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WDATCP – Ag. Development and Diversification Program
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FINAL REPORT

Development of predictive formula for estimation of cheese yield from sheep milk

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Project Background

In 1995, the University of Wisconsin expanded their sheep research at the Spooner station to include dairy sheep. . Since that time, the University of Wisconsin has provided research and technical support to the industry to help producers get started in milking sheep and to help processors learn how to process sheep milk. Some of the research on the processing side has included studies on proper handling of frozen raw milk, manufacture of sheep milk cheeses, yogurt, and dry milk products and potential food uses for sheep whey (1, 2, 3, 4, 5).

Up to the current time, sheep milk has been sold to cheesemakers based on weight only. Milk composition obviously varies between different flocks and also varies throughout the lactation. Cheesemakers have used the Van Slyke-Price cheese yield formula to predict potential cheese yields to expect from cow and goat milk sources and to estimate milk costs. They also use the Van Slyke-Price formula in standardizing their cheese milk to produce specific compositions in their finished cheeses. This is necessary to provide consistency in the quality of their cheeses and to control the cost of producing those cheeses.

Sheep milk is uniquely different from cow or goat milk. Sheep milk has about twice the fat of cow milk and 40% more protein than cow milk. Sheep milk, with the high solids, responds differently in the cheese manufacturing procedure than cow or goat milk. Since sheep milk is about 5 times the cost of cow milk, cheesemakers are very concerned with recovery of those milk solids in the form of cheese.

With this proposed study, we plan to determine fat, casein, and other milk solids recovery data from actual cheesemaking trials. We will evaluate the impact of stage of lactation on these recovery coefficients. We will then determine the best coefficients to use in the Van Slyke-Price formula for sheep milk cheeses. This will then provide the cheesemakers with a useful management tool for predicting potential cheese yields from sheep milk. This can also then be used to determine yield efficiencies in the cheese make procedures of the plant. Eventually, use of the cheese yield formula will impact pricing of sheep milk from the producer. This may be in the form of a cheese yield quality premium for high solids milk or indirectly through payment for fat and protein content in the form a multiple component pricing similar to that of cow's milk. This change in payment structure will certainly impact the breeding, selection and management programs used by dairy sheep producers.

Summary of Project

Manchego cheese was produced from sheep milk from February, May, and August. Solids in the milk decreased as the season progressed. Casein as a percentage of true protein and the casein to fat ratio was higher in May and August milk. Fat in the cheese from February milk was higher and protein lower than May and August. Whey and press whey composition was also impacted by season. Fat and protein losses in whey and press whey from February milk were higher than that from May and August milks. Fat recovery in the cheeses were not affected by milking season and ranged from 83.05 to 84.23 %. Protein recovery in cheese from May milk was significantly better than cheese from February milk. Cheese yield from February milk was higher than May and August milk and was a result of higher solids in the milk. Recoveries of fat, protein, and solids from this study indicate that the Van Slyke-Price cheese yield formula can be used for calculating theoretical cheese yield from sheep milk.

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

INTRODUCTION

Since 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 two primary milk components that are recovered in the cheesemaking process and are directly related to cheese yield. Since the price for raw sheep milk is over four times that of cow milk, it is especially critical for the manufacturers of sheep milk cheeses to be able to estimate cheese yields from milk of varying composition.

The majority of sheep milk in the United States is produced on a seasonal basis, with the lactation running from early spring until fall. Several researchers (Barron et al., 2001; Requena et al., 1999) have reported on seasonal or lactational changes in milk composition of dairy sheep. The composition of sheep milk during the milking season principally reflect the lactational and nutritional differences (Barron et al., 2001). In sheep milk, fat concentration increases at a disproportionate level to casein in late lactation so that the casein to fat ratio in the milk decreases throughout the lactation (Pellegrini et al., 1997). Several reports of cheese yields for sheep milk have been published (Economides et al., 1987, Jaeggi et al., 2003, Jordan and Boylan, 1995; Wendorff, 2002), however, information on stage of lactation or season was not reported.

Currently, adequate information does not exist to predict cheese yield from sheep milk composition. The objectives of this study were to determine the influence of milking season on fat and nitrogen recoveries in Manchego cheese and to determine actual and composition adjusted cheese yields from sheep milk. Manchego cheese originating from the La Mancha region in Spain is the best known of the sheep milk cheeses that are currently imported into the US. For this reason, Manchego-type cheese was manufactured in this study.

