Impact of Seasonal Changes in Ovine Milk on Composition and Yield of a Hard-Pressed Cheese

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ABSTRACT

A hard-pressed, brined cheese was produced from frozen ovine milk collected in February, May, and August. Solids in the milk decreased as the season progressed. This was a result of high solids in early-lactation milk and low solids in August milk because of hot weather and poorer quality pastures. Casein as a percentage of true protein and the casein to fat ratio were higher in May and August milk. Fat in the cheese from February milk was higher and total protein was lower than in May and August. Milk, whey, and press whey composition were influenced by season and followed the trends of milk composition. Fat recovery in the cheeses ranged from 83.2 to 84.2%. Protein recovery in the cheeses was not affected by season. Cheese yield from February milk was higher than from May and August milk and was a result of higher casein and fat in the milk.

(Key words: hard-pressed cheese, ovine, stage of lactation, cheese yield)

Abbreviation key: AM = milk from ewes in August, FM = milk from ewes in February, MM = milk from ewes in May.

INTRODUCTION

Because milk costs represent over 85% of the cost of producing cheese, it is critical to review factors influencing milk composition and resulting cheese yield. Fat and casein are the 2 primary milk components that are recovered in the cheese making process and are directly related to cheese yield. Because the price for raw ovine milk is more than 4 times that of bovine milk, it is especially critical for the manufacturers of ovine milk cheeses to be able to estimate cheese yields from milk of varying composition.

The majority of ovine milk in the United States is produced on a seasonal basis, with the lactation running from early spring until fall. In bovine milk, both fat and protein tend to increase throughout lactation, which should result in higher cheese yield for late-lactation milk (Feagan, 1979; Schultz et al., 1990). However, in some previous studies on bovine milk (Lelievre et al., 1983; Ozimek and Kennelly 1994; Sapru et al., 1997), researchers showed no significant increases and, in some cases, decreases in yield with late-lactation milk. Changes in milk composition and increases in SCC in late-lactation milk have resulted in lower levels of casein, and decreased cheese yield capacity (Gilles and Lawrence, 1985; Sapru et al., 1997).

Several researchers (Requena et al., 1999; Barron et al., 2001) have reported on seasonal or lactational changes in milk composition of dairy sheep. The composition of ovine milk during the milking season principally reflects the lactational and nutritional differences (Barron et al., 2001). In ovine milk, fat concentration increases at a higher rate than casein in late lactation so that the casein to fat ratio in the milk decreases throughout lactation (Pellegrini et al., 1997). Several reports of cheese yields for ovine milk have been published (Economides et al., 1987; Jordan and Boylan, 1995; Wendorff, 2002; Jaeggi et al., 2003); however, information on stage of lactation or season was not reported.

Currently, yield predictability relative to seasonal changes in ovine milk composition is lacking. The objectives of this study were to determine the influence of milking season on fat and nitrogen recoveries in a hard-pressed cheese and to determine actual and composition-adjusted cheese yields from ovine milk. This hard-pressed cheese is similar to Manchego cheese produced from ovine milk in the La Mancha region of Spain. Manchego is the one of the best-known hard-pressed ovine milk cheeses currently imported into the United States.

MATERIALS AND METHODS

Milk Samples

Milk from East Friesian-crossbred ewes was obtained at 3 stages of the milking season [February (FM), May

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(MM), and August (AM)] from the Agricultural Research Station of the University of Wisconsin-Madison located in Spooner, WI. Lambs were removed from the ewes after 24 to 36 h postpartum and ewes were milked twice daily as previously described (McKusick et al., 1999). Milk was collected from ewes starting at d 4 after lambing. The nutrition of the ewes varied throughout the milking season. In February, the ewes were fed 5 kg of alfalfa haylage daily plus 454 g of a 16% CP concentrate made of shelled corn and pelleted soybean meal at each milking. In May, the ewes were pastured on orchardgrass and Kura clover for 9 h and given 454 g of the concentrate at each milking. In August, the ewes were pastured on the orchardgrass and Kura clover and given 227 g of concentrate at each milking.

Milk was collected daily from the flock until 909 kg was obtained for each stage of lactation. To accumulate sufficient milk for cheese making, the milk was frozen in sealed polyethylene-lined 13-kg pails at -19°C and stored for less than 2 mo before it was used for cheese manufacturing. Previous studies have shown that raw ovine milk can be stored frozen for several months at -20°C without significant effect on milk composition or cheese making properties (Bastian, 1994; Wendorff, 2001). Milk was collected in February, May, and August 2002 (FM, MM, and AM, respectively). Somatic cell counts for each lot of milk were analyzed by a State of Wisconsin certified laboratory.

