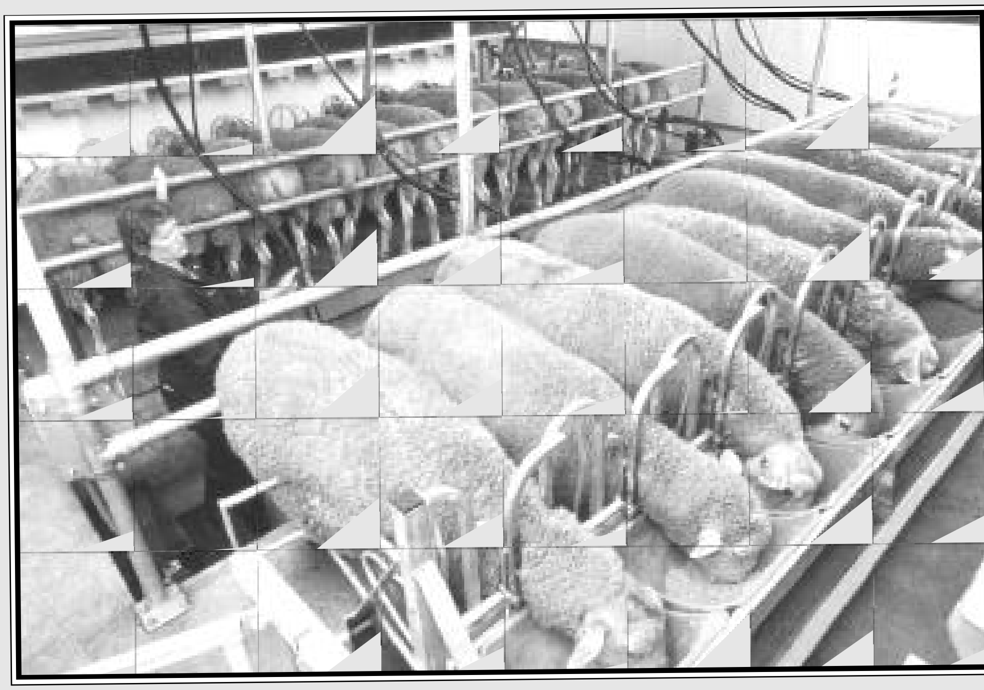
Proceedings of the 7th Great Lakes

Dairy Sheep Symposium



November 1-3, 2001

Eau Claire, Wisconsin

PROCEEDINGS OF THE

7TH GREAT LAKES

DAIRY SHEEP SYMPOSIUM

November 1-3, 2001

EAU CLAIRE, WISCONSIN

Organized By:

Wisconsin Sheep Dairy Cooperative, Strum, Wisconsin, USA

University of Wisconsin-Madison, Madison, Wisconsin, USA
College of Agricultural and Life Sciences
Spooner Agricultural Research Station
Department of Animal Sciences
Office of International Programs

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Top: East Friesian crossbred ewes in the milking parlor at the Spooner Agricultural Research Station, University of Wisconsin-Madison. Photo by Wolfgang Hoffmann.

Bottom Left: One of the first East Friesian crossbred ewes born at the University of Wisconsin-Madison. Photo by Sarah Bates.

Bottom Right:
Specialty cheeses, many of them sheep milk cheeses, in Fairway Market, Manhattan, New York City. Photo by Dave Thomas.

Copies of the 1995, 1996, and 1997 Proceedings of the 1st, 2nd, and 3rd, respectively, Great Lakes Dairy Sheep Symposia can be purchased from the Wisconsin Sheep Breeders Cooperative, 7811 Consolidated School Road, Edgerton, WI 53534, USA (phone: 608-868-2505, web site: www.wisbc.com)

Copies of the 1998, 1999, 2000, and 2001 Proceedings of the 4th, 5th, 6th, and 7th respectively, Great Lakes Dairy Sheep Symposia can be purchased from Yves Berger, Spooner Agricultural Research Station, W6646 Highway 70, Spooner, WI 54801-2335, USA (phone: 715-635-3735, fax: 715-635-6741, email: ymberger@facstaff.wisc.edu)

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Program

7th Great Lakes Dairy Sheep Symposium

Eau Claire, Wisconsin

Thursday, Friday, and Saturday
November 1, 2, and 3, 2001

Thursday, November 1

Noon	**Registration**
1:00-1:40 p.m.	Choice of sheep breeds (Dave Thomas)
1:40-2:20 p.m.	Choice of milking system (Yves Berger)
2:20-2:40 p.m.	Regulations for sheep milk (Bruce Carroll)
2:40-3:20 p.m.	Farmstead cheese and marketing (Steven Read & Jodi Ohlsen)

Break

3:40-4:20 p.m.	The Wisconsin Sheep Dairy Cooperative (Dan Guertin)
4:20-4:40 p.m.	Getting Started in Sheep Dairying (John Tappe)
4:40-5:00 p.m.	Management of a dairy sheep operation (Tom & Laurel Kieffer)
5:00 p.m.	Questions and answers (Panel)
7:30 p.m.	Live ETN session - New scrapie regulations and selection for scrapie resistance (UW-Extension - Dave Thomas)

Friday, November 2, 2001

8:00 a.m.	**Registration**
8:30-9:10 a.m.	Comparison between East Friesian and Lacaune (Dave Thomas)
9:10-9:50 a.m.	Factors affecting the quality of ewe's milk (Roberta Bencini)
9:50-10:30 a.m.	Effects of SCC and milk with low fat content on cheese manufacturing and quality (John Jaeggi)

Break

10:45-11:25 a.m.	New developments in genetic improvement of dairy sheep (Juan José Arranz)
11:25-12:05 p.m.	Effect of omission of stripping and less frequent milking on milk production and milking efficiency of dairy ewes (Brett McKusick)

Lunch

1:15-1:55 p.m.	Light control for year-round breeding (Ken Kleinpeter)
1:55-2:35 p.m.	Effect of nutrition of ewe lambs on subsequent lactation (Bee Tolman)
2:35-3:15 p.m.	Effect of freezing on milk quality and Latest developments in the use of raw milk for cheesemaking (Bill Wendorff)

Break

3:30-4:10 p.m.	The Australian sheep dairy industry (Roberta Bencini)
4:10-4:50 p.m.	Group breeding schemes (Yves Berger)
4:50-5:30 p.m.	Future plans for the symposium and an association of dairy sheep producers
6:30 p.m.	Depart for banquet at Park Inn, Chippewa Falls, Wisconsin
7:00 p.m.	Social and cheese tasting
8:00 p.m.	Banquet

Saturday, November 3, 2001

Tour of three sheep dairy farms, a box lunch will be served

9:00 a.m.	Bus Departs
	1st farm: Newly operating sheep dairy farm. 150 ewes. John & Kris Tappe, Durand, Wisconsin
	2nd farm: In operation since 1997. 200 ewes. Tom & Laurel Kieffer, Strum, Wisconsin
	3rd farm: Small scale operation. 30 ewes. Carolyn Craft, Fall Creek, Wisconsin
4:30 p.m.	Bus Returns

Sunday, November 4, 2001

Open house at the Dairy Sheep Research Farm, University of Wisconsin-Madison

Spooner Agricultural Research Station, Spooner, Wisconsin *(no transportation provided)*

SPEAKERS

Dr. Juan-José Arranz, Dpto. Produccion Animal, Facultad de Veterinaria, Universidad de Leon, 24071 Leon, Spain

Dr. Roberta Bencini, Animal Science, Faculty of Agriculture, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia

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Dan Guertin, Shepherd's Pride Farm, 6380 Lake Elmo Ave., Stillwater, MN 55082-8331

John Jaeggi, Associate Researcher, Center for Dairy Research, University of Wisconsin-Madison, 222D Babcock Hall, 1605 Linden Dr., Madison, WI 53706-1598

Tom and Laurel Kieffer, Dream Valley Farm, N 50768 County Rd D, Strum, WI 54770

Ken Kleinpeter, Old Chatham Sheepherding Company, 155 Shaker Museum Road, Old Chatham, NY 12136

Brett McKusick, Department of Animal Sciences, 470 Animal Science, University of Wisconsin-Madison, 1675 Observatory Dr., Madison, WI 53706

Steven Read and Jodi Ohlsen, Shepherd's Way Farms, 8626 160th St E, Nerstrand, MN 55053

Jon and Kristina Tappe, Tappe Farms, W5332 State Highway 85, Durand, WI 54736

Dave Thomas, Department of Animal Sciences, 438 Animal Science, University of Wisconsin-Madison, 1675 Observatory Dr., Madison, WI 53706

Bee Tolman, Tolman Sheep Dairy Farm, 6066 East Lake Rd., Cazenovia, NY 13035

Bill Wendorff, Chair, Department of Food Science, University of Wisconsin-Madison, 103 Babcock Hall, 1605 Linden Dr., Madison, WI 53706-1598

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CHOICE OF BREED FOR DAIRY SHEEP PRODUCTION SYSTEMS

David L. Thomas

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Few decisions can have as much influence on the success of a dairy sheep enterprise as the decision as to which breed should be milked. The establishment and operation of a dairy sheep farm requires a greater investment of both money and labor compared to establishment and operation of a farm for only meat and wool production. Therefore, a breed or breeds of sheep need to be chosen that can produce enough additional product (milk, meat, and wool) to justify the increased costs of establishment and operation.

Common Breeds in North America Prior to 1992

Commercial sheep production in North America has been based on the production of meat and wool from the very beginnings of the industry, with meat production much more important than wool production. Therefore, selection emphasis has been on traits that result in more efficient production of meat (e.g. litter size, growth rate, mature size) and wool (e.g. fleece weight, fleece quality). Adequate milk production and udder health are important traits so that ewes have enough milk to successfully raise two or three lambs. Indirect selection for increased milk production has been through selection for heavy lamb weaning weights, and ewes are often culled for low milk production, estimated from low lamb weaning weights or ewe udder size, or presence of udder disease. These selection criteria have probably resulted in some, but relatively small amounts, of genetic improvement over time for milk production.

Dr. William Boylan and his students at the University of Minnesota, St. Paul were the first research group in North America to compare several North American breeds of sheep for milk production in a dairy production setting (Boylan et al., 1991; Sakul and Boylan, 1992a; Sakul and Boylan, 1992b; Boylan, 1995). Results presented in two of their studies are reproduced in Table 1. Ewes were milked twice per day for approximately 120 days following the weaning of their lambs at approximately 30 days postpartum. Milk yields are for the machine-milking period.

Averages for all ewes across the two studies were 138 lb. for milk yield, 6.6% for milk fat percentage, and 5.8% for milk protein percentage. Average daily milk yields were approximately 1.15 lb. per day over the 120-day lactation period. Romanov ewes had the lowest milk yields in both studies, and Finnsheep and Lincoln ewes had the second or third lowest milk yields in the two studies. Romanov and Finnsheep are the most prolific of the breeds found in North America and have the greatest need for high milk production for lamb rearing, but it appears that this need has not resulted in high genetic value for milk yield. In the first study (Sakul and Boylan, 1992a), Suffolk, Targhee, and Dorset ewes had above average milk yields and the Rambouillet ewes were close to average.

In the second study (Boylan, 1995), two additional breeds, the Outaouais and Rideau, were added. These two breeds were created by Ag Canada at the Agricultural Research Center – Ottawa by the crossing of several breeds. Both breeds contain a large proportion of Finnsheep breeding and were created to have high levels of prolificacy. In addition, the Rideau contains about 14% East Friesian breeding. East Friesian is a dairy sheep breed from northern Europe. The Rideau ewes exceeded all other breed groups for milk yield and produced 31% more milk than the average of all breeds. The high relative performance of the Rideau demonstrates the value of even a small amount of dairy sheep breeding.

Table 1. Lactation performance of several breeds raised for meat and wool in North America[a]

Breed	Number	Milk yield, lb	Fat, %	Protein, %
Dorset	28 (14)	153.3 (134.2)	6.3 (6.3)	6.1 (5.7)
Finnsheep	31 (23)	138.6 (96.8)	5.6 (6.1)	5.4 (5.5)
Lincoln	31 (15)	137.5 (116.6)	6.2 (6.8)	5.7 (5.8)
Outaouais	-- (18)	------ (118.8)	--- (7.3)	--- (6.1)
Rambouillet	30 (14)	142.6 (143.0)	6.2 (6.6)	5.9 (6.1)
Rideau	-- (24)	------ (169.4)	--- (6.6)	--- (5.8)
Romanov	18 (21)	112.2 (96.8)	6.6 (7.1)	6.0 (5.9)
Suffolk	32 (17)	178.9 (151.8)	6.4 (6.7)	5.8 (5.9)
Targhee	30 (15)	161.3 (136.4)	6.1 (6.9)	5.7 (5.9)
Average		146.3 (129.3)	6.2 (6.7)	5.8 (5.9)

[a]First number of each pair is from the paper of Sakul and Boylan, 1992a, and the second number of each pair (in parentheses) is from the paper of Boylan, 1995.

Since there are over 40 recognized breeds of sheep in North America, the Minnesota studies evaluated less than one-quarter of possible breeds. However, the nine breeds evaluated represented most of the types of breeds available, e.g. finewools, longwools, medium wools, meat breeds, and prolific breeds, so the average production observed of 130 to 145 lb. of milk per lactation is probably very indicative of production levels to be expected from typical North American sheep.

Milk production can be improved through selection. It has a heritability of approximately 30% (similar to the heritability for milk yield in dairy cattle). A within flock selection program for increased milk yield might be expected to increase milk yield by 1.0 to 1.5% per year (1.5 to 2.0 lb. per year) in ewes of domestic breeds. While genetic improvement should be an important component of any dairy sheep operation, it will take at least 30 years to take a domestic breed flock from an average milk production level of 140 lb. to 200 lb. using within flock selection alone.

Foreign Dairy Breeds

While the emphasis in North America has been on the efficient production of meat and wool from sheep, there are some areas of the world where milk production from sheep has been an important agricultural enterprise for hundreds of years. Countries with significant commercial dairy sheep industries are the countries of southern Europe (Portugal, Spain, France, Italy, Greece, and Turkey), eastern Europe (Bulgaria, Romania, Slovakia), and the Middle East (Israel, Syria, Iran). In these areas, sheep breeds have been developed that have the genetic capability for high milk yields (Table 2).

Table 2 is not an exhaustive list of world dairy sheep breeds nor are the milk yields presented average values for all ewes of that breed. There is a large amount of variation in the milk yields, even within breeds in the same country (e.g. Awassi in Israel). Some of the values in Table 2 are average values for all milk recorded ewes in the country whereas other values are for only one or a few flocks. Some of the milk yields came from ewes fed concentrates in intensive systems while others came from unsupplemented ewes grazing sparse range lands. The important point is that the lowest milk yield value in Table 2 for improved dairy breeds is higher than the highest milk yield value in Table 1 for North American non-dairy breeds. It would appear that several, if not all, of these dairy breeds are a potential source of genetic material to improve the milk yield of North American dairy sheep flocks.

Table 2. Examples of milk yields of improved dairy breeds from throughout the world

Breed of sheep	Country	Milk yield, lb.	Reference
Assaf	Israel	422	Gootwine et al., 1980
Awassi	Israel	1,135 – 1,173	Gootwine et al., 2001
Awassi	Turkey	282	Gursoy et al., 2001
Awassi	Israel	460	Eyal et al., 1978
Comisana	Italy	440	Pinelli et al., 2000
East Friesian	Canada	847	Regli, 1999; Barillet et al., 2001
Lacaune	France	484	Barillet, 1995
Lacaune	France	594	Barillet et al., 2001
Lacaune	Spain	344	Barillet et al., 2001
Lacaune	Canada	862	Regli, 1999; Barillet et al., 2001
Latxa	Spain	455	Estban Munoz, 1982
Latxa	Spain	273	Ugarte et al., 2001
Manchega	Spain	182	Barillet et al., 2001
Manchega	Spain	339	Ugarte et al., 2001
Sarda	Italy	413	Sanna et al., 2001

Availability of Dairy Breeds in North America

Due to very stringent animal health regulations controlling the importation of live sheep, ram semen, and sheep embryos into Canada and the U.S., it was very difficult, and impossible from some countries, to obtain the desired dairy sheep genetics in the late 1980's and early 1990's when the industry began its development. However, due to the persistence of a few Canadian breeders (Hani and Theres Gasser in British Columbia, Axel Meister and Chris Bushbeck in Ontario, and some others), dairy sheep semen and embryos were brought into Canada in the early 1990's. There were some subsequent importations of dairy sheep semen and live animals directly into the U.S. from Europe and New Zealand. Due to the outbreak of Foot and Mouth

Disease in the U.K. and subsequently in some other European countries in 2000, it will be impossible to import new dairy sheep genetic material from much of Europe for several months (maybe several years) to come.

The East Friesian breed is now available in fairly large numbers from breeders in both Canada and the U.S. In addition, there is a fairly large population of East Friesian sheep in New Zealand and Australia that were first imported into New Zealand from Sweden. Live sheep, ram semen, and sheep embryos can be imported from both New Zealand and Australia due to their favorable animal health status. The East Friesian is generally regarded as the highest milk-producing breed in the world with yields of 550 to 650 kg reported in northern Europe (Sonn, 1979; Kervina et al., 1984). It was developed in the East Friesland area of Germany. Mature rams and ewes weigh 90 to 120 kg and 65 to 75 kg, respectively, and their face and legs are white and free of wool. A distinguishing characteristic is a long, thin "rat" tail, which is free of wool. A 230% lamb crop can be expected from mature ewes (Kervina et al., 1984).

A second dairy sheep breed, the Lacaune from France, is now available in North America. Josef Regli imported Lacaune embryos to Canada from Switzerland in 1996 (Regli, 1999), and the University of Wisconsin-Madison imported semen from three Lacaune rams into the U.S. from the U.K. and two Lacaune rams from Josef Regli in 1998. The Lacaune is the native breed of south central France where their milk is manufactured into the world-famous blue Roquefort cheese. They are white-faced with long ears. The upper part of the body is covered with wool, but the head, underside of the neck, lower half of the sides, the belly, and the legs are often free of wool (Kervina et al., 1984). They are moderately prolific with a lambing rate of 150%. The Lacaune breed in France has a well-organized and very successful genetic improvement program that utilizes sophisticated milk recording of elite flocks (166,000 ewes), and the use of artificial insemination of progeny tested rams on ewes in both the elite flocks and the commercial flocks (560,000 ewes). Due to this genetic improvement program, average lactation milk yield in the elite flocks has increased from 176 lb. in 1960 to 594 lb. in 1999 (Barillet et al., 2001). Ewes in commercial flocks have average lactation milk yields of approximately 506 lb.

Awassi sheep or embryos have been exported from Cyprus to Australia and from Israel to New Zealand. Therefore, Awassi sheep are now found in countries that can export sheep genetic material to North America. To date, no Awassi sheep have been imported from these countries. While the Awassi is a noted milk producer, it produces a coarse, colored fleece and is fat-tailed. These traits would be undesirable for wool and lamb production. However, they should be evaluated in North America, perhaps in crosses with either East Friesian or Lacaune to minimize their undesirable characteristics.

Evaluation of Dairy Sheep Breeds in North America

The University of Wisconsin-Madison initiated a comparison of the East Friesian dairy breed with the Dorset breed in 1993 (Thomas et al., 2000). East Friesian was chosen because it was the only dairy breed available and Dorset because several of the current dairy sheep producers were milking Dorset or Dorset cross ewes. When the study was started, only crossbred East Friesian rams were available. We mated four crossbred rams (two 1/2 East Friesian, one 3/4 East Friesian, and one 7/8 East Friesian) and several Dorset rams to crossbred non-dairy ewes and evaluated the ewes for first and second lactation performance at one and two years of age, respectively. Ewes nursed their lambs for 30 days and were then milked twice daily for the remainder of lactation.

Presented in Table 3 is the lactation performance of one-year-old ewes in 1996 and 1997, and two-year-old ewes in 1997. The East Friesian-cross ewes had lactations that were 33 days longer and produced 115 lb. more milk (1.91 times as much milk), 2.2 kg more fat, and 2.2 kg more protein compared to the Dorset-cross ewes ($P < .05$, Table 3). Fat and protein percentage of milk from East Friesian-cross ewes was approximately .5 percentage units lower ($P < .05$) compared to milk from Dorset-cross ewes. As mature ewes and under management systems where milking started 24 hours postpartum, these same East Friesian-cross ewes had average milk yields of 519 to 572 lb. (McKusick et al., 2001).

In addition, East Friesian-cross lambs had greater growth rates than Dorset-cross lambs, and East Friesian-cross ewes had greater prolificacy and weaned more lambs per ewe than Dorset-cross ewes (Thomas et al., 2000). Therefore, sheep of 50% or less East Friesian breeding were superior to Dorset-cross sheep in milk production, reproduction, and lamb growth. The only detrimental effect of East Friesian breeding found was reduced lamb survival in lambs of over 50% East Friesian breeding compared to non-East Friesian lambs or lambs of 50% or less East Friesian breeding (Thomas et al., 2000). It appears that lambs of high percentage East Friesian breeding are more susceptible to respiratory disease. This also has been reported with East Friesian and East Friesian-crosses in Greece (Katsaounis and Zygoyiannis, 1986) and France (Ricordeau and Flamant, 1969).

Table 3. Least squares means for lactation performance of young EF-cross and Dorset-cross ewes

	Breed of ewe:	
Trait	Dorset-cross	EF-cross
Number of lactations	76	246
Lactation length, d	92.7 ± 4.2 [a]	126.2 ± 2.6[b]
Milk yield, lb.	125.2 ± 12.1[a]	240.0 ± 7.5[b]
Fat, %	5.54 ± .07[a]	5.02 ± .05[b]
Fat yield, kg	3.3 ± .3[a]	5.5 ± .1[b]
Protein, %	5.42 ± .05[a]	4.97 ± .03[b]
Protein, kg	3.2 ± .3[a]	5.4± .1[b]
Log somatic cell count	4.99 ± .09[a]	5.03 ± .04[a]

[a,b] Within a row, means with a different superscript are different ($P < .05$).

Continued experimentation with East Friesian crosses at the University of Wisconsin-Madison and their performance in commercial dairy flocks in the U.S. and Canada further showed their superiority for milk production, and most commercial operations moved quickly to crossbred, high percentage, or purebred East Friesian ewes. A crossbred East Friesian or high percentage East Friesian ewe is still the most common ewe found in commercial sheep dairies in North America today.

With the availability of both East Friesian and Lacaune dairy sheep breeding in North America in 1997, the University of Wisconsin-Madison initiated a study in 1998 to compare sheep sired by East Friesian rams and Lacaune rams for lamb and milk production under dairy sheep production conditions in Wisconsin. Results have been summarized through 2001 (Thomas et al., 2001). Ewes of 1/2 East Friesian or 1/2 Lacaune breeding were produced by mating non-dairy ewes to one of four purebred East Friesian rams or one of five purebred Lacaune rams. Ewes born in 1999 have been evaluated for milk production as one- and two-year-old ewes in 2000 and 2001, respectively, and ewes born in 2000 have been evaluated as one-year-old ewes in 2001. One-year-old ewes were milked after they weaned their lambs at 30 days postpartum, and two-year-old ewes were milked from 24 hours postpartum.

Lactation results are presented in Table 4. There was a small advantage of the East Friesian-cross ewes for milk production (+31 lb.) but this difference was not significant. The East Friesian-cross ewes had longer ($P < .05$, +11.9 d) lactation lengths but lower ($P < .05$) percentage milk fat (-.40%) and milk protein (-.26%). The differences between the two breeds for lactation traits are not large, and differences between the breeds for reproductive and growth traits also are not large (Thomas et al., 2001). We do not yet have a good measure of differences in lamb mortality between East Friesian and Lacaune breeding. The study will continue for a few more years, but at the present time, it appears that either East Friesian-crossbred or Lacaune-crossbred ewes can be utilized successfully in a dairy sheep operation.

Table 4. Lactation traits (mean ± SE) of F1 ewes produced from East Friesian or Lacaune sires and non-dairy dams during their first and second lactations

Breed group	N	Milk, lb	Lactation length, d	Fat, lb.	Fat, %	Protein, lb.	Protein, %
1/2 EF	75	291.8±14.3	126.3±3.8[a]	16.3±1.0	5.49±.13[b]	13.7±.7	4.65±.09[b]
1/2 LA	83	260.8±13.6	114.4±3.6[b]	15.8±.9	5.89±.12[a]	13.2±.7	4.91±.08[a]

[a,b,c]Means within a column with no superscripts in common are significantly different (*P* < .05).

Josef Regli reported on the performance of purebred East Friesian and Lacaune sheep on his commercial farm in Ontario, Canada (Regli, 1999). He reported similar milk yields between the breeds but higher percentage milk fat and protein from the Lacaune. He also noted that the Lacaune ewes had better udder conformation and were less susceptible to respiratory disease and mastitis compared to the East Friesian ewes. However, the East Friesian ewes were easier to handle than were the Lacaune ewes.

Economic Effects of Breed Choice

Higher levels of milk production will generally result in greater net returns so dairy-cross ewes should be used. Table 5 gives the estimated returns for a 300-ewe flock of either non-dairy, 1/4-dairy, or 1/2-dairy ewes adapted from an economic analysis presented by Berger (1998). The results clearly show the economic advantage of obtaining higher milk yields from dairy-cross ewes. It is difficult to justify a dairy sheep operation based on a non-dairy ewe.

The returns in Table 5 are based on equal milk values from the three production levels. It is true that ewes of the lower production levels will produce milk that is higher in fat and protein and that will generate a greater cheese yield and, perhaps, a higher quality cheese. If there are price premiums for milks of higher solids content and price discounts for milk of lower solids content, differences in returns between these production levels will decrease somewhat. However, the higher production levels will still have significantly higher returns.

Table 5. Returns to owner's labor and management from a 300-ewe milking flock with different levels of milk production

Non-dairy ewes 150 lb. milk/ewe	1/4-dairy ewes 350 lb. milk/ewe	1/2 -dairy ewes 550 lb. milk/ewe
$2,806 $9.35/ewe	$38,806 $129.35/ewe	$74,806 $249.35/ewe

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MILKING EQUIPMENT FOR DAIRY EWES

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Introduction

Milking can be done by hand with ewes standing on an elevated platform or by milking machine in parlors of various levels of sophistication. All methods and techniques, however, share the same principles of emptying the udder as completely as possible, without causing trauma to either the udder or to the teats, in the shortest possible time while keeping the milk as clean as possible.