MATERIALS AND METHODS

Milk Samples

Milk from East Fresian-crossbred ewes was obtained at three different stages of the milking season (FM, MM, and AM) from the Agricultural Research Station of the University of Wisconsin-Madison located in Spooner, Wisconsin. Lambs were removed from the ewes at day 1 and were milked twice daily as previously described (McKusick et al., 1999). 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% crude protein concentrate made of shelled corn and pelleted soybean meal at each milking. In May, the ewes were pasteured on orchard grass and Kura clover for 9 h and given 454 g of the concentrate at each milking. In August, the ewes were pasteured on the orchard grass 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. The milk was frozen in covered and sealed polyethylene-lined 13-kg pails at –19°C and stored for less than 2 mo before it was used for cheese manufacturing (Wendorff, 2001). FM was collected in February 2002, MM in May 2002, and AM in August 2002. Somatic cell counts (SCC) for each lot of milk was analyzed by a State of Wisconsin certified laboratory.

Cheese Manufacture and Sampling

Prior to cheesemaking, the milk was thawed at 7°C over a 3-day period. A licensed Wisconsin cheese maker manufactured the Manchego cheese in the University of Wisconsin dairy processing pilot plant. Five vats of cheese (136.2 kg of milk) were made from each stage of lactation. Milk was pasteurized at 72°C for 15 s. The milk was cooled down 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 by the procedure as outlined in a previous study (Jaeggi et al., 2003). All of the whey collected from draining to pressing was saved for each vat and sampled at the end of cheesemaking. Press whey was collected from each respective group of wheels from each vat and sampled at the end of pressing. Curd was packed into 6 Manchego round hoops each weighing about 3.5 kg and pressed for 4 h at ~ 20°C. Subsequent to pressing, the cheeses were placed in saturated brine for 18 h at 5°C. Polycoat (HB Fuller, Minneapolis, MN) was applied to cheese surfaces and cheeses were aged at 7°C in an 85% humidity-controlled room. At each sampling time point, a representative wedge was cut from a new Manchego wheel and ground for compositional analysis.

All compositional analyses were carried out on the cheeses in duplicate. Pasteurized milk whey, and press whey samples were analyzed for total solids (Green and Park, 1980), fat by Mojonnier (AOAC, 1995), protein (total percentage N × 6.35) by Kjeldahl (AOAC, 1995) and casein (AOAC, 1995). Non-protein nitrogen (NPN) of the milks was also measured using the method described by Johnson et al. (2001). Cheeses were analyzed for moisture by vacuum oven (Vanderwarn, 1989), fat by Mojonnier (AOAC, 1995), pH by the quinhydrone method (Marshall, 1992), salt by chloride electrode (model 926; Corning Glass Works, Medfield, MA; Johnson and Olson, 1985) and protein by Kjeldahl (AOAC, 1995).

Fat and Nitrogen Recovery and Yield Calculations

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. Both the actual and normalized recoveries were calculated as described by Lau et al. (1990). The actual and composition adjusted cheese yield was determined as outlined by Lau et al. (1990) using 39.0 % moisture as the desired cheese moisture.

Statistical Analysis

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 sheep milk for each portion of the season is shown in Table 1. Total solids, milk fat, and total protein decreased as the season progressed. Casein concentration was even throughout the season. 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 day 1 and ewes milked twice daily. The lower levels of fat and protein in early lactation milk reported by Pellegrini et al. (1997) was from milk from ewes 48-55 days after lambing. The slightly lower fat and true protein in AM was varied from the typical lactational trends of higher fat and protein in late lactation sheep milk reported by other workers (Barron et al., 2001; Pellegrini et al., 1997; Requena et al., 1999). This most likely was due to the impact of hotter temperatures during the month of August or poorer pastures resulting in lower solids milk similar to that experienced in cow milk (Barbano and Sherbon, 1984; Lawrence, 1991). SCC were not elevated in late lactation milk as previously reported by some researchers (Antunac et al., 2002; Gonzalo, 1995).

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 C/F ratio in the FM. There was no significant impact of season on moisture of cheeses prior to brining. Salt present in the cheeses prior to brining was recovered from the milk salts present in the serum portion of the cheese. No significant differences were observed in coagulation rate or in time from set to hooping for the three sources of milk. After 2 mo of aging and drying, cheeses from FM and MM were higher in fat and lower in protein than AM (Table 3). Moisture and salt was not significantly impacted by season.

Whey and Press Whey Composition

Fat and protein were significantly higher in FM whey than MM or AM whey (Table 4). Solids in the AM whey were significantly lower than FM or MM. FM whey contained the highest level of fat per unit of true protein of the three milk sources. FM press whey also showed the highest fat, protein and solids of the press wheys. Solids, fat and protein were slightly higher than those 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 three portions of the milking season (n = 15). Accordingly, the data for fat recovery were normalized, as described by Lau et al. (1990). Season had no significant effect on fat retention in the cheeses produced from the three sources of milk (Table 5). 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 – 81.4% for uncooked semi-hard cheese from sheep milk while Economides et al. (1987) reported 86.9% fat retention in Halloumi cheese from sheep milk. Fat retention in Manchego cheese is considerably lower than the typical 93% assumed for

the predicted cheese yield formula for Cheddar cheese (Lau et al., 1990; Van Slyke and Price, 1979). Part of this may be due to the higher percentage of smaller fat globules in sheep milk (Antifantakis, 1986) and partly due to the difference in fat retention with different make procedures (Kosikowski and Mistry, 1997; Wendorff, 2002).