Cheese Manufacture and Sampling

Before cheese making, the milk was thawed at 7°C over a 3-d period. A licensed Wisconsin cheese maker manufactured the hard-pressed cheese in the University of Wisconsin dairy processing pilot plant. Five vats of cheese (136.2 kg of milk) were made from a single commingled batch of milk from each stage of lactation. Milk was pasteurized at 72°C for 19 s. The milk was cooled to the ripening temperature (31°C), and a mesophilic DVS culture (F-DVS 850, Chr. Hansen, Inc., Milwaukee, WI) was inoculated into the milk. Cheese was produced through the end of the whey drainage by the procedure outlined in a previous study (Jaeggi et al., 2003). Twenty minutes from completion of whey drainage, 454 g of salt was added to the curd. All of the whey collected from draining to the beginning of salting was saved from each vat and sampled at the end of cheese making. Press whey was collected from the beginning of salting through the end of pressing. Curd from each vat was packed into 2 Wilson stainless steel hoops each weighing about 11 kg and pressed for 4 h at -20°C . The blocks were then placed in a 10°C tempering room for 16 h. Subsequent to the tempering room, the cheeses were removed from the molds and weighed. They were

then placed in saturated brine for 48 h at 5°C . Upon removal from the brine, the blocks were again weighed, and then dried in a commercial facility at 68% RH and 15°C for 5 wk. The blocks were vacuum-packaged in Cryovac standard clear bags (9Fv86, Cryovac North America, Duncan, SC) and aged at 7°C . At each sampling time, the bag was opened and a representative sample was cut from one of the cheese blocks and ground for compositional analysis.

All compositional analyses were carried out on the cheeses in triplicate. Pasteurized milk whey, and press whey samples were analyzed for total solids (Green and Park, 1980), fat by Mojonnier, (procedure 989.05; AOAC, 2000), protein (total percentage N $\times$ 6.38) by Kjeldahl, (procedure 991.20; AOAC, 2000) and casein, (procedure 998.50; AOAC, 2000). Nonprotein nitrogen of the milks was measured using the method described by Johnson et al. (2001). Cheeses were analyzed before brining and after drying for moisture by vacuum oven (Marshall, 1992), fat by Mojonnier, (procedure 933.05; AOAC, 2000), pH by the quinhydrone method (Marshall, 1992), salt by chloride electrode method (model 926; Corning Glass Works, Medfield, MA; Johnson and Olson, 1985) and protein (total percentage N $\times$ 6.31) by Kjeldahl, (procedure 991.20; AOAC, 2000).

Fat and Nitrogen Recovery and Predictive Cheese Yield Formula

The total weight of fat and N (protein) in milk, whey and press whey, and cheese were calculated and expressed as a percentage of the total weight of fat or N in milk.

Actual percentage cheese yield was determined for each vat of cheese (before and after drying) by dividing the weight of the cheese by the weight of the original standardized milk (including the amount of cultures added during the cheese manufacture), and multiplying by 100. Actual cheese yields were compositionally adjusted as determined by Lau et al. (1990) to a cheese moisture content of 39% (before brining) or 30% (after brining and drying) to eliminate the effects of variations in moisture between trials.

Statistical Analyses

Results were analyzed using one-way ANOVA and Tukey's difference test on Minitab statistical software (Release 13.32; Minitab, Inc., State College, PA). The level of significance was determined at $P < 0.05$.

RESULTS AND DISCUSSION

Milk Composition

Average composition of the pasteurized ovine milk for each portion of the season is shown in Table 1.

Table 1. Influence of season on the composition (Mean $\pm$ SD) of ovine milks used for the manufacture of hard-pressed cheese.

	Milk ¹		
	FM	MM	AM
Total solids, %	19.28 (0.14)	18.81 (0.20)	17.29 (0.40)
Milk fat, %	7.58 (0.03)	6.74 (0.12)	6.59 (0.09)
Total protein, %	5.74 (0.02)	5.61 (0.08)	5.41 (0.05)
True protein, %	5.33 (0.02)	5.27 (0.08)	5.09 (0.05)
Casein, %	4.34 (0.02)	4.33 (0.08)	4.25 (0.06)
Casein/true protein, %	81.50 (0.00)	82.00 (0.02)	83.50 (0.00)
Casein:fat ratio	0.57 (0.01)	0.65 (0.02)	0.64 (0.01)
SCC/mL	480,000	360,000	390,000

¹FM = February milk, MM = May milk, AM = August milk.