It is very important that milking be performed rapidly, in an environment as clean as possible, in a well lighted area, designed for the best comfort of the milker and of the animals.

As in many other countries, the conditions in which the milk of cow, goat and sheep is produced and collected in North America are subjected to many regulations to ensure that the highest quality of milk is sold to consumers. The location of the milking parlor, its design, the material used for construction, the quality of the water for cleaning the milking equipment and many other details need to be respected in order to obtain the milk producer license.

Before starting any type of construction or installing any type of milking system, a producer should contact his/her local dairy inspector in order to be aware of all existing regulations. For example, in the United States, stanchions cannot be built with porous material such as wood.

Types of milking parlor

Hand milking (less than 20 ewes)

Hand milking is still very popular in many Mediterranean countries where management systems, labor resources and energy resources (availability of electricity) are quite different than in other countries. A shepherd can hand milk between 20 to 60 ewes per hour (sometimes more) according to the milking ability of the breed and the milk yield of the ewes. Until 1950, a man could milk only 20 Lacaune ewes per hour in France, which at this time did not have a good milking ability, but could milk 80 ewes per hour in Corsica Island because local breeds were easy to milk.

Because of the generally small size of sheep dairy operations in North America, hand milking could be a very viable option. It is simple and does not require any sophisticated equipment. In a small scale operation equipped with a milking machine, more time is spent in washing the equipment that in actual milking. However, hand milking requires a certain know-how that might no longer be existing and might not be appealing to the modern producer. Moreover, it is difficult to get clean milk because of possible contamination of the milk by external agents.

Bucket milking and elevated platform (between 20 and 120 ewes)

Many sheep dairy producers in the U.S. and Canada have adopted the bucket and fixed stanchion system on an elevated platform because of the modest investment it requires. The stanchion is generally on an elevated platform with 6 or 12 fixed stalls with "cascading" yokes. The first ewe on the platform goes to the furthest end where a yoke is open. By putting its head through to get to the feed, the animal locks itself in and releases the mechanism that opens the next yoke and so on until the whole platform is occupied. The system works fairly well and is easy to build at low cost. The feed is generally distributed by hand between each batch. The milking is performed in buckets developed for cows or goats. The vacuum in the bucket is provided by a vacuum pump located either next to the bucket (as a wheel barrow system) or in an adjacent room, and the pulsator is fixed on the lid of the bucket, which is also equipped with a filter. Two ewes at a time can be milked with the same bucket.

Several disadvantages arise with bucket milking:

- The vacuum level is not always constant which could lead to an unusual high incidence of sub-clinical mastitis reflected by an elevated Somatic Cell Count.
- The pulsators are often old and not adjustable to the required speed for ewes, therefore limiting the stimulation necessary for maximum evacuation of the udder.
- Some difficulties in cooling the milk rapidly
- Heavy weight hauling
- Low throughput of ewes. One milker can milk only 40 ewes an hour.
- Bad working postures
- Much time involved in cleaning equipment

The same type of stanchion can be used with a low line or high line pipe line which greatly facilitates milking, reduces the heavy weight lifting and permits the use of equipment better adapted to sheep milking.

Parlors for larger flocks (above 120 ewes)

The « Casse System »

The « Casse » parlor was born in 1961 in an experimental farm in the Roquefort area of France named Casse farm. This parlor had been developed for the Lacaune breed and for the special working routine developed from the poor milking ability of the ewes at the time. The typical routine during milking used at that time can be described as follows:

- attaching clusters on teats without washing,
- hand massaging after one minute of milking,
- machine stripping and detaching after 180 seconds of milking,
- re-milking by hand for 10 or 20 seconds.

At the beginning of the 1960's, only 80 ewes per hour could be milked with this poor routine by two milkers with 12 milking units and a 24 stall parlor. Much progress has been accomplished since then with the development of better equipment and the simplification of the milking routine: suppression of massaging, stripping and re-milking by hand.

The « Casse System » is a side by side parlor developed from the herringbone parlor which was in its early stage of development in the latter part of the 1950's. In a « Casse » parlor, ewes enter and walk to a manger where a concentrate is distributed either manually or automatically; they are locked by their necks in special yokes. They go to any headlock they want; the other ewes can move on the platform behind those that are already locked in and eating concentrates. When the platform is full, the milker moves the ewes back to the edge of the pit, manually with a crank or automatically with a pneumatic device. The throughput is generally 120 ewes/hour with one milker in a typical « Casse System » (24 ewes – 12 milking units).

New Casse milking parlors

Nowadays, modern and highly efficient milking parlors can be found in bigger flocks. The new « Casse System » has fixed stalls instead of movable stanchions. A gate moves on the platform when ewes are entering; it stops at the first place, an automatic feeder distributes concentrates and the gate opens. The first ewe enters the first place which is equipped with an automatic headlock. When it is locked, the gate moves back to the next place, the second ewe enters the second headlock and so on... The gate carries a special curtain bent or coming from the other side of the fixed stalls refraining ewes from going to an unoccupied headlock. This new system allows for the possibility of distributing the exact amount of concentrate to each ewe according to her level of production. The movable gate is equipped with a transponder reading the electronic ear tag of the ewe and giving information to the feeder (through an interface system with a computer) about the amount of feed to pour in the individual trough. This system called ADC (automatic distribution of concentrate) will solve the logistic problem of properly feeding a large number of ewes which are in different stages of lactation and different levels of production. As a general practice so far, feed has been distributed in an amount sufficient to cover the nutritional needs of the highest milking ewes leading to a waste of energy and proteins.

Most of these parlors, now very popular, have 2x24 places with 24 units and a high line pipeline. Two milkers are working in these parlors except when automatic teat cup removal is set up; in such case only one milker is working. Usually a dog helps ewes entering the platform, and changing batches in the shed is made by another person or by the milker himself.

Other popular milking parlors are rotary parlors. They generally have 30 units or more (from 30 up to 48 places, sometimes 60) and are only used in big flocks of more than 500 to 600 ewes with two milkers. Most of them are now equipped with ACR (automatic cup removal).

Other types of parlors

The parlors described so far rely on the feeding of animals in the parlor, the feed offered being the reward for the ewes to come in. They all work well but they have the common disadvantage of being expensive and complicated. In order to reduce initial cost of the installation, some North American producers have replaced the self locking stanchion system by the "crowding system" developed in New Zealand for dairy cows. A certain number of ewes (12,18, 24) come in the parlor and are squeezed side by side on the platform being stopped from going forward by a simple bar. The concentrate is generally distributed by hand. The feeding of concentrate can also be done outside the parlor after milking. The milking parlor becomes an obligatory passage for the ewes to get to the feed, and therefore they come in willingly.

Throughputs in different parlors

Nowadays the most popular milking parlors are old and new « Casse System » with 2x12 places with 6 or 12 milking units or 2x24 places with 12 or 24 units. Producers with large flocks need equipment, and particularly parlors, with a very high degree of efficiency. The main parameter to consider when choosing a new parlor is its potential throughput, that is the number of animals coming efficiently in and out in a certain amount of time. Many field studies and inquiries have been made to give information to the farmers as guidelines for the choice of their parlors.

In old « Casse » systems, the average throughput observed in field studies is between 100 and 350 ewes/hour depending on the number of units, the number of milkers, the daily milk yield and the number of ewes per unit.

Average throughput in most popular « Casse » parlors

Nb places	Nb units	Milk line	Nb milkers	Nb pushers	Average throughput
2x12	6	Low line	1	0	100-140
2x12	12	High line	1	0	180.250
2x12	12	Low line	1	1	140-200
2x24	24	Low line	2	0	220-300
2x24	24	High line	2	1	270-350

Field studies in the Roquefort area have shown that parlors with a high line pipeline are more efficient than parlors with a low line. Doubling the number of units only increases the throughput about 20 to 25 %. This is the reason why most parlors in the Roquefort area have high pipelines although low line parlors also exist.

For small flocks, it is possible to build only one platform to limit costs. Efficiency of such parlors is about 100 to 200 ewes/hour with only one milker.

Average throughput in one platform « Casse » parlors

Nb places	Nb units	Milk-line	Nb milkers	Throughput
1x12	6	High Line	1	100-120
1x12	6	Low Line	1	90-110
1x24	12	High Line	1	140-200
1x24	12	Low Line	1	120-180

Modern « Casse » parlors have a better efficiency. The following table shows that in a 2x24 place - 24 units, average throughput could be anywhere between 320 and 420 ewes/hour with two milkers. Most of the parlors with 2x24 places and 24 units are now equipped with ACR (Automatic Cluster Removal). In such parlors, one milker can milk between 350 and 400 ewes/hour.

Average throughput in modern « Casse » parlors

Nb places	Nb units	Milk line	Nb milkers	Nb pushers	Average throughput
2x24	24	HL	2	0	360-420
2x24	24	LL	2	0	320-400
2x24	24	HL	1*	1**	350-410

* with ACR
** the pusher can be a dog

Finally, rotary parlors with a large number of units are certainly the most efficient parlors, but are also the most expensive. They are used only by producers with more than 500 ewes. It is possible to milk 420 to 650 ewes per hour depending on the number of units, the number of milkers and the daily milk yield of ewes.

Average throughput in rotary parlors

Nb units	nb milkers	nb pushers	Average throughput
32	2	1**	420-460
36	3	1**	450-500
48	2-3*	1**	600-650

* 1 milker less with ACR
** the pusher is often a dog

Labor organization

The « Casse System » has been developed with the main idea that the number of units must depend on the time spent by the milker to attach the clusters to all ewes, plus miscellaneous and idle time, and coming back to the first one **without overmilking**. Nowadays, the average milking time of Lacaune ewes is about 3 minutes depending on milk yield (2.5 minutes in mid lactation and 2 minutes at the end of lactation). **That means that a milker can work in good condition with only 12 units**. For parlors with more than 12 units, a second milker is needed but could be replaced by ACR (Automatic Cluster Removal).

Each milker works in half the pit on one side of the parlor. For example, milker n° 1 attaches clusters number 1 to 12 and during the same time milker n° 2 attaches clusters number 13 to 24. Then returning to the first ewe, the milkers can carry out the massage of udders in the same order as clusters have been attached (1-12 and 13-24). Nowadays, massaging is very rare and can be eliminated because of improved genetics. Therefore, milkers only strip ewes if needed and detach clusters always in the same order. After detaching cluster from the last ewe, the platform is emptied and milkers swing the milking units to the other side of the pit and the same working routine is repeated. Then the pusher (it can be a dog) helps ewes entering the empty platform in order to have the ewes ready when the milkers have finished the other side. In these conditions, producers can milk more than 350 ewes per hour with a steady throughput of about 450 ewes/hour.

Working posture

A milker who is milking a large number of ewes in a very short time, twice a day during 6 to 7 months, must have good labor organization and comfortable working postures. Inadequate working postures can lead to arm and/or backaches, spine problems and other troubles rendering his/her work unpleasant. The rule of thumb can be described in the four following points:

1 - Stand up as straight as possible when working.
2 - Avoid bending forwards when attaching or detaching clusters or working on udders.
3 - Never work below the level of elbows.
4 - Never work above the level of shoulders.

Good working postures and good working conditions depend largely on good dimensioning of parlors. **One of the most important dimensions, which should be adjusted as well as possible, is the depth of the pit**. In addition to the rules just mentioned above, a milker must know the average height of the teats of ewes to be milked. For example in the Lacaune breed, the distance between the floor and the base of the teat is on average 32 cm for ewes with two and more lactation, and 30 cm for ewes during their first lactation. When ewes are standing on the platform ready to be milked, udders must be at an easy reach of the hands of the milker in respect to ergonomic rules and comfortable working angles for body and arms. That means about 10 cm above the level of elbows with a maximum variation of 20 cm. For example, if a milker is 1.7 m tall (5'9''), his elbows are located at about 1 m (3'5'') from the floor, therefore the height of the pit should be .85 m (2'10''). The following table gives an idea of the depth of the pit, which should always be calculated in relationship to the height of the milker.

Depth of the pit in a milking parlor

Height of the milker	Depth of the pit
<1.5m (< 5')	.75m (2'6")
1.5m-1.62m (5'- 5'5")	.80m (2'8")
1.62m-1.72m (5'5'-5'9")	.85m (2'10")
1.72m-1.82m (5'9"- 6'1")	.90m (3')
1.82m-1.92m (6'1"- 6'5")'	.95m (3'2")
> 1.92m (6'5")	1m (3'4")

High Line vs. Low Line pipelines

Some controversies occur between the partisans of each system, controversies that should not exist. In general high line pipelines are more efficient and cost less to install because the number of milking units is half as in a low line system. A somewhat higher vacuum level is necessary to vacuum the milk, but as long as the vacuum is no higher than 38 kPa (12 inches of mercury) there is no effect on the somatic cell count.

Bulk tank

A bulk tank is an absolute necessity for the good refrigeration of milk after milking. The size, type and brand of bulk tank are, of course, left to the producer's choice. The only requirement of a bulk tank is to be able to cool the milk rapidly to 5-6 degree Celsius.

Freezer

For most dairy sheep producers selling milk to a cheese maker, the freezing of milk is still a necessary evil. Many discussions have been held on the best way to freeze milk correctly. There is certainly no "best" way of freezing milk, but there are certainly better ways than others. However, the method of freezing chosen by the producer will greatly affect the quality of the milk. When frozen slowly, at temperatures higher than –12 degree Celsius, degradation of milk proteins will occur starting after 2-3 months of storage. The degradation of protein would lead to problems in the curd formation. Since the producer selling milk has no control on when the cheese maker is going to use the milk (it could be immediately after sale or it could be several months after the sale of milk), he should be prepared to preserve the quality of milk over a long period of frozen storage (over 3 months). It is recommended that:

- Milk be chilled down to 4-6 degrees Celsius before freezing
- Milk be frozen quickly at low temperature (-25 degree Celsius)

Freezing milk quickly at low temperature requires that the milk be placed in a container with the greatest possible exposed surface such as a flat square plastic bag (FDA approved). The bags can be placed on a shelf in a commercial walk-in freezer. This type of freezing would guarantee a high milk quality for up to 1 year of storage. It is possible that a producer finds the expenses of a walk-in freezer too high or that a cheese maker does not want milk in bags. In this case a clear understanding between producer and cheese maker should be established on the length of storage after freezing or after the sale of milk.

Conclusion

This papaer describes in detail several milking systems with the amount of ewes a person can milk per hour. It contains important information because the choice of a system depends greatly on the number of ewes that a producer plans to milk and whether he is milking alone or with some help.The greater the number of ewes, the more efficient the system has to be so that the producer does not spend all day in the milking parlor. Of course, the overall cost of the system is a determinant factor and often a producer will have to make a compromise between efficiency and cost. However, by decreasing the efficiency of the operation, the producer might never achieve the goals set before hand, leading to poorer financial results than expected.

The choice of the milking system has to be a realistic compromise between efficiency and cost. No compromise can be made on the quality of the milking equipment (pulsator, regulator, clusters, liners…). Only equipment specifically designed to milk sheep should be used in order to have as complete evacuation of the udder as possible without causing trauma to the udder.

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REGULATIONS FOR SHEEP MILK

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History

The WDATCP Food Division, became aware of and began regulating dairy sheep operations in 1989. Hal Kohler of Polk County was the first licensed sheep milker in Wisconsin. At that time sheep milk was not defined as "milk" by State Statute 97 and therefore was not governed by dairy regulations.

The Food Division made the decision to license these early sheep milk farms as food processors. However, it was presumed that eventually these farms would come under the dairy regulation. Guidelines were therefore developed to permit sheep milkers to eventually be licensed as dairy farms.

In 1994 State Statute 97 was amended to include sheep milk in the definition of milk. At that point ATCP 60 became the regulation governing sheep dairies. Since that time, the Food Division has been working with dairy sheep producers to license farms according to Wisconsin Administrative Code ATCP 60, the dairy farm regulation.

Licensing

Wisconsin Administrative Code ATCP 60 requires that all dairy farms in Wisconsin be licensed. The customary way of becoming a licensed farm in Wisconsin is to first choose a plant to receive the milk. The plant then has the responsibility to insure that minimum requirements for a grade B dairy farm are met. Once the requirements are met, the inspector is informed and a licensing inspection takes place.

- Acceptable farm conditions shall include minimum physical facility standards as follows:
- A suitable milking barn with a concrete floor, walls and ceiling in good repair and cleanable, adequate lighting.
- A suitable milk house with a concrete floor, walls and ceiling in good repair and cleanable, doors and windows properly installed, adequate lighting, and a hose port if a bulk tank is used for the collection of milk.
- A safe water supply. **Note**: Water supplies of grade B farms are not subject to enforcement action of Chapter NR 112, Wisconsin Administrative Code by WDATCP staff.
- Hot and cold water under pressure.
- A two compartment wash sink and a hand wash sink.
- Utensils, containers, and equipment shall be of proper design and material.
- A toilet convenient to the milking operation.
- A suitable way of cooling milk under 45° within two (2) hours of milking and freezing milk and keeping it frozen at 0°F or less.

After assuring that the above minimum requirements are met and receiving a properly filled out dairy producer application and inspection form from the plant, the inspector will either grant or deny the dairy producer license. Once the license is granted, it is the plant's responsibility to perform quality tests including antibiotic screening before accepting any milk.

Grade B milk quality is as follows:
1. Standard Plate Count (SPC) shall be 300,000 per ml or less.
2. Somatic Cell Count (SCC) shall be 1,000,000 per ml or less.
3. Milk shall be free of antibiotics as determined by utilization of one of the following antibiotic screening tests:

- Charm Bs Da
- Charm II Sequential
- Delvotest P
- Idexx Snap-BL
- Penzyme Milk Test

It should be noted that at this time there are no FDA approved drug screening tests for sheep milk. However, these tests are approved for goat milk, and the Food Division has made the decision that these tests are the most appropriate to be used to test sheep milk.
Milk not meeting these quality standards shall be rejected.

Permitting

Grade A farms are not only licensed, but also permitted with a grade A permit. Farms wishing to become grade A must meet all the requirements of grade B farms plus the water supply must be inspected and comply with NR 112. The grade A requirement is only necessary if the milk is being processed into a grade A product. Grade A products are as follows: fluid milk, yogurt, sour cream, cream, half and half, buttermilk, and any variation of these products.

If the grade A permit is required, and the milk or milk product crosses state lines, the farm will also come under scrutiny by the Wisconsin Department of Health and Family Services and the FDA. These agencies regulate farms through the Pasteurized Milk Ordinance and the Interstate Milk Shippers list.

The grade A quality standards for sheep milk are:

- SPC – 100,000 per ml or less
- SCC – 1,000,000 cells per ml or less
- Antibiotic tests negative

Grade A farms in Wisconsin are inspected on a “risk based” farm inspection program. Farms are classified by on site inspections and quality counts into one of four categories each having a different inspection frequency. The frequencies are as follows:

- Category 1 every 12 months
- Category 2 every 6 months
- Category 3 every 4 months
- Category 4 every 3 months

Inactive Farms

Normally cow dairies in Wisconsin are allowed six (6) months of dormancy or “dry status” before the farm license is revoked. Since grade B sheep dairies are dry for approximately eight (8) months, the Food Division has waived this rule. Grade A farms are allowed only two (2) months of inactivity before the permit is revoked. This requirement has not been waived and therefore grade A sheep dairies must be permitted every year.

Monthly Quality Tests

A licensed sampler must collect a representative sample of a producer's milk every month on a random basis. This sample is analyzed for SCC, SPC and antibiotics. Any 2 out 4 months of violative samples for SPC and SCC will generate a warning letter to the producer. If the violations continue to 3 out of 5 months, the grade A permit is suspended.

Any positive result for antibiotics requires that the plant reject all shipments of milk until the milk is found clear of antibiotics. The producer must than complete a drug residue prevention protocol within 21 days for grade A producers and 45 days for grade B producers or suffer permit suspension and/or license revocation.

Immediate Response

The immediate response level for sheep milk is 1,000,000 SPC per ml, 1,500,000 SCC per ml. If the immediate response levels are reached by a producer, the plant has 14 days to obtain a sample of less than 1,000,000 SPC per ml. or 1,500,000 SCC. If this cannot be accomplished, the plant must reject all future shipments of milk. Any positive drug residue requires that the plant reject milk shipments immediately.

SHEEP MILK PRODUCER GUIDELINES

These guidelines generally follow the items listed on the DATCP Dairy Producer Farm Inspection form FD-11 (Rev. 9/97)

SHEEP

1. Abnormal Milk

(a) Milk which is ropy, stringy, clotted, thick or abnormal in any way. It includes milk containing pesticides, insecticides or medicinal agents. Regular equipment may be used but not until all other animals are milked.

(b) Abnormal milk must not be squirted on the floor, on the platform or in the producer's hand.

(c) Milking equipment used for handling abnormal milk must be washed and sanitized after such use. Producer should also wash his hands after handling such equipment and handling the teats and udders of animals producing abnormal milk.

MILKING PARLOR/AREA

2. Construction

(a) Floors shall be constructed of concrete or equally impervious material. Ramps and platforms used to elevate the sheep for milking must be constructed of an impervious material such as steel (wooden platforms and ramps are not allowed). Rubber cow mats may be used as long as they are not placed over a wooden platform.

(b) Walls and ceilings must be reasonably smooth and be painted or whitewashed or have other acceptable finish; shall be kept in good repair and surfaces shall be refinished whenever wear or discoloration is evident. Ceilings must be dust tight. Hay or straw chutes must have dust-tight doors which must be kept closed during milking.

(c) Not Applicable
(d) At least 10 foot candles of artificial light is required in a sheep milking parlor. Lighting should be similar to lighting in a dairy cow milking parlor.
(e) Parlors must be properly ventilated in order to prevent excessive condensation and odors.

3. Cleanliness

(a) Cleanliness of the sheep milking parlor should be similar to that of a dairy cow milking parlor. Due to the size and nature of sheep, it should be easier for a producer to keep the parlor clean.
(b) Swine and fowl are not permitted in the milking parlor.

4. Sheep Housing Area

(a) Sheep are generally housed in a "loose housing" building near the milking parlor. This area should be kept reasonably clean. No excessive accumulation of manure is allowed.
(b) Complete separation between the sheep housing area and the sheep milking parlor is required if sheep milker units are stored in the parlor.
(c) Hogs and fowl shall not be housed with sheep.
(d) Not Applicable

MILKHOUSE

5. Construction and Facilities

(a) A milkhouse must be provided for storage and cooling of milk and proper cleaning and storage of equipment. The milkhouse area is the area that needs to be modified to meet the peculiar needs of sheep milking operations. The following requirements apply to a milkhouse whether or not a bulk tank is used: milk may not be placed directly in the freezer prior to cooling.

Sheep are many times milked by means of a modified bucket. The milk is then placed in a single service plastic bag which is cooled by a variety of means. The most effective cooling occurs by floating the bags of milk in a water filled vessel (bulk tanks are used) until the milk is cooled to below 45º. The bags are then placed in a freezer where they remain frozen at 0º Fahrenheit or colder. The frozen milk is then transported to the plant.

Floors

(a) Floors must be reasonably smooth concrete, tile, brick or other impervious material maintained free of breaks or depressions.
(b) Floor must be sloped to drain properly. Joints between floor and wall shall be watertight.
(c) Liquid wastes are to be disposed of in a sanitary manner, preferably underground. If this is impossible, waste may come to the surface far enough away to not constitute a fly or odor hazard, contaminate the water supply or be accessible to the milking herd. Drains must be accessible and must be properly trapped if connected to a sanitary sewer. This means drains must not be located under equipment.

Cast iron or approved plastic soil pipe drains must be located at least eight feet from the well. Glazed tile drains must be not less than 25 feet from the well.

Walls and Ceilings

(a) Must have reasonably smooth surfaces and joints must be tight and smooth.
(b) Windows and doors must fit properly. All panels must be in good repair. Walls and ceilings must be in good repair and finished with a light color.

Lighting and Ventilation

The outside door of the milk house is required to be self-closing unless an outward opening screen door is used which is self closing.

(a) Lighting must be evenly distributed to include a 100 watt bulb located near the double compartment wash sink.
(b) Sufficient ventilation is required to minimize odors and condensation on walls, ceilings and equipment.
(c) Windows and doors must be kept closed during dusty and windy weather.
(d) Vents and lighting fixtures shall not be located directly above bulk tank or utensil areas.

Miscellaneous Requirements

(a) The milkhouse is to be used for no other purpose than milkhouse operations.
(b) There must be no direct opening from the milkhouse into a stable used for the housing of non-milking animals or any room used for domestic purposes. Any direct opening between a milkhouse or milk room and a milking barn, stable or parlor shall be equipped with tight-fitting, self-closing solid doors.
(c) If the milk house drain is discharged to a septic system, it must be trapped. Milk house waste may not come to surface in the sheep yard or any place where the waste will pool and create a fly breeding area or odor problem near the milking barn or milk house.
(d) The freezer used for freezing sheep milk shall be kept in the milkhouse and used exclusively for the storage of sheep milk. Hose ports are not required at this time.
(e) Not applicable at this time.
(f) Not applicable at this time.

Cleaning Facilities

(a) A double compartment wash sink with hot and cold running water plumbed to the sink is required. Each compartment must be large enough to accommodate the largest piece of equipment.
(b) Hot water heaters or hot water supply systems for use in the milkhouse or milk room shall have a capacity of at least 30 gallons for the manual washing of equipment. CIP washing of pipelines, units and bulk tanks require capacity of 75 gallons.
(c) Water under pressure must be piped into the milkhouse to perform cleaning of the equipment.

6. Cleanliness

(a) The milkhouse must be free of dust, cobwebs, peeling paint, dead insects, debris, trash or articles not directly involved in the production of milk. The milk room structure, equipment, and other milk room facilities used in its operation or maintenance must be kept clean.
(b) No poultry or animals are permitted in the milk house.

TOILET AND WATER SUPPLY

7. Toilet

(a) Each farm must have at least one toilet constructed and operated according to the State code. The toilet must be convenient to the milking barn and milkhouse. There must be no evidence of defecation or urination about the premises.

