occurs during the smoking process. For example, Washam et al. (1985) concluded that dehydration during smoking triggered the crystallization of emulsifying salts at the surface of naturally smoked processed Swiss cheese. Naturally smoked Cheddar cheese is an important value-added niche product. Presumably, naturally smoked Cheddar is subjected to increased susceptibility to calcium lactate crystallization due to surface dehydration.

Some researchers have reported wide variations in crystallization behavior among retail-sized samples of Cheddar cheese that were produced from the same vat of milk, ranging from no crystals present to heavy crystal coverage (Dybing et al., 1988; Swearingen et al., 2004). The authors have observed similar variation among samples of smoked Cheddar cheese produced from the same vat. The factors responsible for within-vat variation in crystallization behavior are not well understood. Dybing et al. (1988) found no significant differences in the chemical composition or level of nonstarter lactic acid bacteria of crystallized and noncrystallized cheeses produced from the same vat. However, these authors did not measure the pH, lactate [L(+) and D(–)], or water-soluble calcium (**WSC**) content of the cheese samples, which are critical parameters that affect calcium lactate crystallization (Johnson et al., 1990b; Kubantseva et al., 2004; Swearingen et al., 2004). The objective of the present study was to compare the chemical compositions of crystallized and noncrystallized samples of smoked Cheddar cheese produced from the same vat of milk, with particular emphasis on pH and titratable acidity (**TA**), L(+) and D(–) lactate, and total calcium and WSC contents.

MATERIALS AND METHODS

Sample Preparation

Six pairs of vacuum-packaged random weight (~300 g) retail samples of naturally smoked Cheddar cheese were obtained from local supermarkets. All cheese samples were produced at the same cheese plant, and their dates of manufacture were determined from information supplied by the manufacturer. The cheeses were produced by a milled curd procedure using an automated production line that included enclosed vats (22,727-kg capacity) for coagulating the milk and cooking the curd; an enclosed conveyor series for continuous curd dewheying, cheddaring, and milling; enclosed mechanical metering of dry salt and automated stirring of salted curd; and block-forming towers that produced 19.1-kg blocks. The blocks were vacuum-packaged and aged for 2 to 4 mo before being cut into random-weight chunks for smoking.

The dimensions of a typical cheese sample were approximately 47 × 60 × 100 mm. Each of the 6 pairs contained one crystallized and one noncrystallized sample that were produced on the same day from the same vat of milk. The 6 pairs of samples were produced on different days. The samples ranged from 5 to 6 mo of age from the date of manufacture upon collection, following which they were stored for an additional 5 to 13 mo at 4°C to ensure that the noncrystallized samples remained crystal-free under normal refrigerated storage conditions. Upon completion of the storage period, the wrapping film was removed from the crystallized cheese samples, and the crystals were dislodged and collected from all 6 surfaces of each sample using a sharp blade (1991 Trimming knife blade, New Britain, CT). The scraping was done carefully and quickly to avoid temperature fluctuation and to minimize the inclusion of cheese matter with the crystalline material. The collected crystalline material was immediately weighed and then stored in tightly sealed Whirl-Pak bags (Nasco, Fort Atkinson, WI) at 4°C until analysis.

The crystallized (scraped) and noncrystallized cheese samples were then sectioned into 3 concentric subsamples, representing 3 different depths from each of the 6 surfaces (0 to 5 mm, 6 to 10 mm, and greater than 10 mm). Each of the 3 subsamples was finely grated using a blender (Osterizer, Oster Corp., Milwaukee, WI), and then stored in tightly sealed Whirl-Pak bags (Nasco) at 4°C until analysis.

Chemical Analysis

Cheese subsamples were analyzed in duplicate as follows. Moisture content was determined by drying in a forced-draft oven at 100°C for 24 h. Calcium and Na contents were determined by inductively coupled plasma atomic emission spectrometry. Salt was calculated directly from the Na content. Water-soluble calcium was determined using the extraction method described by Metzger et al. (2001). Cheese pH was measured using a Beckmann Φ50 pH/ISE Meter (Beckmann Instruments, Inc., Fullerton, CA) by direct immersion of a ROSS combination spear-tip pH electrode (Orion Research, Inc., Beverly, MA) into a finely ground cheese sample at ambient temperature. The TA was determined using the method described by Yun et al. (1993). Lactic acid contents [L(+) and D(–)] of cheese samples were determined by a colorimetric method (test kit no.