Influence of Condensed Sweet Cream Buttermilk on the Manufacture, Yield, and Functionality of Pizza Cheese

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ABSTRACT

Compositional changes in raw and pasteurized cream and unconcentrated sweet cream buttermilk (SCB) obtained from a local dairy were investigated over 1 yr. Total phospholipid (PL) composition in SCB ranged from 0.113 to 0.153%. Whey protein denaturation in pasteurized cream over 1 yr ranged from 18 to 59%. Pizza cheese was manufactured from milk standardized with condensed SCB (~34.0% total solids, 9.0% casein, 17.8% lactose). Effects of using condensed SCB on composition, yield, PL recovery, and functional properties of pizza cheese were investigated. Cheesemilks were prepared by adding 0, 2, 4, and 6% (wt/wt) condensed SCB to part-skim milk, and cream was added to obtain cheesemilks with ~11.2 to 12.7% total solids and casein:fat ratio of ~1. Use of condensed SCB resulted in a significant increase in cheese moisture. Cheese-making procedures were modified to obtain similar cheese moisture contents. Fat and nitrogen recoveries in SCB cheeses were slightly lower and higher, respectively, than in control cheeses. Phospholipid recovery in cheeses was below 40%. Values of pH and 12% trichloroacetic acid-soluble nitrogen were similar among all treatments. Cheeses made from milk standardized with SCB showed less melt and stretch than control cheese, especially at the 4 and 6% SCB levels. Addition of SCB significantly lowered free oil at wk 1 but there were no significant differences at wk 2 and 4. Use of SCB did not result in oxidized flavor in unmelted cheeses. At low levels (e.g., 2% SCB), addition of condensed SCB improved cheese yield without affecting compositional, rheological, and sensory properties of cheese.

Key words: buttermilk, functionality, cheese yield, phospholipid

INTRODUCTION

Sweet cream buttermilk (SCB) is a by-product from the butter-making process. Sweet cream buttermilk dif-

fers from skim milk in that it has a significant amount of milk fat globule membrane (MFGM) material, which remains from the butter-making process (Walstra et al., 1999). Milk fat globule membrane contains a mixture of proteins, glycoproteins, and phospholipids (PL), all of which can act as emulsifiers and help the fat globule stay in suspension in milk. Phospholipids, which are partly located on the surface of the milk fat globule, are considered excellent surface-active agents and could be used as emulsifiers in foods. During churning, the MFGM is destabilized and some of this PL fraction can be recovered in the buttermilk. Because buttermilk contains MFGM (along with CN), it is an interesting source of ingredients with the potential to impart certain specific characteristics to cheese made with it. There is growing interest in the cheese industry for cheeses with specific functional/nutritional properties as well as means to economically increase yield. Specific functional and nutritional benefits could include improving fat emulsification and incorporation of nutritionally important phospholipids (e.g., sphingomyelin), respectively. Sphingomyelin, through its bioactive derivatives, has been found to play important roles in transmembrane signal transduction, cell regulation, and apoptosis (Parodi, 1997) and dietary sphingomyelin may inhibit 1,2-dimethylhydrazine-induced colon cancer in mice (Dillehay et al., 1994). Bioactive properties of phosphatidylcholine and phosphatidylserine have also been reviewed (Kidd, 2002). This has led to an increasing number of studies on the use of SCB in cheese making (Madsen et al., 1966; Joshi and Thakar, 1993; Mayes et al., 1994; Mistry et al., 1996; Raval and Mistry, 1999; Poduval and Mistry, 1999).

Sweet cream buttermilk has been used as an ingredient in baking applications (e.g., in pancake mixes); however, SCB is considered a low value-added material due to its limited uses in food products. One of the ways to increase the demand for buttermilk is to find attractive uses for it as a cheese ingredient. Sweet cream buttermilk has been used as an ingredient in cheese making, but currently in the United States it cannot be legally used in cheeses with a standard of identity. According to Codex regulations (Codex Alimentarius Commission, 2003), SCB can be used as an ingredient in cheese as

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it permits the use of “milk and/or products obtained from milk”. It can be used in pizza cheese, a nonstandard of identity cheese. Pizza cheese is functionally and organoleptically similar to low moisture part-skim Mozzarella cheese but it is a nonpasta filata, stirred-curd cheese, manufactured using mesophilic cultures (*Lactococcus lactis* ssp. *cremoris* and *lactis*). This cheese does not produce brown blisters when heated due to the lack of residual sugar because of complete sugar fermentation by the starter culture and the altered manufacturing protocol in which a washing step is incorporated to reduce sugar level in the cheese. Pizza cheese is commonly manufactured from milk with CN:fat ratio of about 1.0 to 1.05 and can be standardized by cream removal or addition of condensed or UF skim milk or NDM. As condensed SCB is available commercially, it would provide another option for standardization of cheesemilk for pizza cheese manufacture. However, the cost of SCB vs. NDM fluctuates and if SCB is expensive compared with NDM, this would impede its use as an ingredient in cheese making.

Research had shown that the use of SCB might alter the physical and melting properties of cheese (Poduval and Mistry, 1999). Previous studies have shown that the addition of SCB lowered free oil formation in low-fat Cheddar cheese (Mistry et al., 1996). The use of SCB in low-fat Mozzarella cheese inhibited blister formation, but reduced meltability (Poduval and Mistry, 1999). Addition of SCB increased the moisture content of reduced-fat cheese (Madsen et al., 1966; Joshi and Thakar, 1993; Mayes et al., 1994; Mistry et al., 1996; Poduval and Mistry, 1999). Additionally, curd fusion was poor in cheeses manufactured with 10 to 25% UF SCB (Mistry et al., 1996). The use of condensed SCB to standardize cheesemilk could increase the lactose level in the serum phase of milk, which would increase the residual sugar content in cheese (unless water is added). This may result in an excessively low pH or discoloration of the cheese when baked.

In Wisconsin, regulations (ATCP 80:44, 2002) require that raw cream used for butter making must be given a minimum pasteurization treatment of 85°C for 15 s. The term “raw cream” refers to cream that the butter-making plant receives before butter making. The extent of heat treatment of this raw cream before arriving at the butter-making plant is not always known (it may have been heat-treated several times either as milk or cream). As a result of severe heat treatments there would be substantial denaturation of whey protein. Because denatured β -lactoglobulin is mostly bound to CN micelles, it would effectively increase the CN content of the SCB. The measured CN content of SCB not only reflects the amount of CN present in the SCB samples

but also the amount of denatured whey proteins associated with CN micelles.