(b) The privy may open directly into the milkhouse. Toilet room and fixtures must be kept clean and free of flies and odor. All toilet room doors are to fit tightly and be self-closing. All outer openings of toilet rooms are to be screened.

(c) No evidence of human wastes around the premises.

(d) Privy covers are to be kept closed. Privy vents are to be screened. Privy pits must be fly and rodent tight.

8. Water Supply

(a) The water supply must be in compliance with the state well code. Reservoirs or storage tanks shall be constructed of impervious material in good repair with approved screened overflow, shoe box type cover, inlet to be above ground level. New reservoirs or reservoirs which have been cleaned are to be disinfected before being placed in service. Wells no longer in use should be properly abandoned following DNR guidelines.

(b) The supply must be approved as safe by a certified laboratory. It must be safe when the farm is licensed and must be resampled at intervals of not over two years or after any repair or alteration has been made to the water system. Water reports must be on file at the dairy plant and in the regional office.

(c) There must be no cross connection between a safe and questionable supply. There must be no submersed inlet. This includes siphon type drinking cups, siphon type hog or poultry waterers and stock tank floats.

UTENSILS AND EQUIPMENT

9. Construction

(a) Milk contact surfaces shall be made of stainless steel of the 300 series, equally corrosion resistant non-toxic metals or heat resistant glass. Plastic or rubber-like material must be relatively inert, resistant to scoring, chipping or decomposition and must be non-toxic and does not impair flavor or odor to the product. All milk contact material must be easily cleaned.

(b) All containers and utensils must be free from breaks, corrosion, and points must be free from pits or cracks. Bulk tank and freezer thermometers should be accurate within +/- 2ºF.

(c) Single service articles shall be protected from chemicals or other contaminants. Single service articles such as strainer material or single service plastic bags are not to be reused. Plastic bags must be food grade.

(d) Strainers are required to be of perforated metal design or so constructed to utilize single service media.

(e) CIP milk pipeline systems must be approved and installed according to 3-A Standards.

10. Cleaning

(a) The product contact surface of all milk handling equipment must be cleaned after each use.

11. Sanitizing

(a) All product contact surfaces of all milk handling equipment must be effectively sanitized before use. Sanitizer must be an approved type with full label directions.

12. Storage

(a) All milk containers and equipment, including milking machine vacuum hoses, must be stored in the milk house.
(b) Milking equipment must be stored to assure complete drainage.
(c) Filters and single service plastic bags shall be stored in the original container inside a protective box. Bags for milk storage must be stored in a manner which protects them from contamination. It is recommended they be stored in an enclosed cabinet.

MILKING

13. Udders and Teats

(a) Milking must be done in a milking barn or parlor.
(b) Not Applicable
(c) Milking ewes must be free of visible dirt on their udders, flanks and bellies.
(d) Teats of all milking sheep are to be cleaned and treated with a sanitizing solution and dried just prior to milking.
(e) Wet hand milking is prohibited.

Surcingles, Milk Stools & Anti Kickers

(f) Not Applicable
(g) Not Applicable

TRANSFER AND PROTECTION OF MILK

14. Protection from Contamination

(a) Not Applicable
(b) All product lines must be physically separated from CIP circuits when milking or when milk is stored in bulk tank.
(c) Overflowed, leaked, spilled or improperly handled milk shall be discarded.
(d) Each bucket or container of milk must be transferred to the milkhouse immediately.
(e) Equipment containing milk must be properly covered during transfer and storage.
(f) Any sanitized product contact surface which has been exposed to contamination is required to be sanitized before use.
(g) Air injectors must be located in the milk house.

15. Drug & Chemical Control

(a) Cleaners and sanitizers must be properly labeled, including instructions for use.
(b) Syringes, bolus guns, etc. shall be stored in a manner to preclude any contamination of milk or milk contact surfaces.

(c) Drugs and medicinals shall be labeled with the name and address of the manufacturer or distributor for over the counter products, or veterinarians name and address for prescription drugs. Drugs and medicinals improperly stored which will not directly contaminate milk or milking equipment are violations of this section. This means non-lactating drugs stored with lactating drugs and/or drug storage on window sills, water heaters, etc.

(d) Self-explanatory; drugs **shall** be labeled with directions for use; withholding times; active ingredients; and cautionary statements, if needed.

(e) Drugs and medicinals **shall not** be used in a manner inconsistent with the label directions or in a negligent manner. Drug and medicinal storage that could result in contamination of milk or milk contact surfaces such as storage on bulk tank in or above the wash vats, or on equipment storage racks is not permitted.

PERSONNEL

16. Hand-Washing Facilities

(a) Hand washing facilities shall be located in the milkhouse and convenient to the milking barn or parlor.

(b) Hand washing facilities including soap or detergent, hot and cold running water plumbed to the hand sink, individual sanitary towels and a lavatory fixture or basin are required. A utensil wash tank may be used as hand washing facilities providing this tank is not required for equipment washing. This tank must be identified as a hand wash vat.

17. Personnel Cleanliness

(a) Hands must be washed, cleaned and dried with an individual towel immediately before milking or performing any milk house function and immediately after any interruption of any milking or milkhouse function.

(b) Milkers and milk handlers must wear clean outer garments while milking or handling milk or milking equipment.

COOLING

18. Cooling

(a) Milk shall be cooled to 45ºF or less within two hours of milking.

(b) Water used for milkhouse and milking operations must be potable. Cooling water used in bulk tanks in which bags of milk are cooled shall be chlorinated. If milk is cooled by pouring into plastic bags and then floating the bags of milk in cooling water, the process must preclude contamination of the milk by the coolant.

INSECTS AND RODENTS

19. Insect and Rodent Control

(a) Effective measures shall be taken to prevent the contamination of milk equipment and utensils by insects, rodents and chemicals used to control such vermin. Fly baiting shall be minimized by approved manure disposal methods.

(b) Manure packs shall be properly maintained.

(c) All milkhouse openings shall be effectively screened or otherwise protected; doors shall be tight fitting and self closing. Screen doors shall open outward.
(d) The milkhouse shall be free from insects and rodents.
(e) Only insecticides and rodenticides approved for use by and registered with the Department or the US EPA shall be used. Pesticides shall be used only in accordance with the manufacturers label and in a manner which will prevent the contamination of milk, containers, equipment, utensils, feed and water.
(f) Pesticides must be stored in an enclosed cabinet if stored in the milk house, separate from other articles.
(g) Surroundings shall be kept neat, clean, and free of conditions which might harbor or be conducive to the breeding of insects and rodents or any other health nuisance.
(h) Feed shall not be stored in the sheep milking area or parlor.

FARMSTEAD CHEESE AND MARKETING

Steven and Jodi Ohlsen Read

Shepherd's Way Farms
Nerstrand, Minnesota

At Shepherd's Way Farms, we believe that there is a way to live that combines hard work, creativity, respect for the land, and a focus on family and friends. We believe the small family farm still has a place in our society.

Everything we do, everything we make, is in pursuit of this goal.

History of Business

Value-added agriculture is a rapidly expanding industry that provides new options for small, family-based farms. Farmstead cheesemaking is one opportunity that can open new doors for the small farm, allowing innovative individuals to take advantage of the growing demand for specialty cheeses and of the consumer's desire for a connection to their food and the grower. Sheep cheese meets the needs of this specialty niche, providing many other capital generating options for the business owner, including agri-tourism and related products.

While sheep cheese has been made for centuries in other countries, the industry is relatively new to the United States, which increases the products' unique appeal. With only a handful of sheep dairy operations in the country, the competition is limited and the marketplace is open to high-quality, handcrafted cheeses.

Shepherd's Way Farms recognized this opportunity and established itself as one of the only sheep dairies in Minnesota in November 1994. The Farm established its dairy flock with 30 Rambouillet yearlings and one 28% Friesian dairy ram lamb. Currently, Shepherd's Way Farms' flock is made up of roughly 500 high percentage Friesian ewes.

In August 1998, Shepherd's Way Farms began processing and marketing its own farmstead cheese, Friesago. From the beginning, Friesago received enthusiastic endorsement from local Minnesota and Wisconsin co-ops and other natural food stores and Twin Cities restaurants. A second cheese, Queso Fresco d'Oveja, was test-marketed in 1999 and became available to select retailers in 2000. Demand for both products has continuously exceeded supply.

Shepherd's Way Farms also provides lamb to local restaurants, markets, and individuals and offers exclusive dairy rams as breeding stock.

Market Analysis and Strategy

In developing the Friesago, the goal was to produce a cheese that offered quality, affordability and versatility as a table and cooking cheese. This was achieved, allowing Shepherd's Way Farms to target a range of cheese consumers that includes the cheese connoisseur, the natural foods consumer, the consumer interested in unique but affordable cheeses, and chefs who are committed to supporting locally produced farmstead cheeses.

1. The majority of the people in the targeted categories are also interested in supporting the small or local producer in contrast to the larger cheese producing companies or international producers. This has given Shepherd's Way Farms a distinct marketing advantage over imports and mass produced cheeses. Retail cheese buyers, chefs and consumers demonstrate a strong buying response to a farmstead cheese when they have the opportunity to meet the producers and feel that they are supporting not only a quality cheese, but also the family farm which produces the cheese. While this is considered a niche market, the United States imported $143 million of sheep milk cheeses in 1997 and consumption continues to rise annually.

   The main retail outlet for Shepherd's Way Farms cheeses are co-ops and natural food stores, which are a growing area of retail foods. There are more than 10 co-ops in the Twin Cities area alone. Nationally, just one of the several natural foods chains - Whole Foods Markets - has over 100 stores.

   Because of the versatility of both the Friesago and Queso Fresco, Shepherd's Way Farms has also developed a strong restaurant base, which is crucial in sales and marketing. Chefs who use the cheeses are asked to contribute recipes that are then made available during samplings and demonstrations. This gives the cheese an additional draw for the consumer as well as additional positive advertising for both the restaurants and the Farm.

2. Currently, most sheep cheeses are imported and are offered at a higher price than Shepherd's Way Farm products. Many small, farmstead cheese operations have difficulty establishing an identity and a functional marketing strategy and can also struggle to deliver consistent quality products in efficient manners. Generally, customers looking for a quality, non-imported artisan cheese would have a very limited selection.

   Shepherd's Way Farms has developed a brand identity and consistent, widely endorsed products. Management of the milking flock includes no use of hormones or steroids, which classifies Shepherd's Way Farms' cheeses as natural. The Farms' identity as a local artisan cheese producer and its coordinated marketing, sales, and service set it apart from competition.

   Some other sheep cheese producers include Old Chatham Shepherding Company (New York), Sally Jackson (California), Bass Lake (Wisconsin), Love Tree Farm (Wisconsin), and Vermont Shepherd (Vermont). Shepherd's Way Farms cheeses are significantly different in type and style of cheese, pricing, and versatility than those provided by other sheep cheese producers and are not directly competing for market shares.

3. Shepherd's Way Farms cheeses are marketed directly to the co-op and natural food stores' cheese buyers and to chefs, through personal meetings and samplings. To promote the cheese in-store, Shepherd's Way Farms coordinates demonstration samplings during peak sales hours. Customers appreciate the opportunity to meet the shepherd and cheese maker, which helps establish a unique customer loyalty. Individual stores also promote the cheese through their own sales and promotions. Personal attention is one of Shepherd's Way Farms strongest sales and customer retention strategies.

4. To date, the response to minimal sales and advertising has been exceptional, with demand continually exceeding supply. Upon expansion, sales efforts will increase accordingly to expand the customer base into a variety of metropolitan areas.

5. Cheese is delivered in person, weekly, within the Twin Cities metro area. Orders from outside the metro area are served by two-day postal delivery, in custom made, insulated boxes with ice packs to ensure that the product remains fresh.

6. Pricing is one of the elements that makes Shepherd's Way Farms cheeses so appealing, both to the retailer and to the customer. In an effort to keep the cheeses accessible to a wide range of consumers, the Friesago and Queso Fresco are priced in the mid-level range which places Shepherd's Way Farms in an advantageous competitive position against more expensive cheeses.

Factor and Demand Conditions

1. Specialized factors for the success of Shepherd's Way Farms include both labor and infrastructure. Cheesemakers with experience producing sheep milk dairy products are crucial for developing the correct product and correct production methods. There are very few individuals with this necessary experience in North America. Our response was to identify individuals with specific experience and to invite them to work and learn with us.

   As for infrastructure, the proper cheese manufacturing, aging and distribution facilities are important to ensure the quality of our product and our success in bringing it to the marketplace.

2. The advantage that sheep milk offers which drives innovation is twofold. One is the composition of the milk and how this affects the types of cheeses and dairy products that would most likely result in a superior product than if other types of milk are used. For example, our Queso Fresco de Oveja is a superior product to one made out of cow's milk because it is firmer, less bitter and has a longer shelf life. Yogurt and butter are two other examples of products that would be superior due to the components of the milk.

   The second driving advantage is the uniqueness of sheep milk. Using the above example, Queso Fresco de Oveja is unique in North America, no other cheesemaker or company produces a similar product. This uniqueness drives innovation without the pressures of competition. Each product will assume a preferred position in the marketplace. The emphasis then becomes choosing those products most marketable.

   Disadvantages of infrastructure drive innovation of a different kind. First of all, the small production capacity required of farmstead cheese manufacturing dictates that maximum use be made of the assets. This is accomplished by ensuring continuous use through the use of frozen milk to guarantee that the highs and lows of the production cycle are mitigated. At the same time, the need to maximize the efficiency and output determine the innovation of products which realize these goals.

3. Our customers are consumers who are cheese lovers, consumers who are looking for dairy alternatives to cow milk products, and individuals who actively support farm based products.

4. The primary suppliers for both equipment and commodities are based in Wisconsin. The main supplier of sheep milk is the Wisconsin Dairy Sheep Cooperative. Equipment and supplies come primarily from cheese product supply companies based in the Madison to Milwaukee area.

Products

1. Shepherd's Way Farms' product list currently includes two products already offered for retail sales. The first cheese offered, Friesago, is a semi-hard cheese with a smooth, slightly nutty flavor, reminiscent of Manchego or Parmesan, with a grainy texture and wonderful after flavor. The second cheese, Queso Fresco de Oveja, is a fresh cheese offered in two flavors, plain and herb and garlic. Both cheeses are versatile as great table and cooking cheeses.

2. Both products are unique to Shepherd's Way Farms and marketed as trademarked products, with registered trademark status being considered.

3. Non-imported artisan sheep cheeses are very few. Shepherd's Way Farms products align well with such competitors as Old Chattham and Vermont Shepherd. Shepherd's Way Farms cheeses are distinct from other sheep cheeses and provide versatility and affordability.

Manuracturing Process

1. The materials used in the processing of cheese are the source milk, vegetarian rennet, enzymes, salt and in some cases, flavoring.

2. Our product is manufactured by pumping milk from a storage tank through a high temperature/short time (HTST) pasteurizer. This type of equipment affords us a great deal of flexibility that is not typically available to small producers. After the necessary heating time, the milk is transferred to the cheese vats through a cooling system. At the appropriate temperature for a specific type of cheese, rennet and then a culture is added. The curd once formed, is harped (cut) and cooked, if necessary, until the appropriate ph level is reached. At this time, the whey is drained and the curd is hooped into the correct moulds or forms.

The Future

Long-term development calls for the Farm to expand to meet production needs as demand continues to increase. Shepherd's Way Farms will continue to expand it's client base to include outlets throughout the United States, focusing on major metropolitan areas. The planned addition of a small herd of Kerry cattle will allow the production of a farmstead cow cheese to expand the consumer base. Additional products include a sheep milk soap, which was well received in an initial test market, sheep's milk butter in response to consistent demand from both retailers and chefs, and lamb and mutton specialty sausages.

The Northfield Club

In November 2001, we initiated a subscription based cheese club called the Northfield Club. We invite individuals and businesses to join us in pursuit of our goals by subscribing to the Northfield Club with membership fees for set periods of time. With their membership, subscribers will receive quarterly deliveries of our artisan, farmstead cheeses for their personal enjoyment. In addition, members will have the opportunity to try any of our new cheeses before they are available publicly. Members will also have the option of substituting their cheese orders with any of the other products available from Shepherd's Way Farms.

This club allows us not only to capture a share of the growing gourmet mail order market, but also to favorably position ourselves as one of the very few farm based distributors of artisan cheeses and products. At this time, all of the current gourmet clubs identified by our marketing research show only general distributors with no direct producer linkages. By inviting subscribers to participate with us, we are engaging them not only as consumers, but providing them with a sense of ownership in support of family farms and our philosophy. This has been a powerful marketing message for our business and will continue to be so as we develop greater brand identification nationally.

This group also represents a select test marketing audience for our own product development research. Both in the marketing of new cheeses, and in gauging demand for alternate farm products, we will be able to privately track those products with the most growth potential before we bring them to the marketplace for general distribution. The main kick off event for this Club will be take place in the fall of 2001.

Agri-tourism

Shepherd's Way Farms will also continue to develop the agri-tourism aspect of the business. Fewer and fewer farms remain that have a diverse range of animal enterprises on site. Specialization has meant that only by visiting several different farms will an individual family or tour be able to experience more than one type of agriculture. Shepherd's Way Farms will offer visitors an opportunity to experience a traditional farm experience with dairy cows, hogs and poultry, with non-traditional enterprises of dairy sheep and cheese-making. This is both a financial and marketing strategy.

In addition, the national interest in bio-diversity has now expanded to include agricultural breeds of animals. This means that the breeds of livestock Shepherd's Way Farms will include on its farm will be defined as 'critically threatened.' The Kerry dairy cow, the Tamworth and Large Black pigs, even the Black Austrolorp chicken, each has a functional role in the farm as an enterprise, while offering greater appeal as marketing and tourist attracting strategies because of their rareness

Conclusion

The future of our industry and of Shepherd's Way Farms is bright. This guarantees not only our personal success, but the success of a way of life many feel is threatened. We take our roles as stewards of our land and animals very seriously. Combined with our commercial success, we hope that we can serve as an example for other small farmers who also believe the small farm still has a future in our communities.

THE WISCONSIN SHEEP DAIRY COOPERATIVE – PAST, PRESENT AND FUTURE

Daniel P. Guertin

Wisconsin Sheep Dairy Cooperative
Strum, Wisconsin

The sheep dairy industry in the upper Midwest began in the mid 1980s with a small group of Minnesota and Wisconsin sheep producers who began supplying sheep milk to a small cheese plant (LaPaysanne) in east central Minnesota that specialized in sheep milk cheeses. By the early 1990s, a second cheese plant (Bass Lake Cheese Factory) in northwestern Wisconsin had also began producing specialty cheeses from sheep milk. During these early days, sheep milk was sold as a food product and did not fall under the MN and WI requirements for milk. By the mid 1990s, sheep milk was reclassified as milk and became subject to the stricter state dairy regulations. Through the mid-1990s, all milk sales were direct sales from the farmers to the cheese plants. Each cheese plant was responsible for inspecting, licensing, and paying the individual farmers who they bought milk from. This led to a very management intensive situation for the cheese plants that required licensing and re-licensing of farms each time the individual farms shipped milk to a different cheese plant. This situation was complicated by the extremely volatile market for domestically produced sheep milk cheeses which led to alternating periods of high demand for sheep milk followed by periods of no demand for sheep milk. The volatility of the sheep cheese market and milk supply led to the demise of La Paysanne in 1995.

In 1996, a third cheese plant (Montchevre), located in southwestern WI, expressed an interest in sheep milk. They indicated, however, that they were only interested in working with a single supply source for sheep milk that would handle all of the licensing, annual inspections, monthly milk sampling, inventory management and payment to individual farmers. This request led to a meeting in the spring of 1996 of existing and potential sheep dairy producers in the Midwest and the subsequent formation of a steering committee to determine the feasibility of establishing a sheep dairy cooperative. By September of 1997, the WSDC had been formed and registered as a cooperative in the state of WI.

During the 1996 and 1997 milking seasons, the WSDC functioned as a Producer Agent for Montchevre. This meant that the co-op functioned under the dairy plant license of the cheese processor and performed all of the required inspections, testing and payments to individual farmers. In the spring of 1998, the WSDC became licensed as a Dairy Plant in the State of Wisconsin. This provided autonomy for the cooperative and allowed the co-op to begin marketing milk to additional customers.

The original goals of WSDC were to: 1) market sheep milk produced by its members, 2) establish a stable market for sheep milk, 3) establish a stable supply of sheep milk and 4) provide the highest quality sheep milk available. In 1998, the WSDC received a grant from the State of Wisconsin's Agricultural Development and Diversification Program to develop marketing strategies for the co-op. As part of this effort, and with the help of the University of Wisconsin Center for Cooperatives, the WSDC established a <u>Three-Year Strategic Plan</u> that incorporated the original goals of the cooperative.

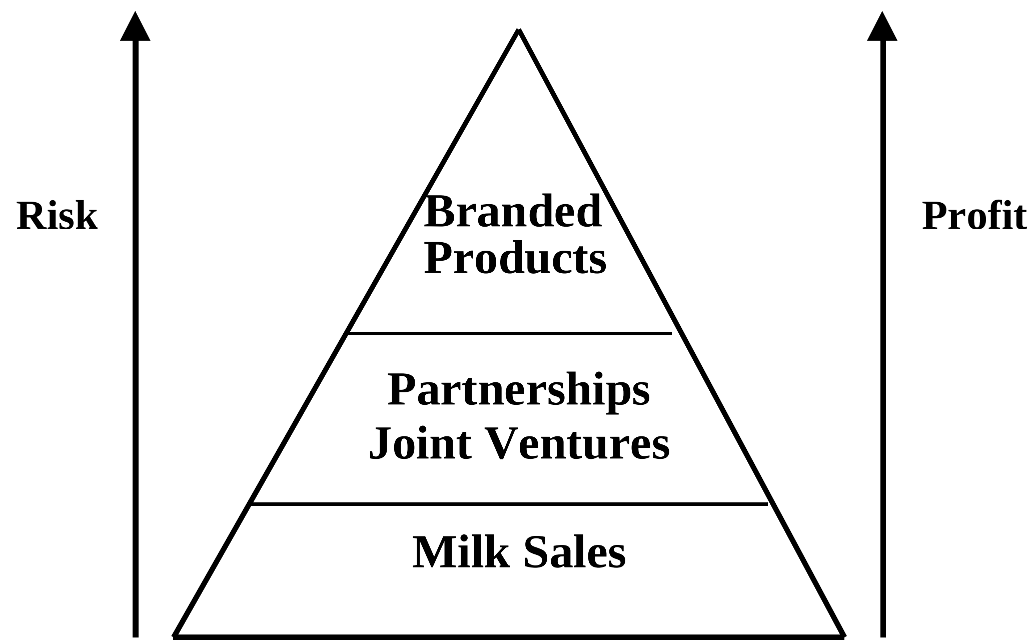
The key points to this plan were:

Year 1 - establish new markets for sheep milk
- establish quality program to insure excellent quality milk
- build infrastructure, management of inventory & transportation

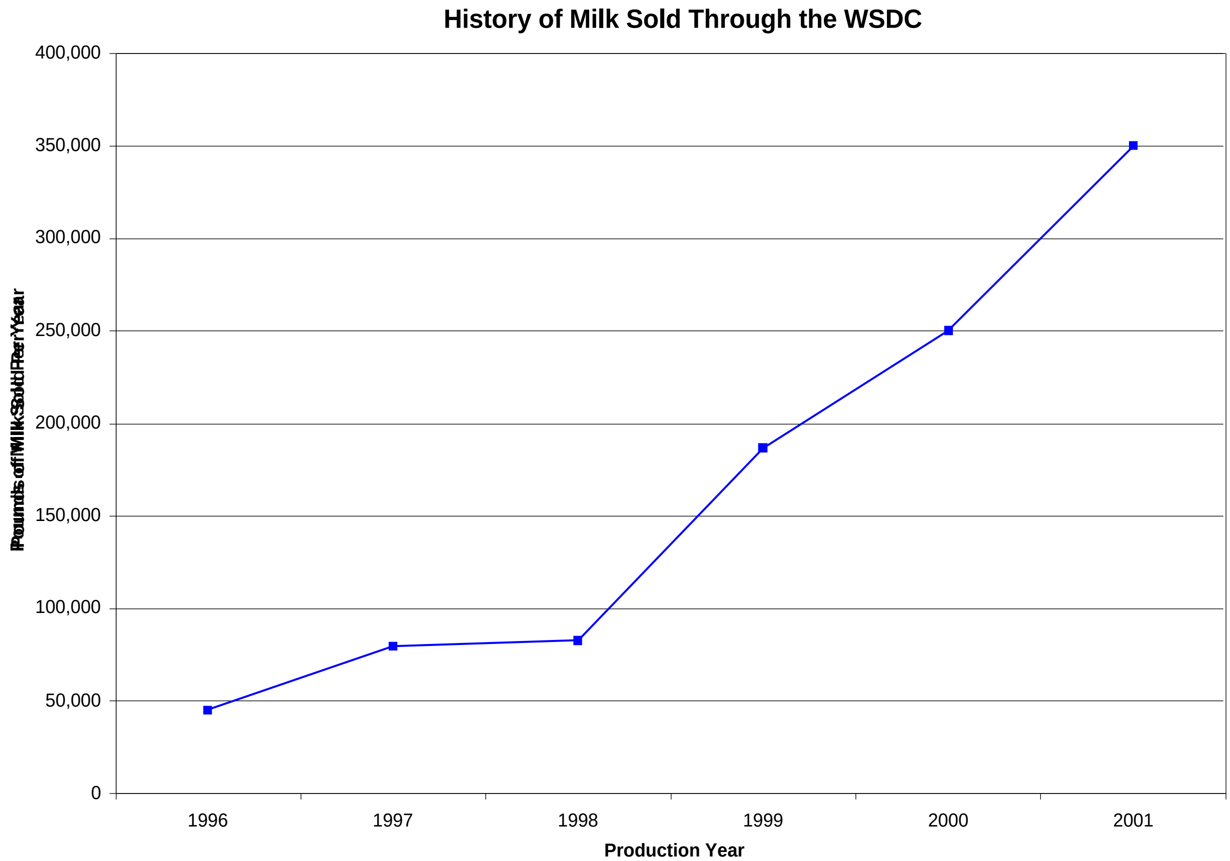
Year 2 - continue to build programs begun in Year 1
- seek partnership and joint venture opportunities
- begin development of 'Branded Product(s)'

Year 3 - continue to build on programs begun during Years 1 & 2
- introduce 'Branded Product(s)' to the marketplace

The philosophy behind these goals is depicted in the figure below. We planned to build the base of the cooperative on milk sales. These sales would then provide operating income that would allow us to pursue partnerships and joint ventures. Revenues from these pursuits would then provide the funding needed to develop and market a branded product(s). At each step up the pyramid, the cooperative would take on higher levels of risk and, at the same time, realize greater profit per pound of milk as we added more value to the milk.