There was no significant difference in total accountability for N during cheese manufacture between the three milk samples (n = 15). Accordingly, the data for N recovery were normalized, as described by Lau et al. (1990). FM had a lower recovery of N in the form of cheese compared to MM and a higher percentage of N in the whey. This result was expected since 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 either casein degradation due to high SCC in the FM or higher whey proteins present in milk from initial stages of lactation. Pirisi et al. (2000) reported protein recovery values for uncooked semi-hard cheese from sheep milk ranging from 75.4 to 79.5%. Casein loss in the whey and press whey of each vat of cheese manufactured ranged from 0.7 to 2.2% which is well within the assumed casein loss of (C-0.1) used in the Van Slyke-Price cheese yield formula (Van Slyke and Price, 1979). Using (C-0.1) as the casein retention value in the Van Slyke-Price, the solids retention factors for FM, MM and AM milk were 1.075, 1.076, and 1.068, respectively.

Cheese Yields

Actual yields and composition adjusted yields decreased as the season progressed (Table 6). These decreases were due to the lower fat and casein present in the MM and AM milk samples. Using the average fat retention factor of .84, casein retention as (C-0.1), and solids retention factor of 1.073, theoretical cheese yields for Manchego using the Van Slyke-Price cheese yield formula would have resulted in cheese yield efficiencies ranging from 98.3 to 99.9 %.

CONCLUSIONS

Results of this study showed that seasonal changes had a significant impact of milk composition, cheese composition and cheese yield. As the season progressed, milk solids decreased resulting in decreased cheese yields. Fat recoveries in the cheese were not significantly different over the season but protein recovery in the cheese was significantly better in May milk than in February milk. Cheese yields were directly related to the level of solids in the initial milk. Results of the study show that the Van Slyke-Price cheese yield formula could be effectively used to predict cheese yield for Manchego cheese from sheep milk. The cheese yield for hard cheese, e.g., Manchego, from sheep milk would be:

$$\text{Cheese yield} = \frac{(0.84F + C - 0.1)1.073}{100 - W}$$

where: F = fat concentration in the milk, %
C = casein concentration in the milk, %
W = moisture, expressed as Kg water per Kg of cheese

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Table 1. Influence of season on the composition of sheep milks used for the manufacture of Manchego cheese.

	FM[1,2]	MM[1,2]	AM[1,2]
Total solids, %	19.22 (.18)	18.80 (.19)	17.34 (.28)
Milk fat, %	7.57 (.03)	6.74 (.12)	6.59 (.09)
Total protein, %	5.72 (.04)	5.61 (.08)	5.41 (.05)
True protein, %	5.31 (.04)	5.27 (.08)	5.09 (.05)
Casein, %	4.33 (.04)	4.32 (.08)	4.25 (.06)
Casein /true protein, %	81.40 (.55)	83.50 (.58)	83.80 (.45)
Casein:fat ratio	.57 (.01)	.65 (.01)	.64 (.01)
SCC/ml[3]	480,000	360,000	390,000

[1] FM = February milk, MM = May milk, AM = August milk.
[2] Mean with standard deviation in parenthesis.
[3] SCC = Somatic cell count

Table 2. Influence of season on the composition of Manchego cheese prior to brining.

	FM[1,2]	MM[1,2]	AM[1,2]
Moisture, %	39.07	39.05	39.40
Milk fat, %	34.04[a]	32.77[b]	32.53[b]
Protein, %[3]	22.51[b]	23.98[a]	23.51[a]
Salt, %	0.51	0.34	0.38
MNFS, %[4]	59.22	58.08	58.40
FDM, %[5]	55.86[a]	53.76[b]	53.68[b]
S/M, %[6]	1.30	0.87	0.95
pH	4.97	4.96	4.94

[1] FM = February milk, MM = May milk, AM = August milk.
[2] Means within the same row without a common superscript differ ($P < 0.05$).
[3] Total % N X 6.31.
[4] Moisture in nonfat substance.
[5] Fat in the dry matter.
[6] Salt as a percentage of the moisture phase.

Table 3. Influence of season on the composition of Manchego cheese after 2 mo of aging.