There are 2 main obstacles in using SCB as an ingredient in cheese making: variability in composition and inconsistent quality of this product due to variations in the cream processing conditions. Thus, we investigated compositional changes in raw and pasteurized cream and fresh unconcentrated SCB, which were collected over a 1-yr period. The objective of this study was also to investigate the impact of using different levels of condensed SCB on pizza cheese manufacture including cheese yield, composition, proteolysis, and functional characteristics. We also wanted to identify any modifications during the manufacture of pizza cheese that may be necessary to successfully use condensed SCB for pizza cheese. Differences in cheese moisture contents also alter functional and ripening properties so modifications to cheese-making procedures will be used to attain SCB-fortified cheeses with similar moistures to control cheese. Little is known about the recovery of the PL present in SCB into cheese. We also wanted to determine how much of the PL were recovered during cheese making.

MATERIALS AND METHODS

Cream and Unconcentrated Buttermilk

Raw cream, pasteurized cream, and unconcentrated SCB were collected from local dairy A for 1 yr at 6 times: January, March, July, September, October, and December. Compositional analyses of SCB and cream samples were carried out.

Standardization

Raw whole milk and cream were obtained from the University of Wisconsin-Madison dairy plant on the day before cheese making. Raw whole milk was partially skimmed (fat content $2.30 \pm 0.05\%$). As dairy plant A did not concentrate SCB, we obtained commercial samples of condensed SCB from local dairy plant B, which was used in the cheese-making experiments. The composition of the condensed SCB used for cheese making is given in Table 1. Four types of cheesemilks were prepared: control, and milks standardized with 3 levels of condensed SCB. Control milk was standardized by blending the part-skim milk with cream to an average of 11.20% ($2.51 \pm 0.08\%$ CN) solids with a mean CN:fat ratio of ~1.0. The 3 SCB-standardized cheesemilks were prepared by the addition of condensed SCB at 2, 4, and 6% by weight basis of cheese milk (the levels were selected based on preliminary trials that covered a wider range of SCB additions) to part-skim milk and cream. The CN and fat content for all treatments was

Table 1. Composition (mean $\pm$ SD, $n = 6$) of part skim milk, cream, and condensed sweet cream buttermilk (SCB, obtained from local dairy B) used in the preparation of the standardized cheesemilks for the different treatments ($n = 6$)

	Composition, %				
	Total solids	Casein	Total protein	Lactose	Milk fat
Part skim milk	11.09 $\pm$ 0.23	2.49 $\pm$ 0.04	3.24 $\pm$ 0.07	—	2.30 $\pm$ 0.05
Condensed SCB	34.02 $\pm$ 2.18	8.98 $\pm$ 0.99	10.82 $\pm$ 0.81	17.75 $\pm$ 1.85	2.52 $\pm$ 0.24
Cream	44.42 $\pm$ 3.44	1.44 $\pm$ 0.08	1.92 $\pm$ 0.11	—	38.89 $\pm$ 3.58

standardized to a CN:fat ratio of ~ 1.0 . The cheese-making procedure was kept the same for all treatments and this set of cheese trials was repeated 3 times.

Cheese Manufacture and Sampling Procedures

The same day as blending, pizza cheese was manufactured by licensed Wisconsin cheesemakers in the University of Wisconsin-Madison dairy processing pilot plant using the method of Chen and Johnson (2001) as described by Govindasamy-Lucey et al. (2005). The control, 2%-SCB, 4%-SCB, and 6%-SCB vats were filled with 227 ± 0 , 216 ± 3 , 206 ± 2 , and 197 ± 2 kg of pasteurized blended milk, respectively. In all experimental vats, milk volume was based on CN content compared with the control vat to keep actual total yield similar in all vats. The amount of starters and rennet added to all vats was standardized on the CN content of the standardized milks (Govindasamy-Lucey et al., 2005). The coagula were cut on similar firmness as evaluated subjectively by an experienced licensed Wisconsin cheesemaker.

Because the first cheese trials demonstrated that the use of SCB increased moisture content and decreased pH, a second set of trials was conducted. In the second set of cheese trials, the manufacturing procedure was modified to obtain similar cheese moisture contents in all cheeses. The SCB-fortified cheeses were subjected to a 20-min stir out during cooking, whereas control cheese had no stir out. The coagulum from the 6% SCB fortified milk was cut using 6.0-mm knives. The second set of cheese trials was repeated 3 times.

Compositional Analyses

All compositional analyses for each sample were carried out in triplicate. Sweet cream buttermilk, milk, whey, wash water, and press whey samples were analyzed for fat by Mojonnier (AOAC, 2000), protein (total percentage N $\times 6.35$) by Kjeldahl (AOAC, 2000), CN (AOAC, 2000), lactose (AOAC, 2000), total solids (Green and Park, 1980), and NPN (AOAC, 2000). The amount of denatured protein from the pasteurization of raw cream was estimated using the method described by Guinee et al. (1995).

The cheeses were sampled after 1 wk for compositional analysis. At the time of sampling, a 2.5-cm slab was cut off from the block; this slab was further sampled for each analysis. The subsampled cheese sample was completely ground and used for analysis. Cheese samples were analyzed for moisture (Marshall, 1992), fat (AOAC, 2000), pH by the quinhydrone method (Marshall, 1992), protein by Kjeldahl (AOAC, 2000), and salt by chloride electrode method (model 926, Corning Glass Works, Medfield, MA; Johnson and Olson, 1985). Proteolysis was monitored during ripening by measuring the amount of 12% TCA-soluble nitrogen at 1, 2, and 4 wk (AOAC, 2000). Free oil formed in the pizza cheeses was analyzed at 1, 2, and 4 wk using the method described by Kindstedt and Rippe (1990). The results were expressed as both the percentage free oil in cheese and the percentage free oil in cheese fat.

Fat and Nitrogen Recovery and Yield

A mass balance was carried out for each vat of cheese. Milk, drain whey, wash water, and press whey were weighed to ± 0.1 kg and cheese was weighed to ± 0.01 kg. The percentage of fat or N recovered in the cheese, drain whey, wash water, and press whey was calculated as the total amount of fat or N in each one of these products divided by the total amount of fat or N in the original standardized milk and multiplied by 100.

Actual yield was calculated for each vat of cheese as the weight of the cheese divided by the weight of the original standardized milk multiplied by 100. Actual cheese yield was also adjusted to the target cheese moisture content (46% for pizza cheese). The approach described recently by Govindasamy-Lucey et al. (2005) was used to determine the predictive cheese yield, and the recoveries of fat, CN, and other solids in cheese. The Van Slyke yield equation was initially developed for Cheddar cheese (Van Slyke and Price, 1936) and we determined what the *RC*, *RF*, and *RS* values would be for pizza cheese. Predictive cheese yields were calculated for each vat using the Van Slyke cheese yield model equation (Eq. 1 as shown below; Van Slyke and Price, 1936).

$$\text{Van Slyke Cheese Yield} = \frac{[(RF \times \% \text{ Fat in milk}) + (RC \times \% \text{ CN in milk})] \times RS}{(100 - \% \text{ Moisture of cheese})} \quad [1]$$

where *RF* is fraction of fat recovered in cheese, *RC* is fraction of CN recovered in cheese, and *RS* reflects the proportion of other milk solids and salt recovered in cheese in relation to the amount of CN and fat in cheese. The *RF* values were determined experimentally as fat recovery for each cheese type during the cheese-making trials. The *RC* was calculated (Govindasamy-Lucey et al., 2005) using the following equation:

$$RC = \frac{\% \text{ CN in cheese}^* \times \text{weight of cheese}}{\% \text{ CN in milk} \times \text{weight of milk}} \quad [2]$$

where estimated percentage CN in cheese (*) = percentage N in cheese $\times 6.31$ (van Boekel, 1993).