The co-op has met and continues to pursue all objectives related to milk sales and establishment of the infrastructure needed to support it. The following chart shows milk sales through the co-op over the last 6 years. As you can see, annual increases in sales have been very strong.



The co-op is actively pursuing business relationships that we expect will result in both mutually beneficial results for the co-op and our partners as well as additional income for the members of the cooperative. Work on a branded product has been delayed, primarily due to the lack of sufficient milk to support this project.

Current Status of WSDC

During the 2001 season, the co-op consisted of twelve member farms. These farms had flocks ranging in size from 25 - 250+ ewes. All flocks are currently using seasonal dairying, with milking beginning in some flocks in February and ending in others in October. The potential for year round milk production will continue to be evaluated as market needs grow. Initial milk production for dairy sheep in the cooperative began at ~120 lbs in 90 days. Though introduction of improved dairy genetics and heavy selection for higher yielding animals, production levels for many animals now exceeds 400+ lbs in 180 days. With an interest from cheese processors on the use of component pricing in the future, the selection process is now shifting to selection of animals with higher % solids, while maintaining high levels of milk production.

The milking equipment used by co-op members has shifted from bucket milking (e.g. Surge buckets) and freezing in chest freezers to pipelines and the use of commercial walk-in freezers running at -15°F. The changes have resulted in a much higher quality of milk with much longer shelf life.

Milk is supplied in two major forms, fluid and frozen. 2001 was the first year the WSDC has shipped fluid milk to cheese processors. By contracting with a local bulk milk carrier, we were able to ship a total of 79,533 pounds of milk between 14 different shipments to two cheese processors. This capability significantly reduces the amount of labor on the farm as well as at the cheese plant. All frozen milk sold this year was placed in milk bags (40# per bag) prior to freezing and then frozen to –10C within 12 hours by placing these bags in commercial walk-in freezers. While frozen milk requires more labor and equipment, it does make use of sheep milk's 'unfair advantage' over other types of milk because it can be stored frozen for at least 12 mo. at -15°F without appreciable chemical or biological degradation. This property allows the co-op to supply milk on a year round basis while still operating seasonal dairies.

Future Opportunities for the WSDC

While the actual number of sheep dairies in the U.S. and Canada is unknown, estimates range from 100 to 150 farms. Sheep milk produced on many of these farms is used to produce farm-stead products that are sold through a variety of outlets. Milk produced on other farms is produced specifically for sale to off-farm processors. The WSDC is currently the only sheep dairy cooperative in the U.S. and the largest sheep dairy cooperative in North America. The WSDC sees a major opportunity for continuing to facilitate the introduction of sheep milk and sheep milk products on a large-scale, (inter) national basis. This can be accomplished by increasing the membership in the WSDC to increase the milk available to our customers as well as by working cooperatively with other cooperatives to help manage the constant challenge of matching supply with demand. By effectively managing the supply of sheep milk, sheep dairy farmers can insure themselves a fair price for their milk while at the same time being able to supply large quantities to processors at a price that allows them to realize a reasonable profit as well. With current estimates for U.S. imports of sheep milk products at more than 72 million pounds annually (equivalent to ~ 360 million pounds of milk), there is a great deal of room for cooperative growth between producer and processors. The WSDC would like to be a central participant in making this dream come true.

GETTING STARTED IN SHEEP DAIRYING

Jon and Kris Tappe

Tappe Farms
Durand,Wisconsin

Goal Setting

- Research
  - Type of milking facilities
  - Sheep breeds
  - Dairy Sheep management
    - Pasture vs feedlot
    - Nutrition
    - Raising Lambs
  - Housing facilities
    - Ewes
    - Lambs
    - Rams
- Determine size of operation

Financing

- Evaluate existing facilities
- Obtain estimates for needed equipment/buildings
- Cash flow worksheets on sheep dairying and other enterprises
- Evaluate economic feasibility
- Mission statement and five year/long range plan
- Obtaining loan

Construction

- Plans
- Timeline
  - Parlor/milk house
  - Fencing/feedlot
  - Sheep arrival
  - Utilities
  - Feed storage
  - Milking start date
- Quality control/supervision

Lessons Learned

MANAGEMENT OF A DAIRY SHEEP OPERATION

Tom and Laurel Kieffer

Dream Valley Farm, LLC
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Ten years ago, we left a very comfortable lifestyle in Eastern Wisconsin to follow a dream. We were quite sure we wanted to raise sheep and pursue a lifestyle and some form of farming that was environmentally and economically sustainable. Mostly we wanted to be self-employed, provide opportunities for our children to grow up as true contributors to a family business and have at least one parent at home throughout our children's growing up. In addition, we considered the possibilities of raising a variety of wholesome, perhaps organic, food products to sell to a regionally-based group of consumers. Ag tourism and school-aged educational experiences also were considered. We decided to settle in West-Central Wisconsin because the geography and climate were aesthetically pleasing to us, good for pasture-based sheep farming, and because land prices at the time were low enough to make its profitability a possibility.

We started out with registered Rambouillets, determined to raise a flock producing high quality wool and decent lambs. And, we did receive recognition from Midwest Wool Growers Cooperative for a top quality wool crop. That was great until the wool subsidy was discontinued and the wool market, for all practical purposes, died. In the meantime, talk was beginning to surface at sheep events about sheep dairying. We wanted to continue with sheep and knew that depending strictly on wool and market lambs wasn't going to be financially viable. We also knew that we did not want to get involved in the show ring breeding stock business and were not ready for the rigors of direct lamb marketing. Laurel had grown up on a cow dairy farm with not only memories of the rewards of dairy farming, but also a reasonable handle on the work demands.

While our decision to sheep dairy was certainly based on many intrinsic values, the reality is that we truly tried to approach the venture as a business. Tom, with a MBA, and Laurel's passion for strategic planning laid the foundation for developing an initial farm 5-year plan and subsequent official business plan. These plans went into detail on investment versus returns, attempted to predict profit margins and long-term profitability. The business plan has been revised every 4-5 years, and we take a 2-day farm planning retreat at least every other year.

In reality, our journey has had plenty of obstacles, delays, and frustrations. Profits have been smaller and slower in coming than we had anticipated. However, there was and continues to be, an excitement in being part of starting a new agricultural industry that has the potential to provide a means for the renewal of the small family farm.

We began milking on August 16, 1997. That rainy evening, we started with 172 ewes that had never been in a parlor before: Rambouillets, Columbias, Dorsets, and some East Fresian crossbreds on loan from Canada. With a crew of 10 people, we began milking at 4:00 p.m. and finished at midnight. Throughout the first two weeks, it took two people about 8 hours to milk the sheep. That first year we regularly questioned our own sanity and our motives. This year, we milked 190 ewes, all East Fresian crossbreds, and it takes about 1 to 1.5 hours, including set up and clean-up per milking.

Dairy Sheep Genetics

Any ewe can be milked, however, there are significant differences in personality, letdown, udder conformation, lactation length, and other factors that impact sheep dairy profitability. We have chosen to select for a combination of milk components and production, as well as conformation. In 1998, we culled our ewe flock heavily based on udder conformation and milking "attitude". Each ewe's udder was rated on a 1-5 scale based on teat placement, strength of fore and rear udder attachment, tightness of fit, "meatiness" and willingness to "let-down" with minimal manipulation.

In 2000 we began unofficial DHI testing through AgSource Cooperative Services. They provide calibrated meters each month that allows us to estimate the production of each ewe in the milking flock. In addition, we receive a monthly status report for each ewe on pounds of milk produced, percent and pounds of butterfat and protein, and somatic cell counts. Using a combination of the age-factor production factors noted by David Thomas[1] , a standardized 180-day lactation and weighting for estimated pounds of milk and of butterfat produced, we have developed a rank-ordering scale for all ewes. Ewes are kept, culled or sold as brood ewes based on those rankings.

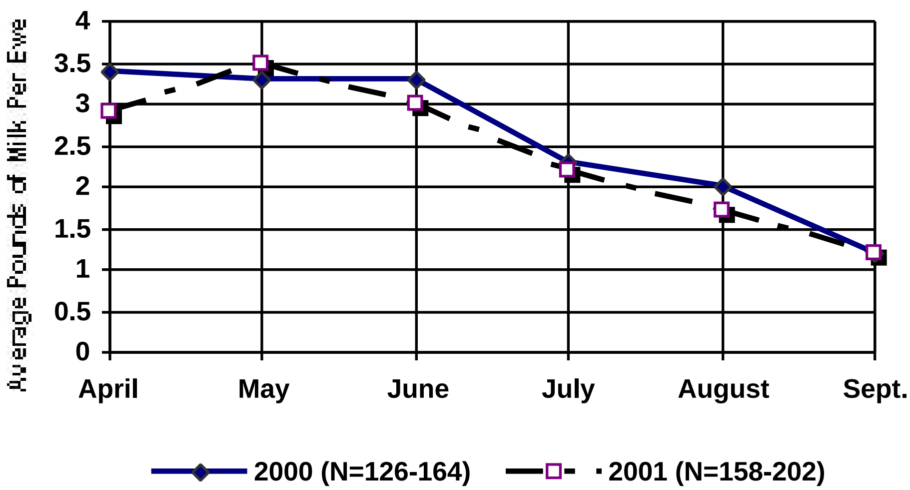
It is uncertain if the culling strategy has had any impact on milk production. In fact, we were somewhat disappointed in the lack of change in production in 2001. Our total number of ewes milked in 2000 was 164: in 2001, 202 ewes. We have typically left the lambs with the ewes for anywhere from 30 to 50 days. While this results in growthy, healthy lambs, it doesn't put the majority of the ewes' milk in the bulk tank. The older ewes are synchronized using teaser rams to lamb within a 3-week period beginning about February 1. We've typically begun milking about March 10-15, which means that many ewes may have already passed their peak production by the time the first DHI test was performed.

As of the September, 2001 test, 171 ewes were still being milked with 52 milking under 1 pound per day. Fifty-one of the ewes are still milking between 2 and 3.5 pounds per day. Several of these ewes lambed January 28-Feb. 9 (11), while most lambed February 12-26 (23), and the remainder lambed in early to mid-March (15). These earliest lambing ewes are still averaging 2.3 pounds of milk per day. The highest producing ewe for this test (3.1 pounds) also had the highest butterfat (8.2%) and is 22% East Fresian. This group of ewes averages 57% East Fresian genetics. Most of these ewes will milk over 210 days, perhaps 220 before drying off. Their estimated milk production for the season is between 675 and 750 pounds, including the amount their lambs took. A few may go over 900 pounds.

Our ewe flock average percentage of East Fresian was 45.1% in 2000 and 50.7% in 2001. In 2001, we will be milking a larger proportion of the flock twice a day further into the fall than in 2000. Fewer ewes have been dried off by the August test date than in previous years. The dairy genetics, coupled with close attention to nutrition, appears to extend the milking season. Late season milk has higher cheese yield due to the increased butterfat and protein content; a higher quality product. From our perspective, it seems that one needs to consider making a commitment to milking an extended season in order to realize the production benefits from an investment in East Fresian genetics. Chart 1 compares 2000 and 2001 flock averages for overall production.

[1] Thomas, David. *Opportunities for Genetic Improvement of Dairy Sheep in North America.* Proceedings of the Great Lakes Dairy Sheep Symposium. 1996.

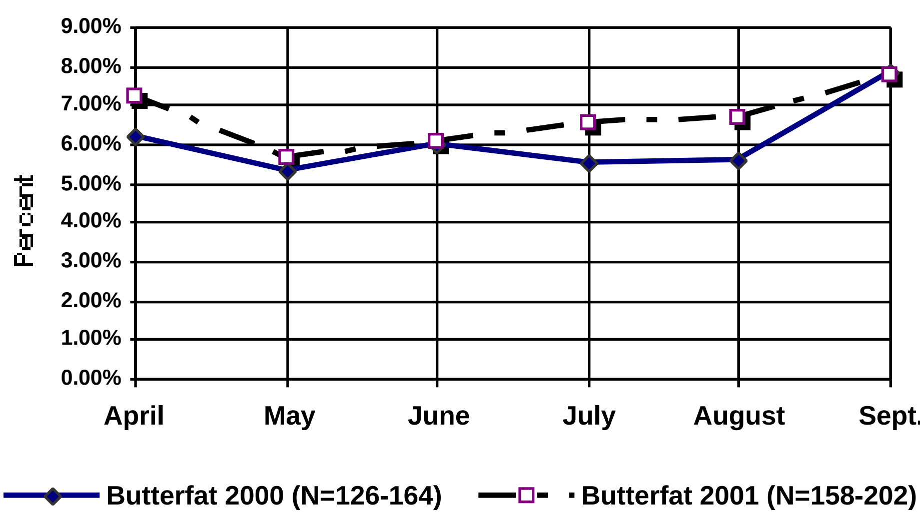
Chart 1: Milk Production Comparisons



It is important to note that the two years were quite different in terms of nutrition and weather. In 2000, we were able to feed high quality haylage throughout the ewes' lactation, while in 2001; the ewes were strictly on pasture. In 2001, the early season haylage was coarse and not as good as the previous year's. Both seasons, the ewes received about two pounds per day of a corn/roasted soybean mixture. In addition, there were extremes in both heat and humidity on both test dates in July and August 2001 that negatively affected production.

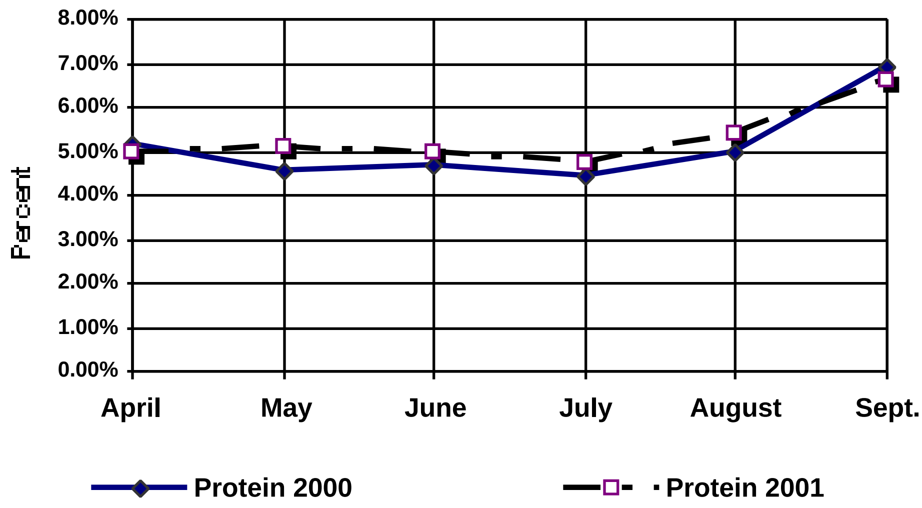
As noted earlier, we selected to retain ewes that met our calculations for both milk and butterfat production. It seems that the focus on butterfat production may have yielded some positive results. However, it is again important to qualify that there is typically a negative correlation between pounds of milk produced and butterfat percent. Chart 2 illustrates the flock averages of percent of butterfat comparing year 2000 and 2001.

Chart 2: Comparisons of Butterfat



While we have not been selecting for protein components, there has been a slight desirable change in protein from year 2000 to 2001 as shown on Chart 3. With the very real possibility of future milk pricing being based on milk components, we will base ewe and replacement ewe selection on production of butterfat, protein and total pounds of milk.

Chart 3: Comparisons of Protein



Genetic improvement and good flock management are both essential to improving production. Great strides can be noted in the first few years of integrating dairy sheep genetics into the flock. However, in order to continue to realize production and component increases, it will soon become necessary to seriously explore sire referencing programs with close monitoring of many progeny. At this time, we can only hope that using the rams from our best ewes will pass the desired characteristics onto their offspring.

Ewe Flock Health

Ewes are dewormed in the fall prior to breeding with Safeguard (if still milking) or Valbazon. They are dewormed just prior to lambing with Safeguard, and then during the summer, only if there seem to be clinical signs of infestation. This will depend on management practices. In 2001, ewes were grazed from May through the fall and showed very limited, if any signs of internal parasites. However, we did not graze intensively this year with ewes eating high on the plants.

Ewes are vaccinated just before lambing with Covex 8. This provides protection against some of the nasty bacteria that can lead to toxic mastitis. East Fresians seldom need hoof trimming which saves labor and minimizes hoof problems. Udders, stomachs, and legs are usually free of wool or have very little wool cover. This helps to reduce the probability of manure or vegetable material getting into the milking system.

We do not pre-wash or pre-dip teats, but teats are post-dipped with a commercial iodine-based teat dip. CMT (California Mastitis Test) solution is used early in the season to identify problems and throughout the season to confirm high lab mastitis tests. We use cow mastitis treatment products to address high somatic cells counts. Ewes are leg-banded and hand milked until a milk sample returns from the lab clear from inhibitors. Withhold time seems to be about double the label requirements for the ewes. We are very insistent that each ewe who has been treated receive a clear lab test before her milk is shipped. Ewes who do not clear up after the first regimen of treatment are sampled for the type of agent present. A decision, based on the probability of success in further treating of the bacteria, is made as to whether to continue treatment or put the ewe on the cull list. At the end of the season, ewe health conditions are evaluated on body condition, overall health, and somatic cell records. Udders are manually evaluated after dry off to identify possible mastitis problems. Dry treatments are used if appropriate.

Facilities and Equipment

The requirements for sheep farming are well known. Items such as barns, grain and forage storage and feeding facilities, lambing and lamb feeding facilities, handling, sorting and weighing equipment, manure-handling equipment, watering and mineral feeding equipment would probably be on everyone's list. For some the list would include: a tractor, planting and harvesting equipment, perhaps a four-wheeler, etc.

There are some additional required investments in facilities and equipment for sheep dairying. For each requirement, there are also options available, depending upon a given farm manager's goals, marketing methods and requirements and chosen approach to the situation.

For us, the basics include: a Grade A milking parlor and milk house with pipeline milking system and bulk tank, a commercial walk-in freezer, barn and lot modifications to facilitate efficient handling of the ewes into and out of the parlor twice a day, a pallet assembly area and truck height loading dock for efficient packaging and shipping of frozen milk

The parlor is a New Zealand style (no head gates, the sheep stand side by side) double-sixteen pit parlor with eight units on each side and a 2-inch low line pipeline system. We went with a system like this for several reasons:

1. Cost. We were able to build the sheep handling system within the parlor ourselves using standard 1 1/4" galvanized pipe and bolt together joint fittings available from many different sources. We saved the cost of headgates and an indexing system which some parlors use. These indexing systems are fairly pricey. This also gave us the ability to adjust the position of the various pipes to effectively handle our animals.
2. We had heard discussions among dairy people who were questioning whether the slightly higher vacuum required to pull the milk up to a high line system would cause damage to the milk, or to the ewes' udders. We decided to use a low line to avoid possible future problems, as this issue seemed unresolved at that time.
3. We constructed our parlor inside of an existing pole building on the farm, which had a limited ceiling height. This eliminated the option of a platform system – we had to go down, there was no room for the sheep to go up.

We hired a dairy facilities specialist to install the pipeline system with bulk tank, vacuum pump, receiver, and clean in place system. We had previously purchased the basic components from an out of business cow dairy farm. In addition to fitting and installing these components, the installer supplied electronic pulsation units with an adjustable central controller. This was very helpful during the first two years because we were able to make small adjustments to the pulsation rate and vacuum, seeking settings that seemed to provide the best results for us. We currently run a pulsation rate of 180 ppm, with a 50/50 ratio and a vacuum of 10 psi (37kpa). Anytime we think the pulsation may not be giving the milking efficiency we desire, it is quite easy to make one quick change and all units will be pulsating at the chosen rate.

We use the "Uniclaw" milking unit made by Interpuls. This assembly uses silicone rubber inflations, which we are very pleased with. The silicone maintains its properties longer than standard rubber, which allows us to change inflations every other season. In addition, because it is almost clear and uses a clear plastic shell, you can visually see if the teat is properly positioned in the unit after placement. This unit also does not contain a claw with reservoir; the two sides are simply connected to a "Y" fitting, and then to the pipeline with milk tubing. We have not perceived a problem with this setup so far, as long as we maintain a downhill slope from the teat to the pipeline to avoid vacuum surges at the teat, and “slugging”, which can cause damage or result in poor milkout. This manufacturer does offer a clawpiece, which would eliminate that problem, should it begin to occur. This would most likely be seen early in the season when the ewes are at peak production. We will be watching this closely with the changes we plan to make for the 2002 season.

We have outgrown our initial 250-gallon bulk tank, and now use a 415-gallon. It is likely that we will need to replace that with a 600-gallon tank for 2003. We must always be able to hold three or four day’s worth of milk for fluid shipments.

The freezer was purchased used from a small grocer who was upgrading. It is 9 1/2 by 16 by 8 feet high. The box had 3 1/2 inch thick insulated panel walls. During installation, we added two inches of extruded polystyrene to the walls and ceiling, and 6 inches of extruded poly under and around the concrete slab to minimize required cooling loads. We hired a commercial refrigeration company to supply and install the required condensing unit and additional evaporator to meet the needs that we specified. We found out that the sizing of these components is primarily a function of the pounds of milk you need to freeze daily, and secondarily a function of the physical size of the freezer. In our case, the cooling capacity required to take 1200 pounds of milk from 40 degrees to minus 10 degrees overnight is plenty to maintain the already frozen product at minus 10 degrees. We use two 2 by 5 foot stainless steel wire shelving units obtained from the freezer supplier to freeze the milk. Each unit has 5 shelves and can hold 15 bags of milk. These are placed in the middle of the freezer in front of the evaporators, not against a wall, which allows for maximum air circulation and optimum freezing conditions. Rapid freezing and extreme cold storage temperatures are essential to maintain high milk quality. The freezer will hold a maximum of 18,000 pounds of milk stacked in bags. To conserve freezer space pallets are not stored in the freezer. We have learned through experience that, even though the floor has insulation under it, bags placed on the floor to freeze will do so in a considerably longer time, and will freeze primarily from the top. This leaves the milk in the center and bottom of the bag at an above-frozen temperature for too long. We would expect that a similar thing would happen if milk were frozen on a solid wood shelf.

Outside the freezer is a concrete slab where we assemble pallets of frozen milk for shipping. A few of us working together can put together a pallet of milk in 15 minutes. There is no danger of significant thawing of milk in the first two hours after it is removed from the freezer.
Below this slab is an approach for tractor-trailer trucks to back in for pallet loading. The height differential of 50 inches allows for efficient loading with a simple dock plate and pallet jack.
The flow of ewes through the parlor is a straight line – in the south doors and out the north. We have built an overhang on the barn where the sheep wait for entry to the parlor. This is about 12 by 90 feet, and allows 250 ewes to be sheltered before milking. We have found that this made a significant difference in the amount of clean up required in the parlor after milking, and in our ability to be milking sheep that are not dripping wet if it is raining. The ewes are usually very calm in the parlor with very little to no urine or manure left behind. The area where the sheep collect after milking is kept in sand to reduce probability of bacterial contamination for the ewes.
We currently plan to add facilities and equipment for lamb rearing in time for the 2002 lambing season. This will include an insulated lamb rearing barn with the necessary pens, year-round watering, and automated milk replacer mixing and feeding. We will then remove most lambs

from the ewes at 12 to 24 hours of age and raise them on milk replacer, shifting them to creep feed as early as they are ready. The purpose for this is to begin milking the ewes right away, thus gaining their early flush of milk in the bulk tank. For most ewes, this is economically viable because the price of milk replacer is less than the price of milk, and because most of our ewes are capable of producing significantly more milk than their lambs' will drink.

The Financial Picture

Sheep dairying is hard, long work. In addition, those of us who are doing it are taking a risk by investing in and attempting to make viable a fledgling industry in this country. Most of us would like to see a financial reward for this.

In the year 2000, Dream Valley Farm posted its first ever positive contribution to management. It was quite small for the work and investment, but it gives us hope for better things to come. With some of the management changes we plan to make this year and next, we expect to see a significant increase. In addition, we know that had we stayed in the lamb and wool business, we would be forever running an expensive hobby farm.

We reevaluate our farm business plan at least every other year to redefine our goals, assess our current situation, and plan the next set of changes. We encourage all who consider themselves to be operating an agricultural business to do a similar thing on an ongoing basis. This should include evaluation of current and anticipated market conditions, personal goals and limitations, infrastructure limitations and requirements, and cash flow planning. For example, our most recent plan includes a 4-year monthly cash flow analysis, and takes in to consideration the fact that our three children are in high school, soon to be gone from home.

Recent financial estimates we have seen for a sheep dairy operation show that it should be possible to attain a return to management of $30,000 or more with a milking flock of 300 ewes producing an average of 400 pounds each. These estimates seem to take in to account all of the factors associated with sheep dairy farming. Our own farm is somewhat comparable, except in the area of capital investment requirements and resulting debt service payments. Ours are significantly higher, resulting in a lesser anticipated return to management. Any individual farm would see variations in capital financing costs, feed costs, etc., but the net result is quite promising. Also, it is interesting to note that not many years ago the commonly used production estimate was 250 pounds per ewe.

It is currently not known what the minimum or optimum size is for a successful family farm scale sheep dairy. Our experience and observation tells us that the minimum number of ewes for a profitable sheep dairy business, not considering possible gains from farmstead cheese production and marketing, is probably in the range of 150 to 200 high producing dairy ewes. The upper limit is unknown, but is probably dependent on the physical and environmental capacity of the producer's farm, and the amount of labor available from family members or through outside hiring. We know that for our operation, a major factor is the cost of debt financing, as we have had to borrow significantly to make the investments required.

Another less mentioned profitability factor is the degree of management skill and diligence one possesses and uses. We have experienced ourselves plenty of costly management mistakes, all of which had an impact on the bottom line.