	FM[1,2]	MM[1,2]	AM[1,2]
Moisture, %	31.41	29.91	30.71
Milk fat, %	37.37[a]	37.57[a]	35.70[b]
Protein, %[3]	22.80[b]	26.55[a]	26.17[a]
Salt, %	1.97	1.91	2.13
MNFS, %[4]	50.15	47.91	47.77
FDM, %[5]	54.51[a]	53.61[a,b]	51.53[b]
S/M, %[6]	6.31	6.39	6.94
pH	5.06[a]	5.01[b]	5.08[a]

[1] FM = February milk, MM = May milk, AM = August milk.
[2] Means within the same row without a common superscript differ ($P < 0.05$).
[3] Total % N X 6.31.
[4] Moisture in nonfat substance.
[5] Fat in the dry matter.
[6] Salt as a percentage of the moisture phase.

Table 4. Influence of season on the composition of whey and press whey from Manchego cheese manufacture.

	FM[1,2]	MM[1,2]	AM[1,2]
Whey			
Solids, %	9.46[a]	9.54[a]	8.70[b]
Fat, %	1.44[a]	1.16[b]	1.24[b]
Total protein, %[3]	1.75[a]	1.63[b]	1.54[c]
True protein, %[4]	1.18[a]	1.13[b]	1.08[c]
F/P, %[5]	1.22[a]	1.02[b]	1.15[a,b]
Press whey			
Solids, %	14.77[a]	13.43[b]	11.58[c]
Fat, %	5.75[a]	4.42[b]	3.33[b]
Total protein, %[3]	1.81[a]	1.70[b]	1.61[c]
True protein, %[4]	1.26[a]	1.22[a,b]	1.18[b]
F/P, %[5]	4.55[a]	3.44[b]	2.83[b]

[1] FM = February milk, MM = May milk, AM = August milk.
[2] Means within the same row without a common superscript differ ($P < 0.05$).
[3] Total % N X 6.35.
[4] (Total % N - % NPN) X 6.35.
[5] Fat in true protein.

Table 5. Influence of season on the normalized fat and nitrogen recoveries during the manufacture of Manchego cheese.

	FM[1,2]	MM[1,2]	AM[1,2]
	(%)		
Fat recovery			
Whey	14.54[a]	13.29[b]	14.58[a]
Press whey	2.41[a]	2.43[a]	1.46[b]
Cheese	83.05	84.23	83.96
N recovery			
Whey	23.96[a]	22.53[b]	23.23[b]
Press whey	1.05[a,b]	1.19[a]	0.89[b]
Cheese	75.17[b]	76.26[a]	75.88[a,b]

[1] FM = February milk, MM = May milk, AM = August milk.
[2] Means within the same row without a common superscript differ ($P < 0.05$).

Table 6. Influence of season on cheese yield from the manufacture of Manchego cheese.

	FM[1,2]	MM[1,2]	AM[1,2]
	(%)		
Actual yield	18.34[a]	17.26[b]	16.83[b]
CACY[3]	18.32[a]	17.37[b]	16.72[c]

[1] FM = February milk, MM = May milk, AM = August milk.
[2] Means within the same row without a common superscript differ ($P < 0.05$).
[3] CACY = Composition-adjusted cheese yield.

Information or educational materials:

Background to the study was reported at the 8th Great Lakes Dairy Sheep Symposium at Ithaca, NY in November 2002. Results of the final project will be reported to the national processors of sheep milk and to the Wisconsin Dairy Sheep Coop. Results will also be reported at the International Dairy Federation Symposium on The evolution of the sheep and goat dairy sector to be held in Zaragosa, Spain on October 28-29, 2004. Information will also be incorporated into our Cheese Technology Short Course that is held twice annually in the UW Food Science Department.

Future plans for project:

Research will continue on the potential cheese yields for soft cheeses from sheep milk. Analyses on soft cheeses produced with the 2003 sheep milk supply will be completed in February 2004 and fat, casein and solids retention factors will be determined that could be used in the VanSlyke-Price cheese yield formula. Retention factors should be close to the hard cheese factors but minor changes may be needed for good accuracy on predictions of cheese yields for soft cheeses. With completion of the soft cheese retention factors, the VanSlyke-Price cheese yield formula should be applicable to most sheep milk cheeses that plants would be producing.

Application of results:

With the establishment of cheese yield formulas for sheep milk, cheese plants will evaluate how close actual cheese yields come to theoretical cheese yields to determine efficiencies of the cheese plants. Once they are confident that the predicted cheese yields are close to actual yields experienced, there is the opportunity to use the cheese yield formula in pricing of raw sheep milk to compensate producers for the production of high solids milk that will yield more cheese for processors. The ultimate goal of the cheese yield formula is to provide the opportunity for processors to be able to predict the value of raw sheep milk based on potential cheese yield and for producers to use the formula as a means of projecting value of increasing milk components through their breeding and feeding programs.