Total solids, milk fat, and total protein decreased as the season progressed. Casein concentration was similar in FM and MM, but lower in AM. Cheese made from FM contained a higher percentage of whey proteins, as indicated by the lower casein to true protein ratio. The higher fat and protein in FM was also observed by McKusick et al. (1999) when lambs were weaned at d 1 and ewes were milked twice daily. The lower levels of fat and protein in early lactation milk reported by Pellegrini et al. (1997) were from milk from ewes 48 to 55 d after lambing. The slightly lower fat and true protein in AM varied from the typical lactational trends of higher fat and protein in late-lactation ovine milk reported by other workers (Pellegrini et al., 1997; Requena et al., 1999; Barron et al., 2001). This was most likely due to the impact of hotter temperatures during August or poorer pastures resulting in lower solids milk similar to that observed in bovine milk (Barbano and Sherbon, 1984; Lawrence, 1991). Somatic cell counts were not elevated in late-lactation milk as previously

reported by some researchers (Gonzalo, 1995; Antunac et al., 2002).

Cheese Composition

Cheeses from FM had higher fat and lower protein than cheeses from MM or AM (Table 2). This was the result of having milk with a lower casein:fat ratio in the FM. There was no significant impact of season on moisture of cheeses before brining. Salt present in the cheeses before brining was the result of salt added to the curd before hooping. No significant differences were observed in coagulation rate or in time from set to hooping for the 3 sources of milk. Coagulation rate ranged from 55 to 61 min after set. Time from set to hooping ranged from 150 to 155 min. After 2 mo of aging and drying, cheeses from FM were higher in fat and lower in protein than MM and AM (Table 3). This resulted in significantly higher fat in the DM of the FM cheese. Moisture and salt was not significantly impacted by

Table 2. Influence of season on the composition of a hard-pressed ovine milk cheese (at 1 d) before brining and drying.

	Milk ¹		
	FM	MM	AM
Moisture, %	38.70	38.78	39.40
Milk fat, %	34.46 ^a	32.78 ^b	32.53 ^b
Protein, ² %	22.63 ^b	24.19 ^a	23.59 ^a
Salt, %	0.50	0.35	0.38
MNFS, ³ %	59.05	57.68	58.40
FDM, ⁴ %	56.22 ^a	53.54 ^b	53.68 ^b
S/M, ⁵ %	1.28	0.90	0.95
pH	4.97	4.96	4.94

^{a,b}Means within the same row without a common superscript differ ($P < 0.05$).

¹FM = February milk, MM = May milk, AM = August milk.

²Total percentage N $\times$ 6.31.

³MNFS = Moisture in nonfat substance.

⁴FDM = Fat in dry matter.

⁵S/M = Salt as a percentage of moisture.

Table 3. Influence of season on the composition of a hard-pressed ovine milk cheese after brining and drying (2 mo of age).

	Milk ¹		
	FM	MM	AM
Moisture, %	30.94	30.39	30.71
Milk fat, %	37.19 ^a	35.46 ^b	35.70 ^b
Protein, ² %	24.84 ^b	26.59 ^a	26.13 ^a
Salt, %	1.99	1.82	2.13
MNFS, ³ %	49.25	47.08	47.77
FDM, ⁴ %	53.87 ^a	50.94 ^b	51.53 ^b
S/M, ⁵ %	6.48	5.98	6.94
pH	5.06 ^a	5.01 ^b	5.08 ^a

^{a,b}Means within the same row without a common superscript differ ($P < 0.05$).

¹FM = February milk, MM = May milk, AM = August milk.

²Total percentage N $\times$ 6.31.

³MNFS = Moisture in nonfat substance.

⁴FDM = Fat in dry matter.

⁵S/M = Salt as a percentage of moisture.

Table 4. Influence of season on the composition of whey and press whey from hard-pressed ovine milk cheese manufacture.

	Milk ¹		
	FM	MM	AM
Whey			
Solids, %	9.50 ^a	9.54 ^a	8.70 ^b
Fat, %	1.46 ^a	1.16 ^b	1.24 ^b
Total protein, ² %	1.75 ^a	1.63 ^b	1.54 ^c
True protein, ³ %	1.18 ^a	1.13 ^b	1.08 ^c
F/P, ⁴ %	1.23 ^a	1.02 ^b	1.15 ^{ab}
Press whey			
Solids, %	14.65 ^a	13.44 ^b	11.58 ^c
Fat, %	5.69 ^a	4.22 ^b	3.33 ^b
Total protein, ² %	1.82 ^a	1.70 ^b	1.61 ^c
True protein, ³ %	1.27 ^a	1.22 ^{ab}	1.18 ^b
F/P, ⁴ %	4.48 ^a	3.46 ^b	2.83 ^b

^{a,b,c}Means within the same row without a common superscript differ ($P < 0.05$).