No correction factor was applied in the estimation of percentage CN in cheese because the amount of non-CN N will be very small (calculated as less than 1% of total N). However, in cheese with denatured serum protein attached to CN, the denatured whey protein is calculated as CN.

The following approach was used to calculate *RS*:

Fat in DM (**FDM**) in cheese was determined experimentally as follows:

$$FDM = \frac{\% \text{ Fat in cheese}}{\% \text{ Total solids in cheese}} \quad [3]$$

The percentage fat in cheese can be calculated as follows:

$$\% \text{ Fat in cheese} = RF \times \% \text{ Fat in milk} \quad [4]$$

The total solids in cheese can be calculated as follows:

$$\text{Total solids in cheese} = \frac{[(RF \times \% \text{ Fat in milk}) + (RC \times \% \text{ CN in milk})] \times RS}{(100 - \% \text{ Moisture of cheese})} \quad [5]$$

Substituting equations 4 and 5 into equation [3], we obtain the following equation:

$$FDM = \frac{(RF \times \% \text{ Fat in milk})}{[(RF \times \% \text{ Fat in milk}) + (RC \times \% \text{ CN in milk})] \times RS} \quad [6]$$

By rearranging equation 6 we obtain the following equation:

$$RS = \frac{RF \times \% \text{ Fat in milk}}{[(RF \times \% \text{ Fat in milk}) + (RC \times \% \text{ CN in milk})] \times FDM} \quad [7]$$

Total PL analysis

The extraction of lipid was carried out using a modified Mojonnier procedure (AOAC, 2000). Depending on the concentration of PL, various amounts of samples were used in this procedure; 30 g for cheese milk, 10 g for condensed SCB, 30 g for drained whey and pressed whey, and 50 g for wash water. To improve recovery of PL, 1.5% (wt/wt) of NaCl was added to the sample (Walstra and de Graaf, 1962).

Digestion was applied to liberate phosphorus from the extracted fat using a modified method as described by Walstra and de Graaf (1962). The extracted fat was rinsed into a Kjeldahl digestion flask using ethyl ether. The solvent was evaporated by placing the digestion flask on a Kjeldahl Micro Digester digestion unit (Lab-conco, Kansas City, MO) and heating it at 70°C until the fat sample was completely dried. Ten milliliters of concentrated HNO₃ (16 M) and 5 mL of concentrated (18 M) H₂SO₄ were added to the flask. The flask was again heated on the heating unit at 250°C until the contents in the flask turned clear. Some HNO₃ (10 to 15 mL) was added if the contents did not become clear after 1 h of digestion. At the end of the digestion, the solution in the flask was clear or slightly yellow. While heating, 30% of H₂O₂ (~1 mL) was added to remove excess HNO₃. The total digestion time was about 2 to 4 h depending on the amount of fat being digested. The contents inside of the flask were rinsed into a 100-mL graduated flask and made up to volume with deionized water.

Phosphorus content was determined using the colorimetric method as described by Walstra and de Graaf (1962). A test was conducted to determine the recovery of PL using this method. A known amount of PL from soy lecithin was extracted and digested using the procedure described above. After the spectrophotometric test, it was found that the recovery of PL was $93 \pm 3\%$. This recovery test was repeated 6 times. The total PL recovery in cheese was determined by subtracting the total PL found in whey, press whey, and wash water from the total PL content in cheese milk.

Rheological Properties During Rennet Coagulation of Cheesemilks

Rennet-induced milk gels are viscoelastic and their small deformation rheological properties can be determined by dynamic low amplitude oscillatory rheometry

by measuring storage modulus (G'), loss modulus (G''), and loss tangent (LT ; Zoon et al., 1988; Van Vliet et al., 1989; Lucey, 2002). The rheological characteristics of the standardized cheesemilks, control, and cheese milk with added lecithin PL (ADM Ultralec, Decatur, IL) during renneting were measured at $34.4 \pm 0.1^\circ\text{C}$ in a UDS 200 Physica rheometer (Physica Messtechnik, D-70564 Stuttgart, Germany) operating in oscillation mode at a frequency of 0.1 Hz and a strain of 1%. This lecithin contained a mixture of phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol, and phosphatidic acid. The amount of lecithin (~30 mg) added was estimated to be similar to the amount of PL found in cheese milk with 6% SCB addition. The measuring system consisted of 2 coaxial cylinders (diameters 25.0 and 27.5 mm). A profiled (serrated) bob was used in this couette-type fixture. Before testing, the milk sample was warmed to 34.4°C for about 30 min in a waterbath, and 100 μL of distilled water containing 1.77 μL of double-strength chymosin (Chymostar, Rhodia, Madison, WI) was added to the milk, and mixed thoroughly; then, approximately 13 mL of the mixture was immediately placed in the cup (maintained at 34.4°C) of the rheometer. Vegetable oil was layered onto the surface of the milk to prevent evaporation during coagulation. Measurements were started 120 s after rennet addition and were taken at 60-s intervals for 100 min.

Small Amplitude Oscillatory Rheology Tests on Cheese

Rheological properties of the cheeses were carried out using a UDS 200 Physica rheometer (Physica Messtechnik) as described by Lucey et al. (2005). At 1, 2, and 4 wk of ripening, cheeses were cut into smaller blocks ($12 \times 10 \times 10$ cm) and thin slices (~3.2 to 3.4 mm in width) were cut using a hand-operated slicer. Using a cylindrical cork borer, 50-mm diameter discs were cut from these cheese slices. The disc-shaped cheese samples were then transferred to plastic bags to prevent dehydration and stored at ~5 to 6°C for at least 2 h before testing. The cheese samples were glued to the bottom plate of the rheometer with cyanoacrylate to prevent slippage (Nolan et al., 1989). To help prevent slippage from the top plate during testing, a serrated plate measuring system (MP31, 50-mm diameter) was used (Rosenberg et al., 1995). The cheese sample was mounted carefully onto the rheometer using the normal force measurement so that the cheese sample was subjected to minimal deformation by the measuring system. The normal force of the rheometer at the start of the test was kept <1 N, to ensure that the sample was in good contact with the measuring system but was not

excessively deformed. The test was not started until a constant normal force reading (~0.7 N) was obtained. Cheese samples were subjected to a heating profile in the rheometer. In this test, a strain of 0.2% was applied at a frequency of 0.1 Hz to the cheese samples. The cheese samples were heated at a constant rate of $1^\circ\text{C}/\text{min}$ from 5 to 80°C and G' (or stiffness), G'' , and LT parameters were measured as a function of temperature. The temperature where LT was equal to 1 (i.e., where $G' = G''$) was also calculated, because this indicates the transition from a solid to a liquid-like system (i.e., a crossover point).