A favorite observation in the business world is that nothing happens until something is sold. In sheep dairying, this means that you can produce all the wonderful milk and or cheese you want, but you need to do some legwork in advance to know who is buying it.

Some approach this from a farmstead perspective and do quite well with it. That is, they use the milk they produce to manufacture products of their design and choosing, and then market and sell those products. We do not feel that we have the energy or time to gain the expertise or take the risk with our family to try this approach. We also simply do not have the interest in being a "lone ranger."

We have been members of the Wisconsin Sheep Dairy Cooperative (WSDC), a producer owned and controlled sheep products marketing cooperative, since its formation in 1996. After some ups and downs in the first few years, the co-op is now growing to be a major source of quality sheep's milk in this country and is in the process of developing other value added products. Through the committed, diligent efforts of co-op members, and particularly the board of directors, our market for milk has stabilized and grown, our milk price has increased, and we are able to focus on managing our farm, knowing that the milk we produce is sold through an organization which we (and the other members) own. A big advantage is that sheep's milk is not a commodity for which huge conglomerates and government forces set the price. The buyers and sellers simply negotiate a price much like many small-scale, specialized products. This gives us a degree of control that most farmers do not have.

WSDC is a known entity in the North American sheep dairy industry and regularly receives inquiries for the purchase of milk. In 2001, WSDC could have sold almost double its production capacity, and the indications are for continued growth. We are very happy with the results we have seen from our cooperative, and eagerly anticipate future developments. Consistent, reliable markets will accelerate the realization of this industry, which holds so much promise for the future of the small family farm in the upper Midwest.

WSDC also finds itself in the position of creating and beginning to establish standards, policies, and procedures for its members to achieve the consistently high quality that customers require, to assure that producers comply with governmental regulations, and to offer cheese makers and marketers convenient access to our product. Much of this work is likely to feed into industry-accepted standards.

Conclusion

We believe that sheep dairying is one of the very few options available to actually make money "doing sheep." We have committed ourselves to the development of this industry and believe that it holds much promise for the midwestern style family farm, sustainable farming, and the health of rural communities. We believe that the market for sheep's milk products is just beginning to show its potential. With over 90% of sheep milk products still being imported, we feel there is nowhere to go but up. If we work together toward the shared goal of a viable, successful North American sheep dairy industry, it will happen.

COMPARISON OF EAST FRIESIAN AND LACAUNE BREEDING FOR DAIRY SHEEP PRODUCTION SYSTEMS

RESULTS FROM 1999 - 2001

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Summary

A study was initiated in the autumn of 1998 to compare the East Friesian and Lacaune breeds for performance in a dairy sheep production system. Matings were designed to produce breed groups of high percentage East Friesian, high percentage Lacaune, and various East Friesian-Lacaune crosses. This paper summarizes data collected through the summer of 2001 on sheep of 1/2 or 3/4 East Friesian or Lacaune breeding and a few East Friesian-Lacaune crosses that are of 3/4 or 7/8 dairy breeding. Data collected during the early years of this long-term study suggest that there are no large differences in performance between sheep of East Friesian and Lacaune breeding. Some small advantages of one breed over the other that may be appearing are greater birth and weaning weights for East Friesian, greater postweaning gain for Lacaune, greater ewe lamb fertility and prolificacy for East Friesian, and greater percentage of milk fat and milk protein for Lacaune. Breed rank for milk production varies depending upon which group of crossbreds is evaluated, but there appears to be a slight advantage of the East Friesian breed over the Lacaune breed for milk production. These results suggest that either breed may be used successfully. However, a crossbreeding program utilizing the two breeds that takes advantage of hybrid vigor may result in greater productivity than using just one of the breeds as a purebred or in a grading-up program.

Background

The raising of sheep for milk is a new enterprise to North American agriculture. Sheep in North America have been selected for meat and wool production. Therefore, one of the first major constraints to profitable sheep dairying was the low milk production of domestic breeds.

Rams of East Friesian breeding, a German dairy sheep breed (Alfa-Laval, 1984), were first imported into the U.S. in 1993 from Hani Gasser in Canada. The East Friesian cross ewes from these rams produced almost twice as much milk per lactation as domestic breed crosses (Dorset-crosses) under experimental conditions at the University of Wisconsin (UW-Madison) (Thomas et al., 1998, 1999a, 2000). Continued experimentation with East Friesian crosses at UW-Madison and their performance in commercial dairy flocks in the U.S. and Canada further showed their superiority for milk production, and most commercial operations moved quickly to crossbred, high percentage, or purebred East Friesian ewes. The accelerated move to East Friesians in North America was facilitated by the importation of semen, embryos, and live animals from Europe and New Zealand starting in 1992 – first to Canada and then to the U.S.

A second dairy sheep breed, the Lacaune from France (Alfa-Laval, 1984), is now available in North America. Josef Regli imported Lacaune embryos to Canada from Switzerland in 1996 (Regli, 1999), and the UW-Madison imported semen from three Lacaune rams into the U.S. from the U.K. and two Lacaune rams from Josef Regli in 1998. Subsequently a small number of Lacaune rams from the Regli flock were used by a few dairy sheep producers in Canada and the U.S.

While our early results at UW-Madison with crossbred sheep of 50% or less East Friesian breeding were very encouraging, previous studies in Greece (Katsaounis and Zygoyiannis, 1986) and France (Ricordeau and Flamant, 1969) had reported some problems with East Friesian breeding, especially at levels of over 50%. In these earlier studies, high-percentage East Friesian sheep had higher mortality rates than domestic breeds from respiratory disease. We also reported decreased lamb survival in lambs of over 50% East Friesian breeding compared to lambs of 50% or less East Friesian breeding at UW-Madison (Thomas et al., 1999b, 2000).

East Friesian ewes also have been reported to have some undesirable milking characteristics relative to the Lacaune. Bruckmaier et al. (1997) reported that East Friesian ewes had a greater proportion of the udder cistern located below the exit into the teat channel, delayed oxytocin release and milk letdown, slower milk flow rates during milking, and longer milking times compared to Lacaune ewes.

The Lacaune breed has been selected in France for increased milk production under a sophisticated selection program incorporating artificial insemination, milk recording, and progeny testing of sires for longer than any other dairy sheep breed in the world. Annual genetic improvement for milk yield in the French Lacaune is estimated at 2.4% or 5.7 kg (Barillet, 1995). In the short - and medium-term, North America may rely on foreign countries for much of its dairy sheep genetics, and it is desirable to import genetics from a breed that is making continuous genetic improvement in its native country.

With the current availability of both East Friesian and Lacaune breeding in North America, UW-Madison initiated a study in 1998 to compare sheep sired by East Friesian rams and Lacaune rams for lamb and milk production under dairy sheep production conditions in Wisconsin. This paper will present results through 2001.

Materials and Methods

During the autumns of 1998, 1999, and 2000, Dorset-cross ewes at the Spooner Station and Polypay and Rambouillet ewes at the Arlington Station were artificially inseminated or naturally mated to East Friesian (EF) or Lacaune (LA) rams. Lambs sired by four purebred East Friesian rams and five purebred Lacaune rams were produced in the springs of 1999, 2000, and 2001. Lambs were fed high-concentrate rations in confinement. Male lambs and a few cull ewe lambs were marketed at approximately 125 pounds liveweight, and the vast majority of the ewe lambs were retained for breeding. Body weights of the lambs born at Spooner (n = 261) were taken at birth, weaning (approximately 60 days of age), and at marketing (approximately 150 days of age, males only).

First-cross (F1) ewe lambs born and raised at both locations in 1999 (n = 65) and 2000 (n = 69) were mated at the Spooner Station in their first autumn at approximately 7 months of age, and they lambed for the first time at approximately one year of age the following spring. Ewes born in 1999 were mated a second time in the autumn of 2000 (n = 63) for a second lambing as two-year-olds in 2001. East Friesian-sired F1 ewes (1/2EF) were mated to either East Friesian or Lacaune rams to produce both 3/4EF and 1/2LA1/4EF lambs. Likewise, Lacaune-sired F1 ewes (1/2LA) were mated to either Lacaune or East Friesian rams to produce 3/4LA and 1/2EF1/4LA lambs. Lambs were raised on their dams or on milk replacer until 30 days of age. After weaning at 30 days of age, lambs were raised on high-concentrate diets in confinement. Male lambs and a few cull female lambs were marketed, and the majority of ewe lambs were retained as replacements.

The ewe lambs of 3/4 dairy breeding born in 2000 (n = 65) were also exposed to either East Friesian or Lacaune rams in the autumn of 2001 and produced lambs of 7/8 dairy breeding in the spring of 2001 of the following breeding: 7/8EF, 3/4EF1/8LA, 5/8EF1/4LA, 1/2EF3/8LA, 1/2LA3/8EF, 5/8LA1/4EF, 3/4LA1/8EF, 7/8LA. Lambs were weaned from their dams at 30 days of age. After weaning, lambs were raised on high-concentrate diets in confinement. Male lambs and a few cull female lambs were marketed, and the majority of ewe lambs were retained as replacements.

In future years, each breed group of ewe will continue to be mated to both East Friesian and Lacaune rams. This mating plan will result in ewes that are of very high percentage dairy breeding with breed groups representing a continuum from high percentage East Friesian and no Lacaune breeding to various combinations of East Friesian and Lacaune breeding to high percentage Lacaune and no East Friesian breeding. Some of the breed groups are now represented in very small numbers, but these will increase as the study progresses.

Dairy ewe lambs were placed on our DY30 milking system for their first lactation at approximately one year of age. The DY30 system is as follows: ewes nurse their lambs for approximately 30 days, after which lambs are weaned onto dry diets, and ewes are milked twice per day until a test day on which their total daily milk yield is less than .5 lb. Second lactation dairy ewes were placed on either the DY1 or MIX milking system. The DY1 system is as follows: lambs are weaned from ewes within 24 hours of birth and raised on milk replacer until weaned onto dry diets at approximately 30 days of age, and ewes are milked twice per day from 24 hours postpartum until a test day on which their total daily milk yield is less than .5 lb. The MIX system is as follows: for the first 30 days postpartum, lambs are separated from their dams overnight, ewes are milked once per day in the morning, and lambs are returned with their dams for the day; lambs are weaned onto dry diets at approximately 30 days of age, and after their lambs are weaned, ewes are milked twice per day until a test day on which their total daily milk yield is less than .5 lb.

Data were analyzed with the General Linear Models Procedure of the Statistical Analysis System. For lamb growth traits, models included the effects of breed group, sex, birth type, dam age, year of record, and two-way interactions. Models for reproductive traits included the effects of breed group, ewe age, year of record, and two-way interactions. Lactation models include the effects of breed group, weaning group, ewe age, year of record, and two-way interactions.

Results and Discussion

Growth. Tables 1, 2, and 3 present birth, weaning, and market weights for various breed groups of lambs. When the information in all three tables is taken together, lambs with 1/2 or greater East Friesian breeding tend to have greater birth (+.76 lb.) and weaning (+1.98 lb.) weights than lambs of 1/2 or greater Lacaune breeding. However, market weights show the opposite trend with lambs of 1/2 or greater Lacaune breeding weighing an average of 3.16 lb. more at 150 days of age than lambs of 1/2 or greater East Friesian breeding. This indicates that Lacaune lambs have greater postweaning average daily gains than East Friesian lambs.

Table 1. Bodyweights (lb.) of F1 lambs produced from East Friesian or Lacaune sires and non-dairy dams

	Birth weight		60-day weight		150-day weight (males only)	
Breed group	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
1/2 EF	136	9.2±.14[a]	123	51.2± 1.01	52	123.8± 2.99[d]
1/2 LA	125	8.6±.14[b]	116	50.6± 1.04	48	131.5± 3.15[c]

[a,b]Means within a column with no superscripts in common are significantly different (*P* < .05).
[c,d]Means within a column with no superscripts in common are significantly different (*P* < .10).

Table 2. Bodyweights (lb.) of lambs produced from 1/2 East Friesian or 1/2 Lacaune dams and sired by East Friesian or Lacaune rams

	Birth weight		30-day weight		150-day weight (males only)	
Breed group	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
3/4 EF	65	11.0±.22[a]	60	32.3±.71 [a,b]	14	120.0±5.28[a,b]
1/2 EF1/4 LA	62	11.2±.23 [a]	58	33.2±.73 [a]	16	126.9±5.08[a,b]
1/2 LA 1/4 EF	60	9.6±.24 [c]	53	30.9±.76 [b]	17	132.1±4.55[a]
3/4 LA	90	10.2±.19[b]	80	30.8±.61 [b]	22	116.6±3.98[b]

[a,b,c] Means within a column with no superscripts in common are significantly different (*P* < .05).

Table 3. Bodyweights (lb.) of lambs born in 2001 from 1/2-dairy and 3/4-dairy ewe lambs and sired by East Friesian or Lacaune rams

	Birth weight		30-day weight	
Breed group	N	Mean ± SE	N	Mean ± SE
3/4 EF	27	11.2±.30[a,b]	26	32.1±1.10 [a,b]
1/2 EF 1/4 LA	24	11.7±.30 [a]	23	35.0±1.13 [a]
1/2 LA 1/4 EF	32	9.2±.27 [d]	27	31.0±1.08 [b,c]
3/4 LA	30	10.2±.27[c]	25	32.2±1.08[a,b]
7/8 EF	19	10.2±.35 [c]	19	29.6±1.29 [b,c]
5/8 EF 1/4 LA	12	11.6±.43 [a,b]	12	32.6±1.58 [a,b]
1/2 LA 3/8 EF	22	10.2±.32 [c]	22	31.0±1.18 [b,c]
3/4 LA 1/8 EF	12	10.1±.43 [c]	10	28.1±1.72 [c]
7/8 LA	11	10.6±.44 [b,c]	11	31.4±1.63 [a,b,c]

[a,b,c] Means within a column with no superscripts in common are significantly different (*P* < .05).

Reproduction. Table 4 compares the reproductive performance of 1/2 East Friesian and 1/2 Lacaune ewes when lambing at approximately one and two years of age. Table 5 presents the reproductive performance of the various 3/4-dairy breed ewes when lambing at approximately one year of age and the 1/2 East Friesian and 1/2 Lacaune ewe lambs that were their contemporaries.

Number of lambs born per ewe lambing (average litter size) was not significantly different among the various breed groups, however, ewes of 1/2 or greater East Friesian breeding gave birth to slightly more lambs than did ewes of 1/2 or greater Lacaune breeding.

Ewe lamb fertility (percentage of ewe lambs that lambed of ewe lambs exposed) was significantly greater for ewe lambs of 1/2 or greater East Friesian breeding than for ewe lambs of 1/2 or greater Lacaune breeding (Table 5), suggesting that East Friesian breeding results in earlier sexual maturity than Lacaune breeding. Evaluating the information in both tables, there was a trend for number of lambs born per ewe mated in these young ewes to be greater for ewes of 1/2 or greater East Friesian breeding than for ewes of 1/2 or greater Lacaune breeding. This was due to the slightly greater litter size and greater fertility of ewes of East Friesian breeding compared to ewes of Lacaune breeding.

Table 4. Reproduction of F1 ewes produced from East Friesian or Lacaune sires and non-dairy dams and lambing at one and two years of age

	Fertility, %		Lambs born per ewe lambing		Lambs born per ewe mated	
Breed group	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
1/2 EF	95	95.7±2.6	91	1.68±.06	95	1.61±.07
1/2 LA	111	91.3±2.4	100	1.61±.05	111	1.47±.06

Table 5. Reproduction of ewe lambs produced from East Friesian or Lacaune sires and non-dairy or 1/2-dairy dams and lambing at one year of age in 2001

	Fertility,%		Lambs born per ewe lambing		Lambs born per ewe mated	
Breed group	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
1/2 EF	34	97.1±5.1[a]	33	1.78±.09	34	1.74±.17[a]
1/2 LA	45	80.0±4.5[b]	36	1.53±.09	45	1.22±.10[c]
3/4 EF	23	100.0±6.3[a]	23	1.78±.11	23	1.78±.14[a]
1/2 LA 1/4 EF	14	100.0±8.0[a]	14	1.71±.14	14	1.71±.18[a,b]
3/4 LA	14	78.6±8.0[b]	11	1.64±.16	14	1.29±.18[b,c]

[a,b,c] Means within a column with no superscripts in common are significantly different ($P < .05$).

Lactation. When looking at the lactation performance of these ewes (Tables 6 and 7), readers are reminded that these are young ewes (most are one-year-olds, a few are two-year-olds), and a majority of them nursed lambs for 30 days before being machine milked. Only milk, fat, and protein obtained from ewes while they were machine-milked was measured. Mature ewes in this same flock that are milked from 24 hours postpartum have average lactation milk yields of 500 to 600 pounds.

There were no significant differences between 1/2 East Friesian and 1/2 Lacaune ewes for weight of milk, fat, or protein produced in a lactation (Tables 6 and 7) even though 1/2 East Friesian ewes had a significantly longer lactation length (Table 6). The 1/2 Lacaune ewes had a significantly higher percentage milk fat and milk protein than did the 1/2 East Friesian ewes.

Table 6. Lactation traits (mean ± SE) of F1 ewes produced from East Friesian or Lacaune sires and non-dairy dams during their first and second lactations

Breed group	N	Milk, lb	Lactation length, d	Fat, lb.	Fat, %	Protein, lb.	Protein, %
1/2 EF	75	291.8±14.3	126.3±3.8[a]	16.3±1.0	5.49±.13[b]	13.7±.7	4.65±.09[b]
1/2 LA	83	260.8±13.6	114.4±3.6[b]	15.8±.9	5.89±.12[a]	13.2±.7	4.91±.08[a]

[a,b,c] Means within a column with no superscripts in common are significantly different (*P* < .05).

There is relatively little data for 3/4-dairy ewes at this time, so the values presented in the bottom half of Table 7 should be viewed as preliminary. In coming years, we will have more data on 3/4-dairy ewes, and we should be able to make more definitive conclusions. These preliminary results suggest that 3/4 East Friesian ewes have longer (P < .05) lactations and produce more (P < .05) milk than do 3/4 Lacaune ewes. However, fat and protein production were not significantly different between these two breed groups. This is due to the fact that the 3/4 Lacaune ewes, while producing less milk, had greater (although non-significant) percentages of milk fat and protein.

Table 7. Lactation traits (mean ± SE) of ewe lambs produced from East Friesian or Lacaune sires and non-dairy or 1/2-dairy dams during their first lactation in 2001

Breed group	N	Milk, lb	Lactation length, d	Fat, lb.	Fat, %	Protein, lb.	Protein, %
1/2 EF	24	191.8±19.1[c]	94.8±5.8[b]	10.4±1.2[c]	5.26±.18[b]	8.9±.9[c]	4.47±.13[b]
1/2 LA	25	208.9±18.7[c]	92.8±5.7[b]	13.3±1.1[b,c]	6.42±.17[a]	10.6±.9[b,c]	5.13±.12[a]
3/4 EF	16	273.0±23.4[b]	114.0±7.1[a]	14.3±1.4[b]	5.23±.22[b]	12.6±1.1[b]	4.65±.15[b]
1/2 LA 1/4 EF	5	394.5±41.9[a]	137.8±12.8[a]	22.7±2.6[a]	5.76±.39[a,b]	19.9±2.0[a]	5.04±.28[a,b]
3/4 LA	10	203.6±29.6[c]	94.6±9.0[b]	12.1±1.8[b,c]	5.80±.28[a,b]	10.3±1.4[b,c]	4.98±.20[a,b]

[a,b,c] Means within a column with no superscripts in common are significantly different (*P* < .05).

The interesting result in Table 7 is the exceptional production of the 1/2 Lacaune, 1/4 East Friesian ewes. There are only five of these ewes, but they had far longer (P < .05) lactation lengths and much greater (P < .05) production of milk, fat, and protein than any other 1/2- or 3/4-dairy breed group. Hybrid vigor may be responsible for a portion of their exceptional performance because they exhibit 100% of maximum hybrid vigor whereas the 3/4 East Friesian and 3/4 Lacaune breed groups exhibit only 50% of maximum hybrid vigor. Individual sire effects also are partly responsible. All five of the 1/2 Lacaune, 1/4 East Friesian ewes were sired by one Lacaune ram (no. 5612). Four of the ten 3/4 Lacaune ewes also were sired by 5612, but the other six ewes were sired by Lacaune ram 5616. Each of the 3/4 Lacaune ewes sired by 5612 produced about 60 pounds more milk than the 3/4 Lacaune ewes sired by 5616, so 5612 is the superior ram. In future years, additional Lacaune sires will be represented in each of the breed groups so individual sire effects will not be so evident.

Conclusions

Data collected during the early years of this long-term study suggest that there are not large differences in performance between sheep of East Friesian and Lacaune breeding. Some small advantages of one breed over the other that may be appearing are greater birth and weaning weights for East Friesian, greater postweaning gain for Lacaune, greater ewe lamb fertility and prolificacy for East Friesian, and greater percentage of milk fat and milk protein for Lacaune. Breed ranking for milk production varies depending upon which group of crossbreds is evaluated, but there appears to be a slight advantage of the East Friesian breed over the Lacaune breed for milk production.

These results suggest that either breed may be used successfully. However, a crossbreeding program utilizing the two breeds and taking advantage of hybrid vigor may result in greater productivity than using just one of the breeds as a purebred or in a grading-up program.

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FACTORS AFFECTING THE QUALITY OF EWE'S MILK

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Introduction

The milking of sheep for dairy production is relatively new for some countries, such those found on the American continent and in Oceania, so that the knowledge in the field is scarce. By contrast, in some countries it is a very traditional industry, such as that found in the Mediterranean countries, where it has been practiced for thousands of years and until recently did not have a strong scientific background. It is only since the mechanical milking of sheep was introduced in France in 1962, that research on sheep milking has been undertaken in most European countries where sheep are kept for dairying (Purroy Unanua 1986). This has produced a body of literature, but it is published mainly in languages other than English.

This paper examines the factors affecting the quality of sheep milk for its transformation into dairy products, particularly cheese.

What is meant by quality of sheep milk?

Most of the sheep milk produced all over the world is transformed into cheese. Some sheep milk yogurt is produced in Greece, and fresh sheep milk is consumed rarely. For this reason, the quality of sheep milk relates to its capability to be transformed into high quality dairy products, and to produce high yields of these products from each litre of milk. This is often described as the processing performance of the milk.

The processing performance of milk could be measured by making batches of cheese by a standard method, allowing it to mature for the required time (up to 6 months in the case of some hard cheeses such as the Pecorino Romano) and determine the important features in the outcome of the cheese such as yield, composition and taste. However, the amount and quality of cheese that can be obtained from each litre of milk depends mainly on the clotting properties of the milk (Ustunol and Brown 1985; Buttazzoni and Aleandri 1990; Cavani *et al.* 1991). These are the renneting time, the rate of curd formation or rate of firming and the consistency of the curd. For this reason milk clotting properties have been widely used by researchers to assess the processing performance of milk.

The clotting properties of milk are affected by the composition of the milk (Chapman 1981; Storry *et al.* 1983; Anifantakis 1986, 1990), by the microbiological quality of the milk, by its somatic cell count (Pulina 1990; Kalantzopoulos 1994) and by the cheese making process itself (Alais 1974).

The relationships linking the milk and the outcome of the cheese are represented schematically in Figure 1. Cheese makers have some control over the clotting conditions, and can vary pH to achieve the desired acidity by varying the percentage of inoculum of starter cultures (Cogan and Hill 1993). They can also standardise the fat content (Dolby 1971; Kalantzopoulos 1993) or increase the amount of soluble calcium in milk by adding calcium chloride (Fox 1993).

This is often done by cheese makers with milk that does not clot (Alais 1974; Losi *et al.* 1982). Cheese makers also control the temperature and the rennet concentration at which the clotting takes place. On the other hand, cheese makers have little or no control over the composition and quality of the milk that reaches the cheese factory. The milk received should be of high microbiological quality, free of antibiotics and have a composition within acceptable limits. However, this does not always occur, despite the fact that often the payment for the milk is based on its quality (Pulina 1990). Also researchers have identified animals that produce milk that does not clot and is therefore unsuitable for cheese making in both dairy cows (Losi *et al.* 1982) and sheep (Casoli *et al.* 1992).

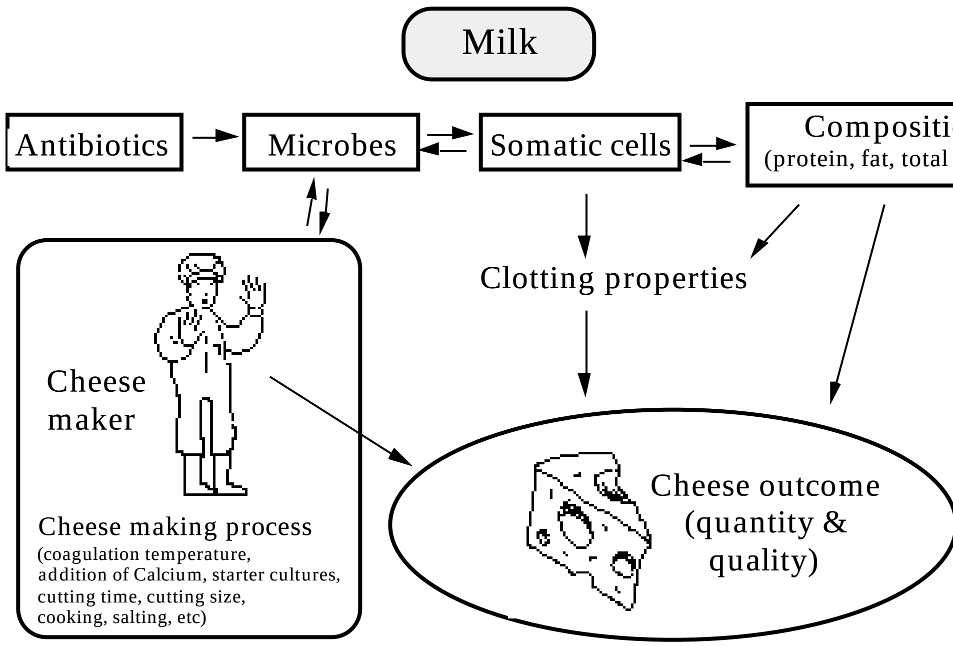

Figure 1. Factors affecting the outcome of sheep milk cheese at the cheese factory level. Cheese makers receive milk with certain characteristics, and have little power to change them. These include the gross composition of the milk (protein, fat, total solids), the presence of microbes (desirable or not), the possible presence of antibiotics that can disturb the starter cultures and the presence of somatic cells that come from the animals. Cheese makers can modify these characteristics only to a limited extent, but their methods of cheese making have a great influence on cheese outcome.