¹FM = February milk, MM = May milk, AM = August milk.

²Total percentage N $\times$ 6.35.

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

⁴F/P = Fat in true protein.

season. Lower percentage fat in the DM of cheese, after brining, was due to an increase in salt content of the cheese.

Whey and Press Whey Composition

Fat and protein were significantly higher in FM whey than in MM or AM whey (Table 4). Solids in the AM whey were significantly lower than FM or MM. Whey from FM contained the highest level of fat per unit of true protein of the 3 milk sources. This could influence the quality of whey protein concentrate produced from the FM whey. Press whey from FM also showed the highest fat and protein of the press wheys. This could be anticipated because the fat and protein content of FM milk was higher in concentration than MM or AM milk. Solids, fat, and protein were slightly higher than previously reported for Manchego whey by Casper et al. (1998).

Fat and Nitrogen Recoveries

There was no significant difference in total accountability for fat during cheese manufacture between the 3 portions of the milking season. Season had no significant effect on fat retention in the cheeses produced from the 3 sources of milk before brining and drying (Table 5). Cheese from MM lost a smaller percentage of fat in whey but a greater percentage of fat in press whey than AM. Pirisi et al. (2000) reported fat retentions of 78.0 to 81.4% for uncooked semihard cheese from ovine milk whereas Economides et al. (1987) reported 86.9% fat retention in Halloumi cheese from ovine milk. Fat re-

Table 5. Influence of season on fat and nitrogen recoveries during the manufacture of a hard pressed ovine-milk cheese (1 d) before brining and drying.

	Milk ¹		
	FM	MM	AM
	%		
Fat recovery			
Whey	14.75 ^a	13.24 ^b	14.83 ^a
Press whey	2.40 ^a	2.42 ^a	1.44 ^b
Cheese	83.8	84.2	83.2
Total fat	100.95	99.86	99.47
N recovery			
Whey	23.33 ^a	22.20 ^b	22.55 ^b
Press whey	1.04 ^{ab}	1.20 ^a	0.86 ^b
Cheese	73.02	75.25	73.84
Total N	97.39	98.65	97.75

^{a,b}Means within the same row without a common superscript differ ($P < 0.05$).

¹FM = February milk, MM = May milk, AM = August milk.

tention in a hard-pressed ovine cheese is considerably lower than the 93% used for the theoretical cheese yield formula for Cheddar cheese (Van Slyke and Price, 1979). Lower fat retention with ovine milk may be due to the higher percentage of smaller fat globules in ovine milk (Antifantakis, 1986) and the structure of the casein network of the curd at cutting. Higher casein milks may produce gels with larger pore size, leading to higher fat loss (Johnson et al., 2001). There was no significant difference in total accountability for N during cheese manufacture between the 3 milk samples. There was no significant difference in recovery of N in the form of cheese. There was a higher percentage of N recovery in the FM whey than the MM and AM whey. This result was expected because the initial casein to true protein ratio of FM was lower than the MM and AM (Table 1). This may have been a result of casein degradation due to elevated SCC in the FM or higher serum proteins present in milk from initial stages of lactation. Pirisi et al. (2000) reported protein recovery values for uncooked semihard cheese from ovine milk ranging from 75.4 to 79.5%.

Cheese Yield

Average actual and composition-adjusted cheese yields are given in Table 6. Substantial differences in composition-adjusted percentage cheese yields, and small differences in percentage fat and percentage nitrogen recoveries between trials, indicate that difference in milk composition (casein and fat) was the major factor responsible for differences in cheese yield.

CONCLUSIONS

Results of this study showed that seasonal changes had a significant impact on milk composition, cheese

Table 6. Actual and composition-adjusted cheese yields before (1 d) and after brining and drying (2 mo).

	Milk ¹		
	FM	MM	AM
Actual yield before brining, %	18.45	17.29	16.78
CACY before brining, ² %	18.52	17.38	16.75
Actual yield after drying, %	17.01	15.84	15.41
CACY after drying, ³ %	16.79	15.80	15.26

¹FM = February milk, MM = May milk, AM = August milk.

²Composition-adjusted cheese yield (CACY) at 39% moisture.

³Composition-adjusted cheese yield (CACY) at 30% moisture.

composition, and cheese yield. As the season progressed, milk fat and casein decreased because of increased solids in early-lactation milk and decreased solids in the milk produced during hot summer temperatures and poorer quality pastures. This resulted in decreased cheese yields. Fat and protein recoveries in the cheese were not significantly different over the season. Cheese yields were directly related to the level of fat and casein in the initial milk.

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