Sensory Analysis

Each cheese was evaluated for bitterness, saltiness, acidity, oxidized flavor, other off-flavors, firmness, and smoothness on a scale from 0 to 7. Seven judges were trained to detect oxidized and off-flavors by sampling oxidized milk and rancid cream samples until their scores for these attributes were consistent. Cheeses were shredded on a pilot plant scale shredder (Urschel model CC, Alard Equipment Corp., Williamson, NY). The cheeses were baked on pizza in a forced-air commercial oven (Impinger Ovens, Lincoln Foodservice Products Inc., Ford Wayne, IN) at 260°C for 5 min and their performances (e.g., oiling-off, strand elasticity, flow-off crust, mouthfeel, chewiness, and flavor, such as acidity, saltiness) were subjectively evaluated by a panel of 6 to 8 panelists.

Experimental Design and Statistical Analyses

Three replicate cheese-making trials were carried out; in each trial, 4 standardized milks (i.e., part-skimmed milk or control, 2%-SCB, 4%-SCB, and 6%-SCB) were used to make pizza cheese. A 4×3 complete randomized block design, which incorporated all 4 treatments and 3 blocks (replicate trials), was used for analysis of the response variables relating to milk, cheese, and whey composition. A second set of experiments was performed in which specific steps were taken to maintain constant moisture content in all the cheeses. The ANOVA was carried out using the PROC GLM procedure of SAS (version 9.1; SAS Institute Inc., Cary, NC). In the ANOVA model, the 4 differently standardized milks (different treatments) were analyzed as a discontinuous variable, whereas cheese-making day (i.e., different batch of milk) was blocked. Scheffe's multiple-comparison test was carried out to evaluate differences in the treatments means at a significance level of $P < 0.05$.

A split-plot design was used to monitor the effects of treatment and time of aging and their interactions on

Table 2. Mean ($n = 6$) and range in the composition of raw cream, pasteurized cream, and unconcentrated sweet cream buttermilk (SCB) obtained from local dairy A over a 1-yr period¹

Composition	Sample ²	Mean	Range
Total solids (%)	Raw cream	44.85	43.68–47.25
	Pasteurized cream	43.94	42.29–47.94
	SCB	7.95	6.51–8.78
Fat (%)	Raw cream	39.56	37.90–43.13
	Pasteurized cream	40.04	37.40–42.70
	SCB	0.70	0.62–0.88
Total protein ³ (%)	Raw cream	1.95	1.64–1.91
	Pasteurized cream	1.88	1.55–2.10
	SCB	2.59	2.08–2.79
True protein ⁴ (%)	Raw cream	1.80	1.49–1.85
	Pasteurized cream	1.76	1.41–2.04
	SCB	2.43	1.93–2.62
Casein ⁵ (%)	Raw cream	1.54	1.15–1.49
	Pasteurized cream	1.61	1.27–1.86
	SCB	2.17	1.69–2.39
Total phospholipid (mg/g of sample)	Raw cream	1.66	1.45–2.05
	Pasteurized cream	1.50	1.32–1.86
	SCB	1.32	1.13–1.53

¹At each time point, 1 sample of raw cream, pasteurized cream, and SCB were collected from local dairy A and analyzed. Results reported here were averages of triplicate analyses.

²Pasteurized cream was cream pasteurized at 86.1°C for 18 s (this is the average temperature and time pasteurization condition that was reported by the dairy plant); SCB was the sweet cream buttermilk remaining after the churning of the pasteurized cream.

³Total protein = total % N $\times$ 6.35.

⁴True protein = (total % N – % NPN) $\times$ 6.35.

⁵Casein = (total % N – % Non-CN N) $\times$ 6.36.

pH, proteolysis (12% TCA-soluble nitrogen expressed as a percentage of total nitrogen), maximum LT values, temperature at which LT was maximum, temperature of crossover point, the amount of free oil formed, and the sensory attributes during ripening. For the whole-plot factor, treatment was analyzed as a discontinuous variable, whereas cheese-making day was blocked. For the subplot factor analysis, age was treated as continuous variable. The interactive term treatment $\times$ cheese-making day was treated as the error term for the treatment effect. The ANOVA for the split-plot design was carried out using the PROC GLM procedure of SAS. Fisher's least significant difference test was carried out to evaluate differences in the treatments means at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Raw Cream, Pasteurized Cream, and Unconcentrated SCB Composition

The composition of SCB collected from a local dairy over a year showed that it was composed of about $2.59 \pm 0.24\%$ total protein, $7.95 \pm 0.75\%$ total solids, $2.17 \pm 0.23\%$ CN, and $0.70 \pm 0.09\%$ fat (Table 2). The composition of the raw cream, pasteurized cream, and unconcentrated SCB varied during the entire year. The fat and solids content of cream were lower in March and

September samples compared with other months (results not shown). Unconcentrated SCB composition followed the same compositional trends as the seasonal variation in cream composition. Total PL composition in unconcentrated SCB ranged from 1.13 to 1.53 mg per g of sample (0.113 to 0.153%). The total PL values obtained in this study agree with those reported by McDowell (1958), who had obtained a mean value of 0.156% and a range of 0.103 to 0.191% for SCB obtained from 2 New Zealand dairy factories measured over a 13-mo period. Pasteurization of cream appeared to degrade some PL, especially phosphatidylethanolamine species (results not shown).

The percentage denatured whey proteins in pasteurized cream varied throughout the year (Table 3). In the fall months, September, October, and December, the percentage denatured whey proteins was the highest; more than 50% of the whey proteins found in the cream were denatured after pasteurization. In the rest of the year, pasteurized cream contained less than 25% denatured whey proteins. The difference in percentage denatured whey proteins found in cream was probably due to the processing conditions at which the cream was pasteurized. Although the average pasteurization temperature and time reported by the local dairy was $\sim 86^\circ\text{C}$ for 18 s, there could be processing variations throughout the year. These variations could affect the composition

Table 3. Whey protein denaturation in pasteurized cream obtained from local dairy A over 1 yr

Analysis date	Whey protein denaturation ¹ (%)
September 2002	58.8
October 2002	56.5
December 2002	46.4
January 2003	18.2
March 2003	21.0
December 2003	52.7

¹Whey protein denaturation was calculated as described by Guinee et al. (1995).

and quality of SCB that is produced from the butter-making process. Another explanation for the variation in percentage denatured whey proteins in pasteurized cream could be the initial heat treatments given to the cream before the butter plant received the cream. As mentioned before, the “raw cream” that the creamery used for butter making is from different dairy plants and this raw cream probably already underwent heat treatments. Because the cream came from different dairy plants, it is not possible to tell the extent of heat treatment the raw cream received. The changes in percentage denatured whey proteins found in cream was probably due to the different sources of cream and the extent of heat treatment it received before its arrival at the local dairy.