High protein, fat and total solids concentrations in the milk are associated with high yields in the resulting dairy products (Chapman 1981; Storry *et al.* 1983). As a consequence, the milk of sheep has a higher yield of dairy products than the milk of cows and goats because it has higher concentrations of protein, fat and total solids (Ucci 1945; Casu and Marcialis 1966; Anifantakis 1986, 1990).

Therefore any factor that affects the composition of the milk, will affect the yield and quality (chemical composition, texture and flavour) of dairy products obtained from the milk.

Factors affecting the quality of sheep milk

As shown in Figure 1, the cheese maker at the cheese factory receives milk of a certain composition and can do very little to change it. In Figure 2 the factors that affect sheep milk quality at the farm level are shown, and it is apparent that the farmer too has little control over some of these factors. However, the farmer has some control over the environmental factors that affect the quality of sheep milk.

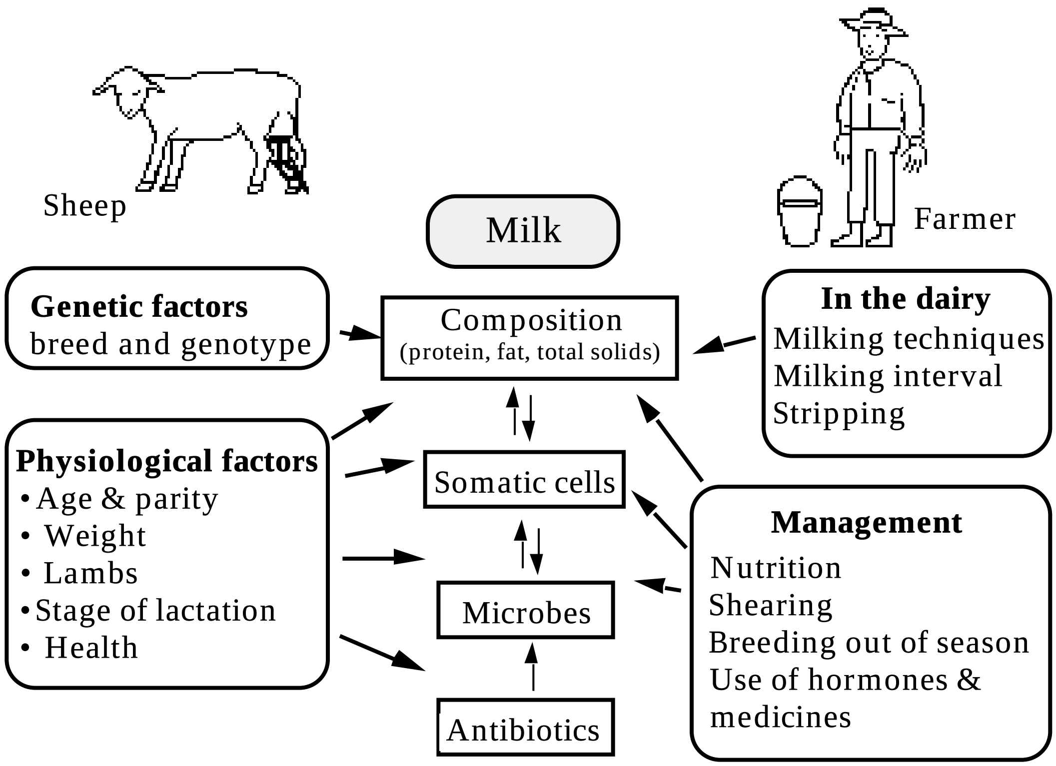

Figure 2. Factors affecting the outcome of cheese at the farm level. Some of these factors can be controlled by the farmer only to a certain extent (eg the genotype of sheep milked). Others depend exclusively on the sheep (eg age and parity, stage of lactation and number of lambs). Others are totally controlled by the farmer (nutrition, shearing, breeding and use of chemicals).

Somatic cell count

The somatic cell count is correlated with the health of the animal (Ruiu and Pulina 1992). Therefore the somatic cell count and the microbiological quality of the milk are correlated. Only 10% the somatic cells are mammary gland cells (eosinophils, epithelial cells), normally secreted together with the milk as a result of cellular turnover in the mammary gland. The remaining 90% of the somatic cells are blood cells (macrophages, leucocytes, lymphocytes). These normally contribute to the immune defence of the mammary gland, but their number increases considerably in the case of inflammatory or pathological processes within the mammary gland (Ranucci and Morgante 1994; Morgante *et al.* 1994).

The health of the sheep in general, and of the mammary glands in particular, influence both the quantity and the quality of the milk produced. The most common pathology of the mammary gland in sheep dairies is mastitis, an inflammation of the udder caused by infection of the mammary tissue. Mastitis is economically important for sheep dairies because it reduces milk production and causes qualitative changes in milk composition which alter the processing performance of the milk and the qualitative characteristics of the dairy products obtained. This is due to a decreased synthetic capacity of the mammary secretory cells and to an increased permeability of the mammary epithelium that causes the passage of blood components directly into the milk (Ranucci and Morgante 1994; Harmon 1995).

The milk of dairy cows (Losi *et al.* 1982) and sheep (Casoli *et al.* 1992) suffering from mastitis does not clot and is not suitable for cheese production.

Somatic cells increase dramatically with any inflammatory or pathological process affecting the mammary gland (Morgante *et al.* 1994). A high somatic cell count results in changes in the composition of milk, with a reduction in fat, casein, and total solids and an increase in total nitrogen, non-protein nitrogen, whey proteins (Duranti and Casoli 1991; Pulina *et al.* 1991; Bufano *et al.* 1994). Milk minerals have also been reported to change, with increased chloride and decreased phosphate, citric acid, potassium and magnesium, and a consequent increase in pH (Harmon 1995). These changes are also accompanied by a worsening of the clotting parameters such as renneting time, rate of curd formation and curd consistency and a reduced cheese yield due to an increased loss of fat in the whey (Duranti and Casoli 1991; Pirisi *et al.* 1994). High somatic cell counts in cow's milk have been associated with problems in the quality of cheese (Politis and Ng-Kway-Hang 1988), but in the only study conducted on the effect of high somatic cell counts on sheep milk cheese no change in quality was detected in the cheese after 2 months maturation (Pirisi *et al.* 1994). Therefore it appears that more research is required to establish if high somatic cell counts are of relevance for manufacture of sheep milk cheese.

Microbial cell count

The microbial cell count in milk is due to the presence of microorganisms of which some (*Lactobacillus spp*, *Lactococcus spp*, *Streptococcus spp*) can be advantageous for transformation into cheeses, while others can cause human diseases (eg *Listeria*, *Salmonella*, *Brucella*) or problems in the maturation of the dairy products (eg Enterobacteriaceae, Coliforms, Psychrotrophs, *Clostridium spp*) (Fatichenti and Farris 1973).

Psychrotrophic bacteria such as *Pseudomonas*, *Leuconostoc* and *Micrococcus* thrive at temperatures below 7°C and produce lipolytic and proteolytic enzymes which destabilise the casein micelles and alter the clotting properties of milk (Moquot and Auclair 1967; Durr 1974; Milliére and Veillét-Poncét 1979; Bloquel and Veillét-Poncét 1980; Juven *et al.* 1981; Mottar 1984; Nuñez *et al.* 1989; Uceda *et al.* 1994a; 1994b).

Enterobacteriaceae and coliforms are generally of faecal origin and ferment the lactose in the cheeses producing large quantities of gas, causing early spoilage of the cheese (Gaya *et al.* 1987).

In Europe, sheep milk can be processed into cheese if its bacterial count is less that 1 million/mL provided the milk is pasteurized prior to processing. For cheese making from raw milk the bacterial count must be less than 500,000/mL, but there are no rules concerning somatic cell counts for the processing of sheep milk (European Union Directive 46-47/1992).

Since in Australia and New Zealand sheep milk is listed as a non defined product, there are no precise law requirements for its microbiological quality, but it can be assumed that regulations applying to cow's milk could be extended to sheep milk. In Australia good quality cow's milk should have a bacterial count of less that 50,000/mL, but maximum allowed counts vary according to the Dairy Industry Acts of the different states. These limits often are reflected in payment schemes, through premiums or penalties, aimed at encouraging the production of high quality milk. The Australian law also requires that all dairy products must be produced from pasteurized milk. This is not strictly required in the Mediterranean countries, where some hard cheeses are produced from raw milk.

The occurrence of undesirable bacteria can be avoided by applying correct milking and milk handling procedures.

Genetic factors

The breed and genotype of sheep can affect the quality of the milk produced. Selection for dairy production has led to the creation of dairy breeds of sheep that produce more milk than meat and wool sheep. For instance the Awassi dairy type can produce up to 1,000 litres of milk in a lactation (Epstein 1985), but the Poll Dorset, a meat breed, produces only 100-150 litres of milk per lactation (Geenty 1980a; 1980b; Geenty and Davison 1982; Pokatilova 1985).

There is a negative correlation between milk yield and milk composition, so that when animals produce more, the milk usually has a lower concentration of fat and protein (Flamant and Morand-Fehr 1982; Barillet *et al.* 1986; Casu and Sanna 1990). This relationship applies not only to the more productive breeds when compared with the less productive (Flamant and Morand-Fehr 1982; Casu and Sanna 1990), but also, within a flock, to those animals that produce more milk (Barillet *et al.* 1986), and within the same animal producing at different levels throughout its lactation (Casoli *et al.* 1989; Pulina 1990). This is generally attributed to the fact that milk volume is determined by lactose secretion, and in highly productive dairy animals the synthesis of fat and protein does not keep up with that of lactose when high rates of milk secretion are achieved (Holmes and Wilson 1984). As a consequence, with high milk production, the total amount of cheese produced from the milk can be higher, but the relative yield of cheese from each litre of milk will be lower.

The genotype of the sheep can affect the composition of the milk. Table 1 shows the concentration of protein and fat for different breeds of sheep. This table supports the concept of a negative relationship between milk yield and concentration of milk components as breeds of sheep highly selected for dairy production (eg Awassi, East Friesian, Lacaune and Sarda) tend to have relatively low concentrations of fat and protein.

Table 1. Concentrations (%) of protein and fat in different breeds of sheep.

Breed	Protein	Fat	Source
Aragat	5.49	5.70	Dilanian 1969
Awassi	6.05	6.70	Mavrogenis and Louca 1980
Babass	5.29	5.84	Dilanian 1969
Boutsiko	6.04	7.68	Voutsinas *et al*. 1988
Bulgaria population	5.83	8.10	Baltadjieva *et al*. 1982
Chios	6.00	6.60	Mavrogenis and Louca 1980
Clun Forest	5.90	5.80	Poulton and Ashton 1970
Comisana	7.30	9.10	Muscio *et al*. 1987
Dorset	6.50	6.10	Sakul and Boylan 1992
East Friesian	6.21	6.64	Shalichev and Tanev 1967
Egyptian population	5.84	8.30	Askar *et al*. 1984
Fat-tailed	6.40	6.26	Mavrogenis and Louca 1980
Finn	5.40	6.00	Sakul and Boylan 1992
Greece population	5.74	6.88	Baltadjieva *et al*. 1982
Karagouniki	6.60	8.70	Anifantakis *et al.* 1980
Karakul	5.57	7.36	Kirichenko and Popov 1974
Lacaune	5.81	7.14	Delacroix-Buchet *et al*. 1994
Massese	5.48	6.79	Casoli *et al*. 1989
Merino	4.85	8.48	Bencini and Purvis 1990
New Zealand Romney	5.50	5.30	Barnicoat 1952
Rambouillet	5.90	6.10	Sakul and Boylan 1992
Romanov	6.10	5.90	Sakul and Boylan 1992
Sarda	5.89	6.61	ARA 1995
Suffolk	5.80	6.60	Sakul and Boylan 1992
Sumava	6.47	7.93	Flam *et al*. 1970
Targhee	4.51	9.05	Reynolds and Brown 1991
Tzigai	5.45	7.41	Margetin 1994
Vlachiki	6.52	9.05	Anifantakis *et al*. 1980
Welsh Mountain	5.40	6.20	Owen 1957

Casoli *et al*. (1989) reviewed the milk composition in 12 breeds of sheep and reported a high variation in the concentration of fat, which varied from 4.6% in the Iraqi Kurdi sheep to 12.6% in Dorset ewes milked in America. Protein concentration was less variable, and it varied from 4.8% in the Grade Precoce to 7.2% in the Armenian Corriedale.

In Australia, few comparisons have been made between milk composition of different breeds. Moore (1966a, 1966b) compared the production and composition of milk of 2 strains of the Merino with those of Corriedale ewes, and found no significant difference between the yields of milk and the concentrations of fat and solids-non-fat. Bencini and Purvis (1990) and Bencini *et al.* (1992) observed no difference in the composition of milk from two different strains of Merino and from Awassi x Merino and Merino ewes, and concluded that nutrition probably plays a more important role in determining the composition of milk. This is also supported by the studies of Geenty (1979), who compared the yield and composition of Romney, Corriedale, Dorset, Romney x Dorset and Dorset x Romney ewes in New Zealand and found no difference in milk composition between these breeds.

The genotype of the sheep may also affect the clotting properties of the milk through different genetic variants of the casein fractions (Feagan *et al.* 1972; McLean 1984; McLean 1987; McLean *et al.* 1984; McLean *et al.* 1987). For dairy cows the presence of certain casein genotypes can affect the composition of the milk (Aleandri *et al.* 1990), and Italian researchers have identified individual cows carrying particular genetic variants of the κ-Casein which make the milk unsuitable for Parmesan cheese making due to poor coagulation (Morini *et al.* 1975, 1979; Mariani *et al.* 1976, 1979; Losi *et al.* 1979, 1982; Losi and Mariani 1984).

In European dairy sheep, polymorphism of the casein has been reported by Lyster (1972), Arave *et al.* (1973), Davoli *et al.* (1985), Russo *et al.* (1981), Chiofalo *et al.* (1982), Bolla *et al.* (1985; 1986) and Manfredini *et al.* (1987). The $\alpha s1$ casein variant, named Welsh, the frequency of which varies from 2.2% (Chiofalo and Micari 1987) to 22% (Caroli *et al.* 1989) provokes a reduction in casein content and a worsening of milk clotting properties in homozygous animals and to a lesser extent, in heterozygous animals (Piredda *et al*. 1993).

In Australian sheep, Thomas *et al.* (1989) reported the existence of genetic variants of the casein, but it is still not clear whether these genetic variants have an effect on clotting properties and cheese outcome.

Few studies have been conducted on renneting times, coagulation patterns, rate of curd formation and curd firmness of sheep milk (Askar *et al.* 1984; Manfredini *et al.* 1987; Casoli *et al.* 1992; Bencini 1993, Delacroix-Buchet *et al.* 1994; Bencini and Johnston 1997).

Despite the reported differences in composition of the milk between different breeds of sheep, Italian researchers have shown that there was no difference in cheese making performance of milk between the breeds Sarda, Comisana, Massese and Delle Langhe (Chiofalo *et al.* 1989; Casoli *et al.* 1990; Ubertalle *et al.* 1991).

In France, Delacroix-Buchet *et al.* (1994) have calculated the coefficients of genetic repeatability in the Lacaune breed for renneting time (0.57) rate of curd formation (0.48) and curd consistency (0.53). They concluded that since these repeatability values were similar to the repeatability for milk production (circa 0.5) family type selection would be needed to achieve genetic progress.

Physiological factors affecting sheep milk quality

Age and parity

Maiden ewes produce less milk than older ewes (Boyazoglu 1963; Casoli *et al.* 1989; Hatziminaoglou *et al.* 1990; Ubertalle *et al.* 1990; Giaccone *et al.* 1992) and maximum yields are generally achieved at the third or fourth lactation, after which total lactation yields tend to decrease (Boyazoglu 1963; Ozcan and Kaimaz 1969; Casoli *et al.* 1989; Giaccone *et al.* 1992). These order-of-parity factors are often confounded with the age of the ewes, so that it is not possible to distinguish between the two. There are contrasting literature reports on the effect of parity on milk composition. For European dairy ewes, the parity of the ewes affects milk composition: with increasing lactation number the milk contains higher concentrations of fat and protein (Olivetti *et al.* 1988; Casoli *et al.* 1989; Boylan and Sakul 1989; Pulina 1990; Giaccone *et al.* 1993; Dell'Aquila *et al.* 1993), higher somatic cell counts (Olivetti *et al.* 1988; Pulina *et al.* 1990a; Bergonier *et al.* 1994) and lower concentrations of lactose (Casoli *et al.* 1989; Pulina 1990).

For the Australian Merino, (Corbett 1968) reported that the concentration of fat is higher in older than younger ewes, but milk production does not differ with age. By contrast, Wohlt *et al.* (1981) reported that the age of the ewes, sibling status and sex of lamb had no effect on the milk composition.

Since the negative relationship between yield and milk quality has been confirmed to apply to individual animals within a flock (Barillet *et al.* 1986) changes in milk yield brought about by age and lactation number are likely to result in changes in the composition of the milk as reported by Pulina (1990) and Pulina *et al.* (1992).

Stage of lactation

The stage of lactation markedly affects the amount of milk produced. Lactation begins at parturition and daily yields increase rapidly for the first few weeks. Peak yields are achieved around the third to fifth week of lactation (Horak 1964; Torres-Hernandez and Hohenboken 1980; Geenty 1980b; Cappio-Borlino *et al.* 1989; Bencini and Purvis 1990; Reynolds and Brown 1991; Bencini *et al.* 1992). After the peak, lactation declines more or less rapidly depending on the breed and genotype and on individual dairy potential. The trends for the concentrations of fat, protein, lactose and totals solids during the course of lactation are very similar to those reported by Holmes and Wilson (1984) for dairy cows, by Pulina (1990), Pulina *et al.* (1992) for Sarda ewes, by Fadel *et al.* (1989) for Awassi ewes and by Bencini and Purvis (1990) and Bencini *et al.* (1992) for Merino and Awassi x Merino ewes in Australia. The concentrations of fat, protein (both casein and whey protein) total solids and somatic cells are high at the beginning and at the end of the lactation, and low at peak lactation, while the concentration of lactose follows closely the lactation yield. The mineral content of milk also is affected by the stage of lactation: throughout lactation there is an increase in chloride (Pauselli *et al.* 1992) and magnesium and a reduction in potassium (Polychroniadou and Vafopolou 1984).

The processing performance of the milk also changes with the stage of lactation. As lactation proceeds the clotting properties of the milk tend to worsen, with an increase in renneting time and rate of curd formation and a decrease in the consistency of the curd (Ubertalle 1989; 1990).

Liveweight of the ewes

Most authors agree that heavier ewes produce more milk (Burris and Baugus 1955; Owen 1957; Boyazoglu 1963), however there are few reports on the effect of liveweight on the quality of the milk for cheese making. Pulina *et al.* (1994a) found positive phenotypic correlations (from 0.26 to 0.56) between the liveweight of Sarda ewes and the concentrations of fat and protein of their milk for the first 10 weeks of lactation.

Number of lambs born or weaned

Sheep suckling twin lambs produce more milk than those suckling single lambs and ewes rearing triplets produce more milk than those rearing twins (Kirsch 1944; Wallace 1948; Banky 1949; Barnicoat *et al.* 1949; Davies 1958; Alexander and Davies 1959; Doney and Munro 1962; Owen and Ingleton 1963; Slen *et al.* 1963; Gaál 1964; Gardner and Hogue 1964; Horak 1964; Moore 1966a; Corbett 1968; Robinson *et al.* 1968; Peart 1970; Karam *et al.* 1971; Peart *et al.* 1972; 1975; Louda and Doney 1976; Geenty 1979; Maxwell *et al.* 1979; Davis *et al.* 1980; Gibb and Treacher 1982; Doney *et al.* 1983; Loerch *et al.* 1985; Geenty and Dyson 1986; Geenty and Sykes 1986; McCann *et al.* 1989; Bencini *et al.* 1992). However, there are few and contradictory reports on the effect of number of lambs reared or born on the quality of milk. Gardner and Hogue (1964) reported that Rambouillet and Columbia ewes rearing single lambs had a lower concentration of fat in their milk than ewes rearing twins. By contrast, in a later study, these authors reported that Hampshire and Corriedale ewes that gave birth to single lambs produced milk with a higher concentration of fat and protein (Gardner and Hogue 1966). This was also reported by Serra *et al.* (1993) who observed that Sarda ewes that gave birth to single lambs produced milk with a higher concentration of fat and protein throughout lactation, but their milk production was lower than that of sheep with twin lambs. The negative relationship between yield and quality of milk may explain why twin bearing ewes who produce more milk have lower concentrations of fat and protein in the milk. The contrasting result reported by Gardner and Hogue (1964) may be due to the small number of ewes (10 single and 10 twin bearing ewes) used in their experiment.

If dairy ewes are allowed to suckle their lambs for the first few weeks of lactation the yields of milk from ewes that reared twin lambs should be, at least initially, higher than those of ewes rearing singles. For this reason in the Middle East the ewes are allowed to suckle their lambs after the evening milking (Finci 1957; Folman *et al.* 1966; Morag *et al.* 1970; Eyal *et al.* 1978). According to some authors this weaning method affects the composition of the milk as the sheep would be capable of retaining the milk fat if allowed to suckle their lambs during the milking period (Dawe and Langford 1987; Papachristoforou 1990). However, it is possible that the lower concentration of fat in the milk observed by these authors was due to the lack of a milk ejection reflex, as suggested by Labussière (1988), as Knight *et al.* (1993a) adopted a mixed weaning method with New Zealand Dorset ewes without affecting either yield or composition of the milk.

Ubertalle (1990) reported that early weaning of the lambs worsened the consistency of the curd derived from the milk even though the composition of the milk was not affected. This probably was due to the fact that oxytocin and prolactin that normally prevent mammary involution are reduced if lambs are removed early (Turner and Huyhn 1991) and their reduction results in a reduction of mammary DNA and an increase of plasminogen activators. These convert plasminogen into plasmin, which is involved in the hydrolysis of β-Casein, so that the final consistency of the curd is reduced.

Management factors affecting the quality of sheep milk

In Figure 2 it was shown how the farmer has control over the management of the flock of dairy ewes and that some management practices can affect the quality of sheep milk.

Milking techniques

In most Mediterranean countries sheep are still hand-milked with the consequence of poor hygiene and high bacterial counts and somatic cell counts in the milk (Gall 1975; Fatouros 1986; Anifantakis 1990). However, the concentration of protein and fat in the milk does not differ between hand and machine milked ewes (Casu *et al.* 1978a).

In Australia and New Zealand sheep are milked by machine and the milk has better micro-biological characteristics.

The machine milking of sheep has been reviewed by Purroy Unanua (1996). The design of milking parlours and the organization of the milking operations have been described by Enne (1976) and Pazzona (1980) in Italian and by Kervina *et al.* (1981), Mills (1989), Gilbert (1992a) and Dawe (1992) in English. The practical recommendations of Gilbert (1992a) and Dawe (1992) are particularly relevant to the emerging sheep milking industries of Australia and New Zealand.

Interval between milkings and frequency of milking

Wilde and colleagues (Wilde *et al.* 1987a; 1987b; 1988; Prentice *et al.* 1989; Wilde *et al.* 1989; Hillerton *et al.* 1990; Wilde and Knight 1990; Wilde and Peaker 1990, Wilde *et al.* 1996) have established that the rate of milk secretion is controlled locally by the Factor Inhibiting lactation (FIL), a fraction of the whey proteins present in milk. As a consequence, the interval and frequency of milking assume a paramount importance in affecting the yield of milk. The findings of Denamur and Martinet (1961) and Grigorov and Shalichev (1962) provided some indirect evidence that an autocrine control of milk secretion is present in sheep. This was later confirmed by Bencini (1993) and McFerran (1996). Therefore the interval between milking, the milking frequency and the adoption of stripping methods to remove additional milk and ensure completeness of milking increase both the daily output of milk and the total lactation yield of dairy ewes by removing the inhibitory effect of milk accumulated in the alveolar tissue of the mammary glands.

In the dairy cow, increasing the frequency of milking increases milk production (Porter *et al.* 1966; Pelissier *et al.* 1978; Phillips *et al.* 1980; Waterman *et al.* 1983; Rao and Ludri 1984; Amos *et al.* 1985; Gisi *et al.* 1986; Barnes *et al.* 1990; Hillerton *et al.* 1990), but milking at different intervals does not change the yield of milk (Elliott 1959) because the rate of milk secretion does not change for the first 16-20 hours after milking (Turner 1953; 1955; Elliott and Brumby 1955; Elliott 1959; Porter *et al.* 1966; Bartsch *et al.* 1981; Van Trinh and Ludri 1984). Changing the frequency of milking or the milking interval also does not affect the composition of the milk (Rao and Ludri 1984; Amos *et al.* 1985; Hillerton *et al.* 1990).

In dairy sheep, several authors have reported that reducing the frequency of milking results in a loss in milk production (Morag 1968; Casu and Labussière 1972; Labussière *et al.* 1974; Geenty and Davison 1982; Papachristoforou *et al.* 1982; Purroy Unanua 1986) and increasing the frequency of milking increases milk production (Morag 1968; Karam *et al.* 1971; Bencini 1993), but there are few and contrasting reports on the effect of milking frequency and interval on the composition of the milk. Casu and Labussière (1972) and Huidobro (1989) reported that omitting one or both of the milkings on a particular day of the week did not affect the composition of the milk. When the milking frequency was reduced from twice to once daily the composition of the milk was not affected in the studies of Casu and Boyazoglu (1974), De Maria-Ghionna *et al.* (1982) and Cannas *et al.* (1991), but fat and protein concentrations were increased in the studies of Battaglini and De Maria (1977) and Battaglini *et al.* (1977; 1979), and reduced in a study by Morag (1968). When the milking frequency was increased from two to three times daily milk composition was not affected according to Morag (1968) and Cannas *et al.* (1991), but the concentrations of fat and protein were increased according to Mikus and Masar (1978).