Condensed SCB and Standardized Cheesemilk Composition

The total protein, fat, total solids, and CN contents of the condensed SCB, for trials with and without modifications to the cheese-making procedure to control the moisture content, were 10.82, 2.52, 34.02, and 8.98%, respectively (Table 1). At the fortification levels used, condensed SCB contributed from 6 to 20% of the total CN content of milk in the cheese vats fortified with SCB. All milks were standardized to a similar CN:fat ratio, 1.03 to 1.04 (Table 4) so that as the concentration of condensed SCB used in cheese making increased, there was more cream added during the blending for the standardized cheesemilks (Table 4). As expected, total solids, fat, total protein, true protein, and CN contents were significantly ($P < 0.0001$) higher in the milks standardized with condensed SCB than in control milks (Table 4). Lactose contents in the milk and in the serum phase in the SCB standardized milks were significantly higher than in the control milks; the lactose content in cheesemilks increased with the increasing amount of SCB added. Although there was no significant difference in the amount of whey protein in all cheesemilks, there was a slightly higher whey protein

content in the 4%- and 6%-SCB cheesemilk compared with the other cheesemilks.

Cheese Composition

Standardization of milk with condensed SCB resulted in pizza cheeses with higher moisture content; the moisture difference between the control and cheeses with 6% SCB added was ~5% (Table 4). After changes were made to the manufacturing procedure, the moisture contents for the 4 treatments were not significantly different ($P > 0.05$) and there was no significant difference in the composition of cheeses once moisture was corrected (Table 4). There were 2 possible reasons why the addition of SCB increased the moisture content of pizza cheeses. First, the addition of condensed SCB would have introduced denatured whey proteins into the system. The cream that was used to produce the SCB was pasteurized at a high temperature (average ~85°C for 15 s). After butter making, the SCB underwent additional heat treatment to produce the condensed SCB. When the condensed SCB is added to cheesemilk, it must undergo another pasteurization. Denatured whey proteins, such as β -lactoglobulin, interact with CN and form CN-whey protein complexes that impair the coagulation of milk and prevent the usual syneresis of the cheese curd. This complex formation slows down the enzymatic reaction by reducing the accessibility of κ -CN and the aggregation of rennet-altered CN micelles (Leaver et al., 1995; Lucey, 1995). The strength of the renneted milk gel is weaker due to disruption of the continuity of the gel network caused by attachment of denatured whey proteins to CN micelles (Lucey, 1995). After the rennet gel is cut, normal syneresis cannot take place due to the presence of whey proteins in the gel. Because syneresis is impaired, more moisture is retained in the cheese. Denatured whey proteins are also thought to have a high water-holding capacity. When they interact with the CN micelles and are incorporated into the CN matrix, they can further increase the moisture content of cheese (Lawrence, 1987).

The presence of MFGM fragments and PL may also play a part in increasing the moisture content of cheeses. The addition of these PL may alter the structure of the rennet gel during the coagulation phase. Phospholipids could potentially interact with proteins and form lipoprotein complexes (Drake et al., 1996). These complexes may interfere with the normal structure of the gel and CN interactions (in an analogous way to the presence of denatured whey proteins). Any alteration of the gel can prevent normal syneresis from occurring and result in more moisture being retained in cheese. Laloy et al. (1998) reported that the addition

Table 4. Compositions of standardized milk (n = 6) and cheese (n = 3) produced using the same and modified manufacturing protocol for pizza cheese

Component	Treatments ¹				SEM	P-value
	Control	2%-SCB	4%-SCB	6%-SCB		
Standardized cheesemilk						
Total solids, %	11.18 ^d	11.71 ^c	12.24 ^b	12.69 ^a	0.049	<0.0001
Milk fat, %	2.41 ^d	2.54 ^c	2.70 ^b	2.79 ^a	0.016	<0.0001
Total protein, ² %	3.20 ^d	3.34 ^c	3.51 ^b	3.63 ^a	0.015	<0.0001
True protein, ³ %	3.01 ^d	3.14 ^c	3.30 ^b	3.41 ^a	0.019	<0.0001
CN, ⁴ %	2.51 ^d	2.63 ^c	2.77 ^b	2.88 ^a	0.016	<0.0001
NPN, %	0.030 ^b	0.032 ^{ba}	0.036 ^a	0.034 ^{ba}	0.0011	<0.01
CN to total protein, %	78.31 ^b	78.74 ^b	78.82 ^b	79.49 ^a	0.149	<0.001
CN to true protein, %	83.22 ^b	83.81 ^{ba}	83.96 ^{ba}	84.57 ^a	0.224	<0.01
Whey protein, ⁵ %	0.505	0.508	0.529	0.525	0.009	NS ⁶
Whey protein in serum phase, ⁷ %	0.532	0.536	0.559	0.556	0.009	NS
Lactose, %	4.55 ^d	4.77 ^c	5.05 ^b	5.20 ^a	0.029	<0.0001
Lactose in serum phase, ⁸ %	4.78 ^d	5.03 ^c	5.35 ^b	5.52 ^a	0.032	<0.0001
CN:fat ratio	1.04	1.04	1.03	1.03	0.005	0.18
Cheese (no moisture adjustment)						
Moisture, %	45.43 ^c	48.29 ^b	48.61 ^b	51.00 ^a	0.645	<0.01
Fat, %	23.44 ^a	21.87 ^{ba}	21.75 ^{ba}	20.44 ^b	0.367	<0.01
Total protein, ⁹ %	25.81 ^a	24.37 ^{ba}	24.43 ^{ba}	23.48 ^b	0.390	0.03
Salt, %	1.35	1.50	1.48	1.63	0.085	NS
MNFS, ¹⁰ %	59.33 ^b	61.80 ^{ba}	62.11 ^{ba}	64.11 ^a	0.590	<0.01
FDM, ¹¹ %	42.93	42.30	42.31	41.72	0.348	NS
SM, ¹² %	2.98	3.10	3.04	3.21	0.171	NS
Cheese (with moisture adjustment)						
Moisture, %	47.09	46.14	46.68	47.13	0.502	NS
Fat, %	23.22	23.09	23.04	23.40	0.200	NS
Total protein, ⁹ %	24.88	25.29	25.61	24.97	0.355	NS
Salt, %	1.44	1.46	1.55	1.51	0.076	NS
MNFS, ¹⁰ %	61.33	59.99	60.64	60.71	0.517	NS
FDM, ¹¹ %	43.89	42.87	43.19	42.35	0.310	NS
SM, ¹² %	3.07	3.17	3.32	3.22	0.164	NS

^{a-d}Means within the same row not sharing a common superscript differ ($P < 0.05$).

¹Treatments: 2%-, 4%-, and 6%-SCB indicate various levels (wt/wt) of added sweet cream buttermilk (SCB) used for cheesemaking.

²Total protein = Total % N $\times$ 6.35.

³True protein = (Total % N - % NPN) $\times$ 6.35.

⁴Casein = (Total % N - % Non-CN N) $\times$ 6.36.

⁵Whey protein = true protein - CN.

⁶Nonsignificant (F -test for full statistical model $P > 0.05$).

⁷Whey protein in serum phase = % whey protein/(100% - % Fat - % CN).

⁸Lactose in serum phase = % lactose/(100% - % Fat - % CN).

⁹Total protein = Total % N $\times$ 6.31.

¹⁰MNFS = Moisture in the nonfat substance of the cheese.

¹¹FDM = Fat content on a dry weight basis.

¹²SM = Salt in the moisture phase of the cheese.

of liposomes (composition was ~80% phosphatidylcholine) to Cheddar cheese greatly increased the moisture content and suggested that the presence of PL interfered with the syneresis process.

Coagulation Properties

The control gel had higher G' values than gels made with PL-fortified milks (Figure 1), which indicated that the control gel was stiffer. The addition of PL did appear to slightly weaken the rennet gel. Because the source and the type of PL from lecithin were very different

than PL in SCB, the effect of PL from SCB on rennet gel structure might be different. This experiment showed that the addition of a soy-derived lecithin could slightly weaken a rennet gel. Further study is needed to examine how PL derived from SCB influence rennet gel formation.

Fat, Nitrogen, and PL Recovery in Cheese

Fat recoveries in the control, 2%-, 4%-, and 6%-SCB cheeses were 89.81 ± 1.02 , 88.44 ± 0.91 , 87.66 ± 0.37 , and $87.49 \pm 0.48\%$, respectively. There were no statistically

Figure 1. Storage modulus, G' , as a function of time for rennet gels made with cheese milk without addition of phospholipids (PL) (control, ●) and cheese milk with addition of PL (~30 mg of lecithin, ▽) (means, $n = 3$). Rheological properties were measured by applying a constant strain of 1% at a frequency of 0.1 Hz. Vertical line indicates cutting time as reported in cheese-making experiments.

significant differences in fat recovery in the various cheeses although the fat recoveries in the SCB cheeses were slightly lower than the control cheeses (Table 5). The SCB-fortified cheeses did have significantly ($P < 0.01$) higher fat losses in the drain whey compared with control cheese (Table 5). The fat recovery in the control cheese exhibited considerable variation, possibly due to seasonal changes in milk or other sources of error; this reduced the likelihood of the control cheese having

a statistically significant difference with the SCB-fortified cheeses. The amount of N recovered in the 4%- or 6%-SCB cheeses was significantly ($P < 0.01$) higher than in the control or 2%-SCB cheeses. Mistry et al. (1996) also reported slightly higher (but not significant) protein recovery in reduced-fat Cheddar cheese made with 5% UF SCB. It is possible that because there was some additional denatured whey protein associated with CN in SCB (due to heat treatments), there might have been a slight increase in N recovery in cheeses fortified with higher levels of SCB.

The percentage PL recovery in cheeses was highest for the control and decreased with increasing SCB level (Table 5). Overall recovery of PL in cheese was low (<40%); other studies have also reported low and variable recoveries of PL during cheese making (Sachdeva and Buchheim, 1997; Turcot et al., 2001). This low recovery of PL could be explained by the origin of the PL in milk. Only about 60% of the PL is present in the milk fat globules, and the rest is in the skim milk serum phase (Huang and Kuksis, 1967; Patton and Keenan, 1974). The PL in SCB were from both the disrupted MFGM materials and PL present in milk serum phase. It was unclear how much of the PL from SCB were recovered in the cheese (because there are PL in the milk as well).

Cheese Yield

As expected, actual and moisture-adjusted yields in the SCB cheeses increased (Table 6), due to the higher

Table 5. Fat, nitrogen, and phospholipid (PL) recoveries for pizza cheeses ($n = 3$) made using the modified manufacturing protocol to adjust for the moisture in the sweet cream buttermilk (SCB) cheeses

Component recovery	Treatment ¹				SEM	P-value
	Control	2%-SCB	4%-SCB	6%-SCB		
% Fat recovery						
Cheese	89.81	88.45	87.66	87.49	0.488	NS
Drain whey	9.71 ^c	10.63 ^b	10.95 ^b	12.07 ^a	0.085	<0.0001
Pressed whey	0.05	0.06	0.07	0.07	0.007	NS
Wash water	0.48	0.44	0.43	0.53	0.057	NS
Total	100.05	99.59	99.11	100.16		
% Nitrogen recovery						
Cheese	73.65 ^b	74.51 ^b	75.81 ^a	76.07 ^a	0.340	<0.01
Drain whey	24.03	24.00	23.74	23.65	0.156	NS
Pressed whey	0.15	0.17	0.16	0.19	0.014	NS
Wash water	0.59	0.64	0.64	0.82	0.065	NS
Total	98.42	99.32	100.35	100.73		
% Drain whey ²	75.75 ^a	75.08 ^a	73.51 ^b	72.49 ^c	0.351	<0.01
% Pressed whey ²	1.75	1.75	2.28	1.93	0.201	NS
% Wash water ²	13.86 ^b	14.27 ^b	14.73 ^b	15.92 ^a	0.182	<0.01
% PL recovery in cheese	39.42 ^a	32.84 ^b	31.99 ^{bc}	30.14 ^c	0.410	<0.0001

^{a-c}Means within the same row not sharing a common superscript differ ($P < 0.05$).

¹Treatments: 2%-, 4%-, and 6%-SCB indicate various levels (wt/wt) of added sweet cream buttermilk (SCB) used for cheesemaking.

²Amount of drain whey, press whey, and wash water obtained from 100 kg of cheesemilk.

Table 6. Actual and calculated cheese yield values for pizza cheese ($n = 3$) made using the modified manufacturing protocol to adjust for the moisture in the sweet cream buttermilk (SCB) cheeses

Yield value	Treatment ¹			
	Control	2%-SCB	4%-SCB	6%-SCB
<i>RF</i> value ²	0.898	0.885	0.877	0.875
<i>RC</i> value ³	0.940	0.940	0.960	0.960
<i>RS</i> value ⁴	1.097	1.113	1.095	1.114
Actual yield (%)	9.37	9.69	10.22	10.79
Van Slyke cheese yield ⁵ (%) using <i>RF</i> , <i>RC</i> , and <i>RS</i> values	9.37	9.69	10.22	10.79
Averaged moisture-adjusted yield to 46% moisture, %	9.18	9.67	10.09	10.57

¹Treatments: 2%-, 4%-, and 6%-SCB indicate various levels (wt/wt) of added sweet cream buttermilk (SCB) used for cheesemaking.