Such contrasting reports may be due to the fact that these studies were carried out with different breeds of sheep which might have efficient or inefficient autocrine control of milk secretion according to the degree of selection for dairy production. Bencini (1993) reported that milk composition was affected by the milking interval and frequency in breeds that are not selected for dairy production because they have an efficient control of milk secretion. On the contrary, breeds selected for dairying have an impaired autocrine control mechanism and therefore do not respond as much to changes in milking frequency (Karam *et al.* 1971; Wilde and Peaker 1990; Bencini 1993). To confirm this, Pulina *et al.* (1994b) observed that, in Sarda sheep selected for dairying, hourly secretion rates of milk and milk components did not vary for milking intervals of 9 to 15 hours.

Stripping method

Labussière and colleagues (Labussière 1969; Labussière *et al.* 1969; Labussière *et al.* 1984; Labussière 1985; Labussière 1988) showed that European sheep had two different kinds of milk ejection patterns: some ewes released their milk in a single peak and others had a delayed let down, so that two distinct peaks were observed in the milk release curve. Double peaked sheep are present in a greater proportion within the specialized dairy breeds. Labussière *et al.* (1969) studied the milk ejection reflex in Préalpes ewes and concluded that the second peak of milk ejection occurred because the ewes released oxytocin, that promoted a milk ejection reflex. Labussière (1969) and Ricordeau (1974) observed that the milk obtained from double peaked animals had a higher fat concentration and concluded that the double peak was due to a delayed release of endogenous oxytocin, so that the first peak corresponded to the removal of the cisternal milk and the second peak, within a minute of the first, corresponded to the alveolar milk ejected due to the release of endogenous oxytocin. This is in agreement with Ranieri (1993) who measured the composition of milk fractions collected during milking and observed a progressive increase in the concentration of fat, but no changes in the concentrations of protein and lactose as milking proceeded. Mayer (1990) measured plasma oxytocin concentrations in single and double peaked ewes and confirmed the conclusions of Labussière (1988) and Purroy Unanua (1986), that ewes with a double peak had an effective ejection reflex, which allowed for a better removal of milk from the mammary glands. By contrast, ewes with a single peak of milk ejection did not release oxytocin so that only the cisternal milk, which has a low concentration of fat, was collected.

In the Australian and New Zealand sheep dairy industries, milkers often attempt to increase the completeness of milking by adopting some method of stripping to remove further milk after each milking. The fact that animals with single peaks have high residual milk, shorter lactations (Labussière 1985; 1988; Purroy Unanua 1986) and lower concentration of fat in the milk (Mikus 1970) supports the adoption of these practices. Labussière (1985; 1988) demonstrated that, for sheep with one peak of milk ejection, stripping by hand or by machine is necessary and that this increases the fat concentration in the milk. However, for Sarda sheep with a double peak of ejection Casu *et al.* (1978b) reported that double cupping can be eliminated without affecting the composition of the milk and Purroy Unanua (1986) reported that manual stripping can be replaced successfully with machine stripping, or double cupping, without compromising the amount of milk withdrawn.

In Australia and New Zealand sheep milkers use either the double cupping or a massage of the udder to obtain additional milk from dairy ewes. Bencini and Knight (1994) confirmed that double cupping or machine stripping are necessary to maximize milk withdrawal and increase the fat concentration in the milk of New Zealand Dorset ewes. From their results it appears that unselected local breeds milked in Australia and New Zealand have a physiology of milk ejection similar to that of European dairy sheep that have only one peak of milk ejection.

Management of the ewes

Some management practices such as shearing, out of season breeding and the use of hormones may affect the quantity and quality of milk produced.

Shearing

Shearing sheep before or immediately after lambing increases the concentration of protein and fat in the milk of dairy Poll Dorset ewes (Knight *et al.* 1993b), with improved processing performance of the milk. This may be caused by an increase in feed intake (Wodzicka-Tomaszewska 1964; Ternouth and Beattie 1970; Morgan and Broadbent 1980; Glanville and Phillips 1986; Vipond *et al.* 1987) leading to an increase in blood glucose (Kirk *et al.* 1984), probably in response to cold stress (Wheeler *et al.* 1962).

In hot climates shearing could reduce heat stress, which has been shown to affect feed intake and milk production (Dattilo, 1971).

Breeding out of season

In the Mediterranean countries, sheep milking is seasonal, and even the largest and most modern sheep milk cheese factories are closed during summer. This is probably because the European breeds are seasonal breeders. In Sardinia (Italy) work has now been undertaken to breed the ewes out of season and establish a year-round supply of milk. European researchers, however, have established that sheep milk produced in summer has poor cheese making performance (Delacroix-Buchet *et al.* 1994) due to long renneting times, poor consistency of the curd and high proteolytic and lipolytic activities. This suggests that environmental factors may be important for the quality of sheep milk: high temperatures do not have an effect on the composition of sheep milk (Thomson *et al.* 1982), but long day lengths result in lower protein concentrations in the milk (Boquier *et al.* 1990) and in reduced rates of secretion of fat and protein (Pulina *et al.* 1994b). However, the major factor affecting milk quality in summer may be the poor nutritive value of pasture, as Pulina *et al.* (1993) have shown that a balanced ration restored the cheese making performance of summer milk.

When sheep dairying was first established in Australia and New Zealand, farmers opted for a year-round supply of milk, which was made possible by the fact that the local sheep were less seasonal than the European breeds, and if appropriately managed, could be bred out of season (Scaramuzzi and Martin 1984; Signoret 1990). However, sheep dairy farmers experience a number of problems connected to the out-of-season breeding of their dairy flocks. First, only a proportion of ewes will mate out-of-season, so most of the lambings are concentrated in winter. Second, the availability of good pasture during summer is low, especially in Australia, and those sheep that have lambed tend to produce less milk. As a consequence severe shortages of milk occur during the summer months, when the demand for fresh sheep milk yoghurt is highest.

The differential nutrition also changes the processing performance of the milk and consequently the quality of the derived dairy products. So, it is difficult to maintain a constant and consistent production throughout the year. These problems have not been addressed so far and are a source of uncertainty in the Australian and New Zealand sheep dairy industries.

Use of hormones

Growth hormone increases milk production in dairy cows (Peel and Bauman 1987; Zinn and Bravo-Ureta 1996). This occurs also in dairy sheep, where the increase in milk production is accompanied by increases in milk fat content and reductions in milk protein, which is not desirable for cheese making (Fleet *et al.* 1986; 1988; Holcombe *et al.* 1988; Pell *et al.* 1989; Sandles *et al.* 1988; Stelwagen *et al.* 1993). In any case, the use of hormones to increase milk production is not allowed in Europe and Australia.

Nutrition

Since nutrition affects both the yield and the composition of the milk produced, it also affects the quantity and quality of cheese. Kervina *et al.* (1981), Treacher (1983), Robinson (1988) Mills (1989) and Gilbert (1992b) have written practical recommendations on the nutritional requirements of dairy sheep.

Early work was concentrated on the effect of nutrition on milk yield, but effects on milk composition were not examined (Wallace 1948; Thomson and Thomson 1953; McCance and Alexander 1959).

With the exception of Peart (1967) who reported no effects of supplementation in late pregnancy on future milk yield, most authors agree that ewes supplemented in late pregnancy produce heavier lambs (Treacher 1970; Stern *et al.* 1978), and have greater production of milk (Treacher 1970; Egan 1984; Hossamo and Farid 1986; Bencini and Purvis 1990). Mellor and Murray (1985) reported that ewes severely underfed in late pregnancy had a reduced development of the udder and lowered prenatal and postnatal accumulation of colostrum. Most authors also reported that underfeeding ewes in early lactation impaired milk secretion and the growth rate of the lambs (Coop *et al.* 1972; Jagush *et al.* 1972; Maxwell *et al.* 1979), but did not report on the effects on the quality of the milk.

Poulton and Ashton (1972) examined the effect of the quality of diet on milk yield and composition and demonstrated that diets rich in carbohydrates and poor in fibre disturbed the function of the rumen and resulted in lower milk yields and lower concentrations of fat in the milk.

The concentration of fat in the milk is correlated positively with the concentration of fibre in the diet. Pulina and Rassu (1991a) have calculated the relationship between milk fat and Neutral Detergent Fibre (NDF) in the diet (Fat % = 4.59 + 0.05 NDF; $r = 0.48$). However, this relationship is difficult to interpret because a higher concentration of NDF provokes a reduction in the digestibility of the diet and a reduction in feed intake which in turn results in a reduction in milk production and a consequent increase in milk fat concentration.

An important aspect of dietary fibre is related to its dimension as it affects both chewing time and rate of passage through the rumen: Cannas (1995) observed that in sheep fed hay and concentrates, for a given concentration of NDF, a reduction in the particle size of hay resulted in a reduction in chewing time and an increase in feed intake. As a result the digestibility of DM and NDF decreased, but the amount digested per day was not affected. The composition of volatile fatty acids in the rumen showed increased concentrations of propionate and butyrate and a stable concentration of acetate. As a consequence there was an increase in milk and milk protein yield.

Excessively high doses of concentrates can reduce the intake of fibre and therefore reduce chewing times and rumen pH. This can depress milk production and reduce the concentration of fat in milk (Oddy 1978; Chiofalo *et al.* 1993) probably because they cause rumen acidosis (Rossi *et al.* 1988).

Various workers (Perez Hernandez *et al.* 1986; Rossi *et al.* 1991; Horton *et al.* 1992; Sklan 1992; Chiofalo *et al.* 1993) have shown that feeding protected fat to ewes increases the fat concentration in their milk, confirming previous findings in the dairy cow (Palmquist and Jenkins 1980; Dell'Orto and Savoini 1989). This is accompanied by a reduction in milk protein due to a reduced capacity of the mammary gland to utilize amino acids (Cant *et al.* 1993). However, protected fat added to the diet has no effect on the relative proportion of nitrogenous compounds (Campus *et al.* 1990) and on the clotting properties of the milk (Campus *et al.* 1990; Chiofalo *et al.* 1993). Bertoni (1992) cautioned against the inclusion of protected fat in the diet of dairy ewes because it is expensive and fat concentration in sheep milk is already high, so there appears to be no need of increasing it further.

The protein content of the diet affects the quantity and the partition of nitrogenous substances in the milk: Calderon-Cortes *et al.* (1977) reported that milk protein was significantly reduced if ewes were fed a protein deficient diet. Robinson *et al.* (1974), Calderon-Cortes *et al.* (1977), Robinson *et al.* (1979), Cowan *et al.* (1981) and Pulina *et al.* (1995) all have shown that milk yield and concentration of milk fat can be increased by increasing the protein content of the diet. However, in the study of Pulina *et al.* (1995) the increase in milk fat was accompanied by a decrease in milk protein, which worsened the processing performance of the milk. By contrast Sinclair and Gooden (1990), Lynh *et al.* (1991) and Rossi *et al.* (1991) reported that high concentrations of protein in the diet can increase the concentration of protein in milk, together with non protein nitrogen (Pulina *et al.* 1990a), and especially urea (Cannas *et al.* 1995) which results in a poorer processing performance of the milk.

Increases in dietary protein was generally accompanied by increases in food intake. The consequent increase in milk production masks the increased synthesis of protein in the mammary gland, and the concentration of protein in the milk does not change (Robinson *et al.* 1974; Cowan *et al.* 1981; Penning *et al.* 1988; Frey *et al.* 1991).

McHattie *et al.* (1978) showed that supplementing lactating ewes with fishmeal increased both their milk yield and the protein concentration in the milk. This finding was later confirmed by Gonzales *et al.* (1982; 1984), but contradicted by Hadjipanayiotou (1992), Vincent *et al.* (1988), Ngongoni *et al.* (1989) and Limandis *et al.* (1992). These contradictory results may have been due to the variable rumen degradability of the fishmeals used by different researchers. Recently Chiofalo *et al.* (1993) found a significant reduction in milk protein of sheep fed high doses of starch and sugars, in agreement with similar findings of Murphy and O'Hara (1993) for dairy cows.

Little research has been done on the composition of fatty acids of sheep milk, but the diet seems important on this regard. Casoli *et al*. (1989) reported that sheep milk fat contains high percentages of palmitic and oleic acid, while essential fatty acids, linoleic acid and linolenic acid are low. Volatile fatty acids range from 15 to 30 % and are more saturated than unsaturated. Casoli *et al.* (1989) and Rossi and Pulina (1991) also reported that nutrition affects the fatty acid composition of the fat in the milk. If the ewes are underfed and mobilize their body reserves, the proportions of high molecular weight fatty acids are increased. In particular, there is an increase in oleic acid, which derives from stearic acid after the action of a mammary desaturase. So, the ratio C18/C10 in the milk provides an indication of the nutritional status of the animal. Ewes generally mobilise body reserves for the first 4-5 weeks of lactation (Pulina 1990). The presence of unsaturated fatty acids in the milk could generate processing problems which, however, would not be detected in European sheep dairy systems as for the first 4-5 weeks of lactation the milk is consumed by the lambs. Processing problems in the first few weeks of lactation have been reported by sheep dairy manufacturers in Australia, where the ewes are separated from the lambs and milked soon after birth. The hypothesis that these processing problems in early lactation may be due to the presence of unsaturated fatty acids in the milk is currently being investigated by researchers at the University of Western Australia.

The fatty acid composition of the fat in the milk also can be modified by feeding protected fat, as demonstrated by the work of Pulina *et al.* 1990b, Sklan (1992) and Chiofalo *et al.* (1993) who observed significant increases in long chain fatty acids, especially unsaturated fatty acids, in ewes fed protected fat.

Pulina (1990) observed that improving the quality of the diet can reduce the somatic cell count in the milk, especially toward the end of lactation (Pulina *et al.* 1992). This is probably due to an improved functionality of the rumen which results in the combined effect of increasing production, resulting in a dilution of the somatic cells and of slowing down mammary cell turnover. Somatic cell counts can increase in sheep grazing green pasture due to excessive nitrogen intake (Cuccurru *et al.* 1994). The use of regulators of rumen fermentations such as Flavomycin (Hoechst Ltd) may result in reductions in the somatic cell count (Pulina and Rassu 1991b).

Nutrition has a limited effect on the microbiological characteristics of sheep milk, which are mainly attributable to hygienic conditions during milking. However, dietary imbalances (excess carbohydrates, excess nitrogen, insufficient fibre) causing anomalous fermentations in the rumen or the hind gut can provoke the output of highly contaminating faeces because of their low consistency and high content of microbial cells (Bertoni 1992). Also selenium deficiency can compromise the anti-oxidant properties of the mammary tissue and cause an increase in the somatic cell count of the milk (Ronchi *et al.* 1994).

The use of silage can also increase the number of spore-forming bacteria, especially *Clostridium spp*, in the milk (Manfredini *et al.* 1987; Cavani *et al.* 1991), which could affect the keeping properties of the cheese.

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EVALUATION OF SENSORY AND CHEMICAL PROPERTIES OF MANCHEGO CHEESE MANUFACTURED FROM OVINE MILK OF DIFFERENT SOMATIC CELL LEVELS

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Abstract

As ovine milk production increases in the United States, somatic cell count (SCC) is increasingly used in routine ovine milk testing procedures as an indicator of flock hygiene and health. Ovine milk was collected from 72 East Friesian (EF) - crossbred ewes that were machine milked twice daily. The milk was segregated and categorized into three different average SCC groups: < 100,000 (Group I); 100,000 to 1,000,000 (Group II); and > 1,000,000 cells/ml (Group III). Milk was stored, frozen at –19°C for 4 mo. Milk was then thawed at 7°C over a 3-d period before pasteurization. Casein content and casein to true protein ratio decreased with increasing SCC group 3.99, 3.97, to 3.72% casein, and 81.42, 79.66, to 79.32% casein to true protein ratio, respectively. Milk fat varied from 5.49, 5.67, and 4.86 in Groups I, II and III, respectively. Manchego cheese was manufactured in duplicate from the three different SCC groups. As the level of SCC increased, the time required for visual flocculation increased, resulting in longer times to reach the desired firmness for cutting. Cheese yield at 1 d decreased from 16.03 to 15.97 to 15.09% with increasing SCC group. Lower yields were attributed to lower casein and fat contents of the higher SCC milk. Cheeses were coated with a polymeric coating and ripened at 7°C and 85% humidity for 9 mo. Cheese samples were analyzed at 3 d, 1, 3, 6, and 9 mo for soluble nitrogen and both total and individual free fatty acids. Cheese graders noted increased levels of rancidity in the higher SCC level cheeses at each of the sampling points. No major differences were noted in cheese texture between the different SCC levels.
(**Key words:** Manchego cheese, ovine, somatic cell counts, fatty acids)

Introduction

The American dairy sheep industry, particularly in states like Wisconsin is beginning to grow both in milk volume and cheese production. In 1983, 11.4 million kg of sheep milk cheese was imported into the U.S. and by 1998 those imports had increased to 28.2 million kg, which is one-half of global importation (FAO, 1998). Currently in Wisconsin, most cheese manufactured from dairy sheep milk is produced in small cheese plants or on-farm generally with artisinal manufacturing protocols. Compared to dairy cattle, dairy ewes produce less milk but of a much richer content (6 to 8% milk fat, 4 to 6% milk protein, Anifantakis, 1986). Since milk production per ewe is low, milk is typically frozen in polyethylene-lined pails until a sufficient quantity is collected for manufacturing.

SCC is often used to differentiate between healthy and infected mammary glands in ruminants, and is increasingly used in routine dairy sheep milk testing procedures as an indicator of individual and flock udder hygiene and health. Gonzalo et al (2000) have proposed three sanitary categories for ovine flocks based on bulk tank SCC (cells / ml):(< 500,000), average (500,000 to 1,000,000), bad (> 1,000,000), (Pirisi et al., 2000). Infection rates within these three groups were 30, 40, and 45% respectively. However, large discrepancies still exist in the literature with regards to the "normal" amount of SCC in sheep milk (e.g., a range of 100,000 to 1,500,000 cells/ml, Ranucci and Morgante, 1996). As a consequence, little is known about the effects of high SCC in sheep milk on cheese flavor and texture. Pathological increases in SCC resulting from inflammation and/or infection can have deleterious effects on milk yield and milk composition (Politis and Ng-Kwai-Hang, 1988a; Barbano et al., 1991; Pirisi et al., 1996; Pellegrini et al., 1997), and cheese production (see reviews by Pirisi et al., 1996; Bencini and Pulina, 1997).

In this present study, the effects of three different levels of SCC on milk composition, cheese flavor and texture were studied. Manchego cheese originating from the La Mancha region in Spain is a well known sheep milk cheese of those currently imported into the US. For this reason, Manchego-type cheese was manufactured in this study.

MATERIALS AND METHODS

Milk Samples

Milk from mid-lactational EF-crossbred ewes was obtained from the Agricultural Research Station of the University of Wisconsin-Madison located in Spooner, Wisconsin. A few days prior to experimental milk collection, milk samples from 72 ewes were submitted for Fossomatic SCC analyses at a State of Wisconsin certified lab. Ewes were then ranked and grouped into three categories of SCC: < 100,000 (Group I); 100,000 to 1,000,000 (Group II); and >1,000,000 cells/ml (Group III). Milk was collected daily from the three groups until 275 L was obtained for each category, which took approximately 2 wk. Milk samples were analyzed every 3 d for SCC to assure that a ewe was still producing milk with the appropriate number of SCC for her group. If ewes were found to produce milk of SCC outside of the assigned category, the ewe and her milk was reassigned to the appropriate category. The milk was frozen in lined 13-kg pails at –19°C and stored for 4 months before it was used for cheese manufacturing.

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 Manchego cheese in the University of Wisconsin dairy processing pilot plant. Two vats of cheese were made from each SCC group. Milks were pasteurized at 72°C for 15 s. The cheesemilks were cooled down to the ripening temperature, 31°C and a mesophilic DVS culture (850, Chr. Hansen, Inc, Milwaukee, WI) was inoculated into cheesemilks. After 10 min of ripening, 17 ml double strength chymosin (Chymax, Chr. Hansen, Inc., Milwaukee, WI) was added to 113.5 kg milk that was allowed to set at 31°C. An experienced licensed cheese maker subjectively evaluated coagulum development and firmness at cutting. The cheese maker did not cut the different vats by time but rather by his evaluation of the coagulum firmness. The coagulum was cut with 8 mm knives and the pH was ~ 6.41. The temperature of the vat was raised to the cooking temperature of 39°C and cooked over a 30-minute period. The whey was drained after the cooking temperature was reached. Curd was packed into 3.5 kg Manchego round hoops and pressed for 4 h at ~ 20°C. Subsequent to pressing, the cheeses were brined for 18 h at 5°C. Polycoat (RV XP164, Natural Purity, Inc. Minneapolis, MN) was applied to cheese surfaces and cheeses were aged at 7°C in an 85% humidity-controlled room. At the time of sampling, a representative wedge was cut from the Manchego wheel and ground for compositional analysis.

Analytical Methods

All compositional analyses were carried out on the cheeses in duplicate. Pasteurized milk 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). Proteolysis was monitored during ripening by measuring the amount of 12% TCA soluble nitrogen at 3 d, 1, 3, 6 and 9 mo (AOAC, 1995).

Extraction of Free Fatty Acids

Individual free fatty acids (FFA) were determined using a modified version of the procedure of Ha and Lindsay (1991) at 1, 3, 6 and 9 months. Approximately 5 g of finely grated cheese, 0.4 ml of diethyl ether containing 500 μg of nonanoic acid (internal standard), 15 ml of diethyl ether and 0.5 ml of 5.5 N H_2SO_4 were mixed in a Qorpak tube (Fisher Scientific, Chicago, Il). The mixture was blended thoroughly with an homogeniser (Ultra-Turrex® T25 basic, IKA® Works, Inc., Wilmington, NC) fitted with the dispersing tool 25 (S25N 10G) at a speed of 13,000 min^{-1} for 2 min. The dispersing tool was rinsed twice with 10 ml of hexane. Each rinsed solution was combined with the sample extract. To remove water, 12.5 g of anhydrous Na_2SO_4 was added to each tube and vortexed thoroughly. The mixture was then centrifuged in a padded cup of Babcock centrifuge for 5 min and the supernatant was then used for isolation of FFA.

Alumina columns were prepared by filling empty 20 ml BondElut columns (Varian Inc., Walnut Creek, CA) with 5 g of deactivated alumina and the columns were placed onto the vacuum manifold unit (Supelco, Sigma-Aldrich, St. Louis, MO). Deactivation of the alumina was carried out as described by Ha and Lindsay (1991). The pooled ether/hexane extract was passed through the alumina column twice. The column was then washed twice with 10 ml of hexane:diethyl ether (1:1, v/v) each to remove any neutral lipids. The alumina, with the adsorbed FFA, was dried under vacuum for a few seconds and transferred to a screw-capped tube. 5 ml of 6% formic acid in Na_2SO_4-dried diisopropyl ether (v/v) were added to the alumina and mixed thoroughly. Samples were then centrifuged at 2,000 x *g* for 5 min and the supernatant was then carefully transferred to a screw-capped tube containing 2.5 g of Na_2SO_4 to remove any water. The contents were mixed thoroughly and centrifuged again for 5 min. Supernatant were carefully transferred to screw-capped graduated glass centrifuge tubes (17 × 117 mm, Heavy-duty Kimax Brand, Fisher Scientific, Inc., Chicago, IL) and concentrated to 500 μL using a nitrogen stream in a vacuum manifold system with the drying unit attached to it (Supelco, Sigma-Aldrich, St. Louis, MO). Three separate extractions were carried out per sample.

Gas Chromatography

The underivatized sample (1.0 μL) was then separated using a fused silica capillary column (DB-FFAP; 30 m × 0.25 mm i.d.; 0.25 μm film thickness; J & W Scientific, Folsom, CA) in an Agilent model 6890 Series gas chromatograph (Agilent Technologies, Inc., Wilmington, DE) equipped with an automatic on-column injector (Agilent 7683 Series, Agilent Technologies, Inc., Wilmington, DE) and a flame-ionization detector (FID). The carrier gas was high purity hydrogen at a flow rate of 1.0 mL/min. The make-up gas used was high purity nitrogen, which was maintained at a flow-rate of 40 mL/min. High purity hydrogen (40 mL/min) and compressed air (450 mL/min) were supplied to the FID. The injector and detector temperatures were 250 and 300°C, respectively. The column oven temperature was programmed to hold at 100°C for 5 min, it was then increased from 100 to 250°C at 10°C/min and held at 250°C for 12 min.

Calibration curves were prepared using a mixture of high purity (> 99%) FFA standards: $C_{4:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{12:0}$, $C_{14:0}$, $C_{16:0}$ and $C_{18:0}$ (Sigma-Aldrich, St. Louis, MO and Nu-Chek Prep, Inc. Elysian, MN) extracted through the whole procedure as for the cheese samples. As in the extraction of cheese samples, $C_{9:0}$ was used as an internal standard.

Sensory Analysis

Licensed Wisconsin cheese graders using a Wisconsin Cheese Makers Association World Championship Cheese Contest Form scored the cheeses for flavor defects, body, texture, appearance and color defects at 1, 3, 6, and 9 mo.

RESULTS AND DISCUSSION

Casein contents were 3.99, 3.97, and 3.72%, in milk from Groups I, II, and III, respectively (Table 1). The decrease in the casein content with increasing SCC was probably due to increased proteolysis; a similar trend is seen in mastitic bovine milk (Politis and Ng-Kwai-Hang, 1988b). Further evidence of enhanced proteolysis in high SCC milk can be seen in the decrease in the casein to true protein ratio (Table 1). Cheese yield at 1 d decreased from 16.03 to 15.97 to 15.09% with increasing SCC levels. Lower yields were attributed to lower casein and fat contents of the higher SCC milk (Table 1).

Clotting time increased with higher levels of SCC (results not shown) probably due to the enhanced proteolysis in these milks; a similar trend is often seen in mastitic and late-lactation bovine milks (Lucey, 1996). Cheese yield decreased with the high SCC milk was possibly due to the lower casein and fat levels in these milks. In addition, nitrogen recovery was lowest in Group III milks (results not shown). The higher moisture contents in Group III cheeses (Table 2) probably reflect reduced synergetic ability caused by casein hydrolysis. There was no difference in the pH of all the cheeses over the entire ripening period (Table 3). There were slightly higher levels of 12% TCA soluble nitrogen at all stages of ripening in cheeses made from Group III milks (Table 4).