²*RF* is the fat recovered in cheese, determined experimentally from cheese trials.

³*RC* was estimated using equation 2.

⁴*RS* was calculated using equation 7.

⁵Van Slyke cheese yield was calculated using equation 1, using milk and cheese composition data given in Table 4.

CN and fat content in the SCB-standardized milks (Table 4). Van Slyke cheese yield equations (equation 1) were developed for all 4 cheeses (Table 6). It has been our experience that an *RC* value of 0.96 perhaps reflects a maximum or ideal situation for CN recovery, and that, in practice, *RC* will be slightly lower. The *RC* values were calculated for control, 2%-, 4%-, and 6%-SCB cheeses using equation 2 and found to be 0.935, 0.940, 0.958, and 0.956, respectively. The calculated *RC* values were slightly higher for the SCB cheeses compared with the control cheeses, and increased with the increasing amount of SCB used (possibly due to some additional denatured whey proteins that were recovered along with CN in this cheese). Thus, all calculations were carried out using individual *RC* values for each cheese type as shown in Table 6. In this study, *RF* was determined experimentally from the cheese trials, and using the calculated values for *RC*, *RS* was calculated using equation 7. The developed Van Slyke cheese yield (Table 6) formula simultaneously predicted the experimentally obtained actual cheese yield and FDM (equation 6; results not shown).

pH and Proteolysis

When the manufacturing protocol was adjusted, both pH and the amount of 12% TCA-soluble nitrogen formed were similar among all the treatments (Table 7). The pH of all cheese slightly decreased with aging (Figure 2). As expected, the amount of 12% TCA-soluble nitrogen increased with age (Table 7). In our study, as the rennet:CN ratio was kept the same for both the control and experimental milk, there was no difference in the amount of 12% TCA-soluble nitrogen formed between any of the cheeses.

Rheological Properties

When cheese was heated, the values of G' decreased and LT increased at $>40^{\circ}\text{C}$ before decreasing at high temperatures ($\geq 70^{\circ}\text{C}$; results not shown). The maximum LT value and the temperature where this maximum occurred are shown in Figure 3. Cheeses from the control treatment tended to have the highest maximum LT values at all times studied compared with cheeses from SCB treatments; this became significantly ($P < 0.05$) different by wk 4 (Figure 3a). The value of LT at higher temperature has been used as index of meltability (Mounsey and O'Riordan, 1999). A high LT indicates a more liquid-like system, which could then flow and melt (Lucey et al., 2003). This result suggested that control cheeses were more meltable than cheeses with added SCB. The slightly lower maximum LT values in cheeses with added SCB could be due to the presence of denatured whey proteins (from SCB) complexed with CN, via disulfide bonds. This binding might hinder melting by cross-linking CN polymers and reduce the ability of the CN matrix to flow (Lelievre and Lawrence, 1988). A similar phenomenon also occurs in cheese made from severely heated milk (Banks et al., 1994; Lucey et al., 2003).

There was no significant difference in the temperature at which maximum LT occurred for any of the cheeses at each ripening point (Figure 3b, Table 7); the cheeses from 6% SCB treatment melted at lower temperature than other cheeses. The temperature at which maximum LT occurred decreased as a function of age (Figure 3b). This indicated that the older cheese melted at a lower temperature probably due to ongoing proteolysis and the shift from insoluble to soluble Ca; both of which occur during cheese ripening (Lucey et al., 2003, 2005). The crossover point (i.e., when $\text{LT} = 1$)

Table 7. Mean squares, probabilities (in parentheses), and R^2 for pH, 12% TCA-soluble N as a percentage of total nitrogen, rheological properties, and free oil formed (on fat basis) during ripening for 4 wk at 7°C of pizza cheese made with different content of sweet cream buttermilk (SCB, wt/wt) using the modified manufacturing protocol to adjust for the moisture in the SCB cheeses

	df	pH	12% TCA-soluble N (% of total N)	Temperature at which loss tangent (LT) = 1	Max. LT	Temperature at LT Max	Free oil formed on fat basis
Whole plot							
Treatment (T)	3	0.010 (0.110)	0.018 (0.98)	2.71 (0.40)	0.808** (<0.01)	17.32 (0.06)	58.51** (<0.01)
Day of cheese making (D)	2	0.011 (0.108)	2.74* (<0.05)	6.67 (0.13)	0.003 (0.87)	25.49* (<0.05)	136.60** (<0.01)
Error (T × D)	6	0.003	0.319	2.32	0.018	4.09	3.41
Subplot							
Age (A)	1	0.004* (<0.05)	2.43** (<0.01)	44.24** (<0.01)	1.64** (<0.01)	13.60** (<0.01)	539.14** (<0.01)
A × A	1	—	0.692* (<0.05)	—	—	—	382.82** (<0.01)
A × T	3	0.0004 (0.88)	0.021 (0.90)	1.25 (0.24)	0.127 (0.09)	1.63 (0.32)	41.28** (<0.01)
A × A × T	3	—	0.019 (0.91)	—	—	—	31.50* (<0.05)
Error	16	0.001	0.228	5.58	0.055	9.17	6.56
R^2		0.83	0.95	0.91	0.88	0.89	0.94

*0.01 < P ≤ 0.05; ** P ≤ 0.01.

has been used as another indicator of cheese meltability (Sutheerawattanonda and Bastian, 1998). There was no significant difference in the temperature of this crossover for any of the 4 cheese types (Table 7).

Free Oil Formation

The levels of free oil in cheese are shown in Figure 4. Free oil was expressed on a fat basis. The percentage free oil as a percentage of total cheese fat showed that addition of SCB significantly lowered ($P < 0.05$) free oil

formation at wk 1 (Figure 4, Table 7), but there were no significant differences at wk 2 and 4. The free oil formed in all cheeses increased with time except in control cheese. Control cheese had relatively constant levels of free oil during ripening (Figure 4). Mistry et al. (1996) found that reduced-fat Cheddar cheeses made with added SCB also had lower free oil levels than cheeses without added SCB. Poduval and Mistry (1999) suggested that the emulsification properties of the MFGM materials could have helped to reduce free oil formation.

Figure 2. pH for control (●), 2% sweet cream buttermilk (SCB) (▽), 4% SCB (■), and 6% SCB (◇) cheeses made with different contents of SCB (wt/wt) using the modified manufacturing protocol to adjust for moisture in the SCB cheeses during 4 wk of ripening of pizza cheeses at 7°C. Vertical bars represent standard deviations.

Sensory Evaluation

A summary of the sensory properties of cheese is shown in Table 8. Judges did not detect any high levels of oxidized flavors or any other off-flavors in the unmelted SCB cheeses. Treatment did not significantly affect oxidized flavors or any other off-flavors in the unmelted cheeses (Table 8). Buttermilk contains a high concentration of polyunsaturated fatty acids that could make it susceptible to oxidative deterioration (O'Connell and Fox, 2000). Mistry et al. (1996) reported that the flavor and flavor intensity scores were not different among treatments but an off-flavor was noted occasionally by some panelists in cheeses made with 5% UF SCB. Drake et al. (1998) determined that granulated soy lecithin improved yields and the texture of 33% reduced-fat cheeses; however, at the concentrations studied (i.e., as little as 0.025% wt/wt), off-flavors occurred as a result of soy lecithin catalyzing lipid auto-oxidation reactions in cheeses. Soy lecithin contains phosphatidylcholine, phosphatidylethanolamine, and

Figure 3. Changes in the maximum loss tangent (LT) (a) and the temperature of the maximum LT (b) as a function of ripening time for the control (●), 2% sweet cream buttermilk (SCB) (▽), 4% SCB (■), and 6% SCB (◇) cheeses made with different content of SCB (wt/wt) using the modified manufacturing protocol to adjust for moisture in the SCB cheeses during 4 wk of ripening of pizza cheeses at 7°C. Vertical bars represent standard deviations.

phosphatidylinositol (Nawar, 1985). Because more than 50% of the fatty acid in granular soy lecithin is linoleic acid and as this unsaturated fatty acid is susceptible to lipid oxidation, linoleic acid may be a source of off-flavor (Drake et al., 1998).

After modification of cheese moisture contents, there were no differences in bitterness, saltiness, acidity, firmness, or smoothness between the unmelted control and SCB cheeses (results not shown). Strand length is an empirical parameter used to analyze the stretch quality of cheese. Stretch is the ability of protein network to maintain its integrity when a stress is applied to cheese (Lucey et al., 2003). The extent of stretch for pizza cheeses with added SCB was significantly lower ($P < 0.01$) than for control cheese (Table 8). Strand thickness and cohesiveness were significantly ($P < 0.01$) higher in control cheeses compared with cheeses made with SCB (Table 8). For cheeses with similar moisture, denatured whey proteins from SCB probably disrupted

Figure 4. Changes in the free oil formed on fat basis for the control (●), 2% sweet cream buttermilk (SCB) (▽), 4% SCB (■), and 6% SCB (◇) cheeses made with different content of SCB (wt/wt) using the modified manufacturing protocol to adjust for moisture in the SCB cheeses during 4 wk of ripening of pizza cheeses at 7°C. Vertical bars represent standard deviations.

the CN network and inhibited stretch. As the cheeses aged, the strand length decreased for all cheeses, probably due to breakdown of the CN network by residual coagulant (Lucey and Fox, 1993).

Control cheeses were significantly ($P < 0.05$) chewier after baking compared with cheeses fortified with condensed SCB. The matrix in cheeses fortified with SCB may have been weaker, which could explain why these cheeses were less chewy. Mistry et al. (1996) reported that reduced-fat Cheddar cheese made with 5% UF SCB had lower hardness values after 4 wk of ripening than control cheese (cheeses had similar moisture contents). Control cheese exhibited more extensive flow compared with cheeses made with added SCB (results not shown). This finding agreed with the higher maximum LT results in control cheese (Figure 3a).

Cheeses from control treatment exhibited significantly ($P < 0.05$) more oiling-off on pizza than cheeses made with SCB (Table 8), especially at the 6% SCB level. As the cheeses aged, the amount of free oil did not significantly increase. This finding did not agree with the chemical analysis of free oil and suggested that the chemical extraction method may not be as useful (i.e., of practical value) for the determination of free oil for this type of cheese. The chemical method for the assessment of free oil was developed for Mozzarella cheese (Kindstedt and Rippe, 1990), which is known to exhibit considerable oiling-off during baking. The pizza cheese used in this experiment was not a stretched curd cheese and free oil formation on pizza was relatively low.

Table 8. Mean squares, probabilities (in parentheses), and R^2 for sensorial properties of the cheeses made with different content of sweet cream buttermilk (wt/wt) using the modified manufacturing protocol, melted on pizzas in a forced-air commercial oven during the 4-wk ripening period

	df	Free oil	Strand length	Thickness of strand	Cohesiveness of strand	Chewiness	Oxidized flavor ¹
Whole plot							
Treatment (T)	3	4.25* (<0.05)	304.17** (<0.01)	2.94** (<0.01)	21.40** (<0.01)	0.36* (<0.05)	0.22 (0.39)
Day of cheese making (D)	2	8.59* (<0.01)	41.80 (0.09)	23.44** (<0.01)	3.22 (0.29)	3.62** (<0.01)	1.37* (<0.05)
Error (T × D)	6	0.692	4.78	0.241	2.10	0.07	0.19
Subplot							
Age (A)	2	0.049 (0.86)	35.34 (0.06)	1.51 (0.23)	4.17 (0.06)	1.00* (<0.05)	1.28 (0.08)
A × T	6	0.234 (0.64)	4.78 (0.84)	0.50 (0.78)	0.62 (0.80)	0.04 (0.96)	0.23 (0.50)
Error	16	0.323	10.65	0.938	1.24	0.19	0.25
R^2		0.87	0.87	0.81	0.83	0.79	0.68

¹Oxidized flavor of the unmelted cheese chunks.*0.01 < P ≤ 0.05; ** P ≤ 0.01.

CONCLUSIONS

Without adjusting the cheese-making procedure, the addition of SCB greatly increased the moisture content and resulted in high-acid cheeses. Altering the manufacturing protocol eliminated differences in moisture contents. For cheeses of similar moistures, the addition of SCB improved yield and had little impact on sensory attributes of cheeses. However, melt and stretch characteristics were slightly lower for cheeses with 4 and 6% SCB addition. The increase in moisture content and lower melt could be due to the presence of denatured whey proteins in the condensed SCB, as it had been subjected to several heat treatments. Phospholipid recovery in SCB-fortified cheeses was low; much of the nutritionally valuable ingredient was not recovered. Significant levels of oxidized off-flavors were not noted in SCB-fortified cheeses. High levels of SCB did result in significant decrease in free oil on pizza, suggesting that SCB could be a potentially useful ingredient in cheese making. Overall, using SCB as a cheese ingredient at high levels (≥6%) could adversely affect cheese texture, melt, and sensory properties. At low levels (~2%), however, the addition of condensed SCB improved cheese yield without adversely affecting the compositional, rheological, and sensory properties of pizza cheese (when the cheese moisture content was adjusted to be similar to that of the control cheese). Using very high levels of condensed SCB causes acid defects because of the high lactose content in the condensed SCB. This issue could be alleviated using UF or diafiltration to produce concentrated SCB with reduced lactose content.

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