Manchego cheeses made from milk in Groups I and II were judged to have more flavor defects at 6 and 9 mo (Table 5), although lipase flavor was detected in the cheese manufactured from Group III milk in the first month. Judges scoring for body and texture defects also noted more textural defects at 6 and 9 mo in the cheeses manufactured from milks with the two higher SCC levels (Table 6).

Free nonanoic acid ($C_{9:0}$) is either found in ovine milk cheeses in trace quantities or to be totally absent (Sousa and Malcata, 1997). In our preliminary work (results not shown), only trace concentrations of $C_{9:0}$ were found in Manchego cheese and did not change significantly during ripening. Thus, $C_{9:0}$ was used as an internal standard. As moisture contents of the cheeses were changing with age, the fatty acid concentrations were expressed as g per kg of fat.

The FFA concentrations generally increased as ripening progressed for all the three cheeses, although the increase was not constant in all cases. Similar trends for fatty acid concentrations were observed in Groups I and II. Cheeses made from Group III milks had the highest total as well as individual FFA levels at all stages of maturation (Table 7). The main FFA observed during maturation were butyric (short-chain), capric (medium-chain), myristic acid (medium-chain) and palmitic (saturated long-chain). A similar trend has been observed by other authors during ripening of Manchego cheese (Pavaia et al., 2000, Poveda et al., 2000). The most abundant FFA in all the three cheeses, irrespective of SCC levels and ripening time, was palmitic acid (representing 30-32 % of total FFAs). Short-chain FFA comprised 17-22% of the total FFA, of which butyric was the main short-chain fatty acid, accounting for 7-10% of the total FFA. Although the short-chain fatty acids are found in low amounts, they contribute more to cheese flavor than the long-chain FFA (De la Fuenta et al., 1993, Poveda et al., 2000). Higher SCC levels affected the concentration of both individual and total FFA ($C_{4:0}$-$C_{18:0}$). The cheese made from Group III milk contained the highest concentration of FFA compared to the other two SCC groups over the entire ripening period. Although there was only a slight increase in the FFA concentrations with increasing the SCC from Group I to II, the cheese made from the Group II was judged to have more flavor defects. This probably was due to the concentrations of FFA in the higher SCC cheeses being sufficiently higher than the aroma threshold.

The results demonstrated that high SCC in ovine milk results in lowered cheese yields due to lower casein, fat and solids levels in the milk. Flavor defects such as increased rancidity were noted by licensed Wisconsin cheese graders and verified from testing individual and total free fatty acid concentrations. Even moderate differences in SCC showed a difference in total free fatty acid content at 1, 3, 6, and 9 mo.

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Table 1. Composition of pasteurized cheesemilks used for the manufacture of the Manchego cheese (means from duplicate samples)

	SCC/mL		
	<100,000	**100,000-1,000,000**	**>1,000,000**
	Group I	**Group II**	**Group III**
Total solids %	16.69	16.84	14.38
Milk fat %	5.49	5.67	4.86
Total Protein[1] %	5.23	5.31	5.02
True Protein[2] %	4.90	4.98	4.69
Casein[3] %	3.99	3.97	3.72
Casein to Total Protein %	76.31	74.77	74.00
Casein to True Protein %	81.42	79.66	79.32
Casein:Fat ratio	0.73	0.70	0.77

[1]Total % N x 6.35

[2] (Total % N - % NPN) x 6.35

[3] (Total % N - % Non Casein N) x 6.36

Table 2. Average Manchego cheese composition analyzed at 1 month

	SCC/mL		
	<100,000	**100,000-1,000,000**	**>1,000,000**
	Group I	**Group II**	**Group III**
% Moisture	38.02 ± 0.23	37.29 ± 0.51	40.28 ± 0.11
% Fat	31.58 ± 0.27	30.97 ± 0.43	29.33 ± 0.29
% Salt	0.56 ± 0.03	0.68 ± 0.05	0.69 ± 0.07
% Protein[1]	25.06 ± 0.14	25.88 ± 0.02	24.67 ± 0.49
% MNFS	55.56 ± 0.13	53.96 ± 0.47	57.00 ± 0.08
% FDM	50.95 ± 0.25	49.26 ± 0.16	49.11 ± 0.40
% S/M	1.47 ± 0.08	1.83 ± 0.16	1.71 ± 0.17

[1] % Total N **x** 6.31

Table 3. Changes in Manchego cheese pH during ripening

Ripening Time	SCC/mL		
	<100,000 Group I	**100,000-1,000,000 Group II**	**>1,000,000 Group III**
3 days	4.96 ± 0.01	4.96 ± 0.02	4.96 ± 0.00
1 month	5.11 ± 0.02	5.08 ± 0.01	5.11 ± 0.02
3 months	5.15 ± 0.03	5.16 ± 0.03	5.18 ± 0.01
6 months	5.30 ± 0.03	5.32 ± 0.02	5.32 ± 0.06
9 months	5.32 ± 0.02	5.32 ± 0.02	5.34 ± 0.06

Table 4. Changes in the % proteolysis of Manchego cheese during ripening (12% TCA soluble nitrogen expressed as a % of total nitrogen)

ipening Time	SCC/mL		
	<100,000 Group I	**100,000-1,000,000 Group II**	**>1,000,000 Group III**
month	4.95	4.86	6.07
months	8.02	7.83	9.69
months	14.27	14.93	15.19
months	11.74	14.28	15.45

Table 5. Flavor defects[1] and sensory comments

Ripening time (months)	SCC/mL					
	<100,000 Group I		100,000-1,000,000 Group II		>1,000,000 Group III	
	Flavor	Comments	Flavor	Comments	Flavor	Comments
1	43.63 ± 0.18	sl flat, oxidized	44.25 ± 0.35	sl flat	43.25 ± 0.35	Lipase
3	43.25 ± 1.06	sl tallow, sl lipase, sl flat	42.00 ± 1.41	sl acid, sl lipase, sl tallow, def old milk	42.75 ± 1.06	lipase, vs bitter
6	45.00 ± 0.00	No off flavors noted	41.75 ± 1.77	def lipase, sl bitter, sl old milk	42.00 ± 0.00	def lipase
9	44.75 ± 0.00	Vs lipase, vs flat	43.75 ± 0.35	sl lipase, sl unclean	41.25 ± 0.35	pron lipase, def astringent

Table 6. Body and texture scores[1]

Ripening Time (months)	SCC/mL		
	<100,000 Group I	100,000-1,000,000 Group II	>1,000,000 Group III
1	35.00 ± 0.00	34.25 ± 0.35	34.75 ± 0.35
3	33.00 ± 1.41	33.50 ± 0.71	34.50 ± 0.00
6	34.00 ± 0.00	31.50 ± 0.71	32.75 ± 1.77
9	34.13 ± 0.18	32.75 ± 0.35	32.25 ± 0.35

[1]Scale of 1-35 with a score of 35 being a cheese with no defects

Table 7. Mean concentrations (g/kg fat) and standard deviations of FFAs in Manchego cheeses during ripening

NEW DEVELOPMENTS IN THE GENETIC IMPROVEMENT OF DAIRY SHEEP

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Introduction

Sheep have been traditionally farmed to take advantage of nutritional resources non-usable by other species, in geographic areas with hard environmental conditions, or as a complement of economically more interesting species. Management systems in sheep generally involve an important extensive component that is specific for each region and breed, but dairy sheep must also adapt to milk management procedures and this constitute a serious limiting factor for certain indigenous sheep. In the Mediterranean area ovine milk production is mainly manufactured as gourmet or artisanal farmhouse cheese, economically of high importance in these countries.

In comparison with dairy cattle, selection schemes have been applied much later in sheep. The application of these quantitative genetic methods has produced a remarkable increase in milk yield and farmer livelihood in the different sheep breeds (Haenlein, 2001). However, the genomic revolution occurred in the recent years will hopefully provide, in the near future, valuable complements to classical breeding methods.

The possibility of access to the molecular architecture of production traits will presumably permit a more efficient selection. Expectedly, the identification of particular chromosomal segments explaining part of the additive variance (QTL), will make the identification of the genes underlying these traits possible. But in the meanwhile, it is necessary to better manage the productive factors known to influence the profitability of sheep enterprises.

The ovine milk is mainly orientated towards the fabrication of cheese, and consequently parameters affecting “cheese yield” should be “selection objectives”. The difficulty to directly measure this trait makes selection possible only on the basis of indirect traits as milk protein and milk fat contents. The establishment of a trustworthy method for the measurement of the cheese yield would improve dairy sheep selection.

Another important aspect is sheep husbandry. An animal affected by a pathological process cannot express all its genetic potential, and this not only causes a direct decrease in production but also influences negatively the future generations since a correct genetic evaluation of the reproducers is not possible.

Improvement of reproductive technology is also of importance in sheep breeding since it largely affects both the flock production and the progress of the genetic improvement. The low fertility obtained at the moment with the AI, the difficulties in semen conservation and other limiting factors, negatively influence the efficiency of selection programs applied in sheep.

In this paper we will try to briefly approach all these aspects, with particular attention to those in which we have more research experience.

Present Development of Selection Schemes in Dairy Sheep

In the last ICAR (International Committee for Animal Recording) congress held in Slovenia in 2000 a report of the working group on sheep milk recording was presented (Astruc and Barillet, 2000) whose milk recording results are shown in Table 1. For breeds with a relevant number of recorded flocks, milk yield is high for Lacaune, Sarda, Assaf and Valle del Belice. For the rest of the breeds, yield ranges are generally between 1 and 1.2 l/day.

Table 1. Flocks and number of head under official milk recording and performances in the main European breeds (Elaborated from Astruc and Barillet, 2000)

Breed	Country	Population size	Recorded flocks	Recorded ewes	% of breed	Milk yield (l) (length in days)*
Assaf & Awassi	Israel	46,200	17	10,950	23.7	Assaf: 320 [a] Awassi: 530 [a] **
Churra	Spain	750,000	72	27,150	3.6	119 [ref:120] [a]
Comisana	Italy	750,000	724	101,220	13.5	176 [b]
Corse	France	100,000	71	16,942	16.9	108 (170) [b]
Karagouniki	Greece	210,000	258	17,750	8.5	
Lacaune	France	825,000	384	165,932	20.1	270 (165) [b]
Latxa (Black Faced)	Spain	277,400	166	61,747	22.3	126 [ref:120] [a]
Latxa (Blond Faced)	Spain	160,800	61	21,659	13.5	126 [ref:120] [a]
Lesvos	Greece	180,000	94	10,300	5.7	
Manech & Basco-Bearnaise	France	470,000	352	98,673	21.0	125 (141) [b]
Manchega	Spain	925,000	100	38,844	4.2	153 [ref:120] [a]
Sarda	Italy	4,700,000	1,168	195,610	4.2	193 [b]
Tsigai	Slovak Rep.	89,000	49	14,397	16.2	97 [b]
Valachian	Slovak Rep	118,000	68	25,257	21.4	105 [b]
Valle del Belice	Italy	60,000	365	48,229	80.4	188 [b]

* [a] total milk yield, taking into account the milk consumed by the lamb; [b] milk yield during the milking period

**Only one flock recorded

From Table 2 it can be seen that considerable investments are being made in selection, especially in France, Italy and Spain. Genetic responses per year for Spanish races have been estimated between 1 and 2% (Ugarte et al., 2001). Phenotypic responses are normally more important due to the general improvement in the management; for example in the Churra breed, the mean in 120 days lactation has increased from 100 to 120 litres in 12 years (from 1987 to 1998) for the whole population under recording (De la Fuente, 2001). In the Manchega breed the mean in total milk yield has increased from 147 to 166 between 1990 and 2000 (CERSYRA, 2001). For Latxa Black Faced the phenotypic response from 1987 to 2000 has been of 18 litres and for Latxa Blond Faced of 31 litres (Ugarte, 2000).

Table 2. Year of start, number of artificial inseminations (AI) per year and number of progeny-tested rams per year (elaborated from Astruc and Barillet, 2000)

Breed	Country	Year of start	AI per year (semen)	Number of AI progeny-tested rams per year
Churra	Spain	1985	3,183 (fresh) 11,052 (frozen)	40
Corse	France	1992	5,200 (fresh)	30
Lacaune	France	1968	135,000 (fresh)	470
Latxa	Spain	1984	20,588 (fresh)	84
Manchega	Spain	1988	16,636 (fresh) 338 (frozen)	43
Manech & Basco-Bearnaise	France	1977	53,000 (fresh)	190
Sarda	Italy	1986	20,600 (fresh) 2,500 (frozen)	80

In Italy, the Sarda breed is having a genetic progress of 3-3.2 litres per year (Sanna et al., 2000). In this case the phenotypic trend is less: from 1985 to 1999 the milk yield of ewes had increased from 182 litres to 194 litres (milk yield during milking period). The responses in the Lacaune breed have been higher: from 1985 to 1999 the milk had increased by 84 litres (from 186 litres in 162 days to 270 litres in 165 days) and the genetic response is around 6 litres (2,4%) per year (Barillet et al., 2001).

Most of the genetic programs are focused only on milk yield (Table 3; Barillet, 1997) and all of them use the same methodology for genetic evaluation.

Table 3. Criteria of selection and method of genetic evaluation in European dairy sheep breeds (from Barillet, 1997)

Breed	Criteria of selection*	Method of genetic evaluation
Churra	MY	BLUP-AM
Lacaune	MY, FY, PY, FC,PC	BLUP-AM
Latxa	MY	BLUP-AM
Manchega	MY,FY,PY	BLUP-AM
Manech & Basco-Bearnaise	MY	BLUP-AM
Sarda	MY	BLUP-AM

*MY= milk yied; FY= fat yield; PY= protein yield; FC= fat content; PC= protein content

These programs are expensive to run. The cost was evaluated in 1995 in the Latxa breed (Ugarte et al., 1995), with 8.38 Euro per head and year. Milk recording, in spite of being simplified (alternate recording) is the most costly operation, with more than 4 Euro per ewe and year, followed by the selection itself (purchase and keeping selected rams, hormonal treatments and AI). The milk recording cost of obtaining one calculated lactation (about 25% of lactations cannot be calculated because they do not comply with the rules) has recently been estimated in the Manchega breed to be 5.3 Euro (Montoro, 2001). This means that the cost of one head under recording is about 4 Euro, similar to the estimation in Latxa.

Breed Usage in Europe

Crossbreeding or substitution with high-yielding breeds has also considerably been used in some European countries, especially in Spain. In a recent study (Ugarte et al., 2001) it has been estimated that 45% of Spanish dairy sheep are affected by crossbreeding and that Assaf, Awassi, Lacaune and East-Friesian have 800,000, 150,000, 75,000 and 10,000 head respectively as pure breeds or with a high percentage of blood. These breeds have been introduced when farmers wished to increase the genetic level of their populations because they are able to improve or intensify the management of the animals and are not willing to wait until local breeds reach the desired level through selection. Available results on the use of these high-performance breeds indicate that around 1.5 l/day can be obtained in F1 crosses and 2 l in pure-breds, which means an increase of 50% and 100%, respectively, in relation to the production of the local breeds. Nevertheless these high yielding genotypes generally need a more careful management that may increase costs and limit their use in extensive or semi-intensive systems. Furthermore, they could be environmentally negative due to the non-use of natural resources of marginal areas, well exploited by the local breeds, and to the genetic contamination of local and well adapted local breeds.

In Italy, the results of the use of the crossbreeding between the East Friesian and the native Sarda (Sa) breed have recently been reported by Sanna et al. (2001). Descendants of those crosses, having on average about 50% of East Friesian genes, were classified as belonging to a "syntethic" breed (FS). From 1978 to 1992 more than 5,000 FS and Sa lactations were recorded on an experimental farm. The comparison between the native and the "synthetic" genotypes was made on liveweight, reproduction performances, lamb production and milk, fat and protein yields. FS resulted heavier than Sa (52 vs 44 kg liveweight) and showed higher prolificacy and higher lamb production. Milk yield resulted only slightly different between genotypes: 193.7 vs 187.7 for FS and Sa ewes, respectively. Nevertheless, due to lower liveweight and related feed requirements for maintenance, Sa ewes resulted more profitable than FS in terms of gross income per metabolic weight (9.53 vs 8.66 Euro per kg, respectively).

In Turkey, Gursoy et al. (2001) report the results of milk production and growth performance of a Turkish Awassi flock when outcrossed with Israeli Improved Awassi rams. The offspring of the highly selected Israeli Improved Awassi genotypes were found to give higher performance of 5% (lamb growth) and 20% (milk) than local sheep.

Selection Criteria other than Milk Yield

Milk Composition

The main use of ewe´s milk is its transformation into cheese since its composition is fairly well adapted to the required processes. As a consequence cheese yield is a parameter of high economical importance for cheese manufacturers. At the present moment milk recording schemes include estimations of milk parameters such as fat, protein, total solids and somatic cell count (SCC), but there is no automated method available to obtain individual cheese yield estimations. In this regard an investigation has been performed in the selection nucleus of Spanish Churra sheep aiming at developing indirect methods to estimate cheese yield (Othmane et al., 1995; 2000) although its application in practice is not economically interesting for the moment. A variable named "individual laboratory cheese yield" (Othmane, 2000) and presumably closer to industrial cheese yield than milk composition variables was proposed.

Descriptive statistics of the population for different milk traits (Table 4) show a high variation as expected for semi-extensive ovine farms under a high environmental component and at a first step of a selection program.

Table 4. Descriptive statistics of the milk traits

Trait	Mean	Min.	Max.	σ	CV(%)
Milk yield (L30-L120), l	95	40	272	33.37	35.27
Milk yield (L0-L120), l	137	50	338	47.46	34.60
Fat content, g l^{-1}	71.1	23.3	120.1	12.44	17.49
Protein content, g l^{-1}	59.9	43.1	86.9	5.66	9.45
Casein content, g l^{-1}	47.6	33	71.9	4.94	10.38
Serum protein content, g l^{-1}	12	7.2	14.9	1.07	8.94
Lactose content, g l^{-1}	42.6	28.2	57.9	4.34	10.18
MU	131	66.9	207	16.11	12.30
Total solids content, g l^{-1}	182.6	124.4	256	16.12	8.83
PH	6.62	6.13	7.54	0.17	2.62
LnSCC	12.15	9.31	16.19	1.32	10.84
LILCY	26.71	12.19	49.73	4.22	15.78

LnSCC: lactation mean of somatic cell (in their natural logarithmic form). LILCY: lactation mean of individual laboratory cheese yield.

Several analyses on genetic and environmental parameters for milk yield and milk composition have been performed in Churra sheep (Gonzalo et al., 1994; El-Saied et al., 1998, 1999). Results indicated a high importance among the environmental factors of variation of "flock-year-season" with high significant effects on milk yield and also milk composition traits. It is also to be noted that a negative phenotypic correlation was found between milk yield and any of the milk components with the exception of lactose, the latter also showing negative correlations with the rest of milk components.

Heritability estimates resulted in a low value (0.08) for the trait "individual cheese yield" and this together with its high variation degree indicates that it is not useful as a selection criterion. A low heritability (0.08) was also obtained for fat content, which was attributed to several factors such as the high variability in nutrition, milking systems and non-identified factors. This low estimate obtained for fat content is possibly related to the low heritability obtained for cheese yield. However, these results should be considered as provisional and similar studies should be performed in other sheep breeds, particularly in those showing larger fat content heritabilities.

Regarding genetic correlations, the two estimates of total milk yield (30-120 days and 0-120 days) seem to represent the same variable on the basis of the correlation found between them as well as among them and the milk components. Protein fractions appear markedly correlated among themselves (0.97 to 1) and also with fat content (0.77 to 0.82). Variables with a greater relationship with cheese yield were total solids content (0.82), casein content (0.81) and protein content (0.79). Is should also be mentioned the high and negative correlation obtained between cheese yield and milk yield estimates (-0.53 and -0.54).

Other results indicated a significant effect of the lactation phase on milk composition clearly influencing the aptitude of milk for cheese processing. In the same way, older ewes have resulted to produce milk with a higher content in casein, proteins and total solids indicating a better aptitude for cheese fabrication.

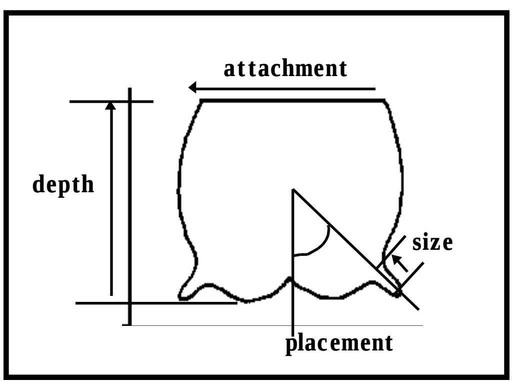
Regarding the possibility of using casein content instead of protein content in selection, heritabilities obtained were very much alike and the genetic correlation between both traits was nearly 1. As a consequence this change is not adequate since it has no advantages and it is more expensive to measure.

Udder Morphology

Mechanical milking in sheep encounters several problems among which we can point out the high udder morphology variability within populations and the negative evolution of udder morphology with milk performance improvement. This situation has led to the establishment of the optimal ovine udder morphology for mechanical milking called "udder machine" by Mikus (1978) which main characteristics are: well attached (inserted) udders with vertical teats of intermediate size and lower external cistern height. It is not difficult to obtain such an udder type through genetic improvement if an adequate methodology for mammary morphology evaluation is available. However, the methods traditionally used in sheep cannot easily be incorporated into selection programs. The method described by Labussière et al. (1981) is based on several measures performed directly on each animal and as a consequence it shows some drawbacks such as low speed, laboriousness and expense in personnel making its application infeasible for commercial farms. For its part classification by types (Sagi and Morag, 1974) is at a disadvantage because BLUP methods are less suited for estimating genetic values for the non-continuous traits involved in these analyses.

In order to solve this situation a system for morphological appraisal of the udder based on a linear scale was proposed for dairy ewes as an alternative (de la Fuente et al., 1996). This method relies on a limited number of traits, those with greater influence on aptitude for mechanical milking. Of them four are basic udder traits (illustrated in figure 1) and the fifth globally defines udder morphology.

Figure 1. Basic traits proposed for a linear evaluation of the udder in sheep



A linear scale "1 to 9 points" was fixed for the evaluation similarly to the methodology that efficiently solved the appraisal of cattle studs for morphological types. The five traits proposed for the evaluation method are described below following de la Fuente et al. (1996) and the punctuation scale is illustrated in figure 2:

Udder depth is defined by the distance between rear attachment and the udder floor, using as a reference the hock. Udders with excessive depth (below the hock) usually reflect deficiencies in the suspensory ligament.

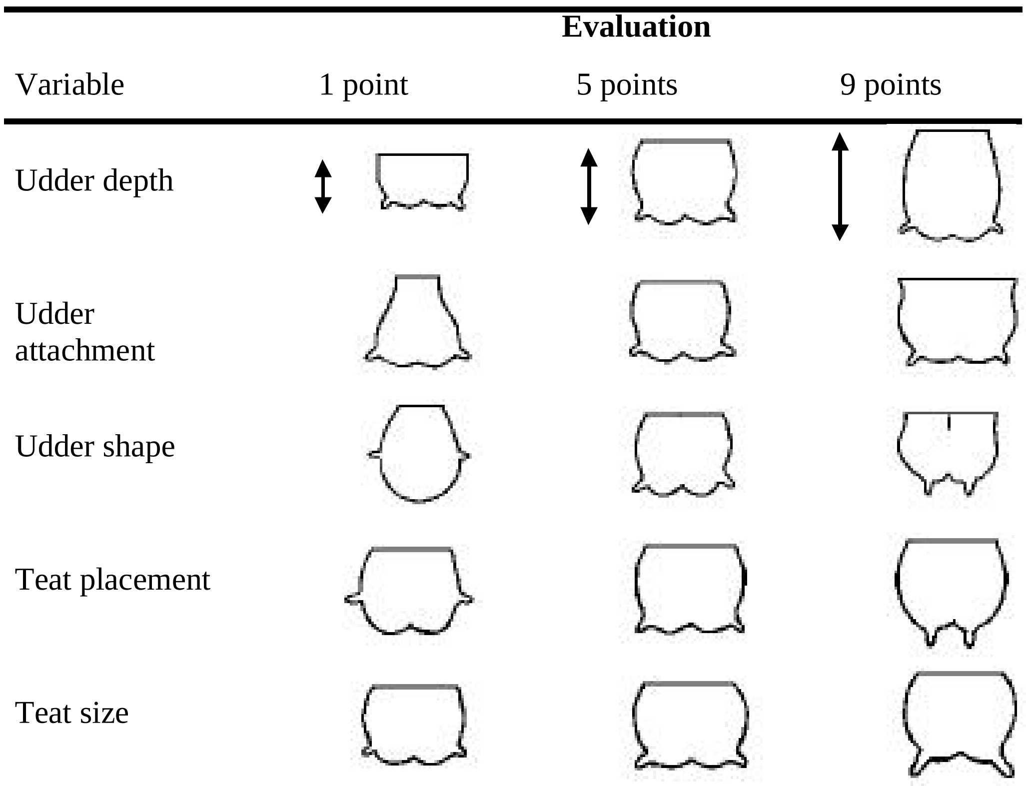
Udder attachment is determined by the perimeter of the insertion to the abdominal wall of the ewe. The maximum insertion base (9 points) is considered optimum.

Teat placement is defined by the teat angle. The optimum is completely vertical teats (9 points), directed toward the ground, which coincide with minimum cistern height.

Teat size is determined by length. Extreme sizes impede adaptation to standard teat cups, manual milking and suckling. In the Churra breed, the average teat length is 3.83 cm (Fernández et al., 1995), corresponding to 5 points on the scale.

Udder shape (US) measures the morphology of the udder relative to the optimum for machine milking (9 points) and corresponds to the “udder machine” described by Mikus (1978). Udder shape is scored by its symmetry, depth, attachment, teat position and size. Although udder shape includes several udder traits, it is also considered in the method in order to have a general parameter of the udder, similar to the “dairy form” in cattle.

Figure 2. **Punctuation scale for the udder traits**



The method was developed on the selection nucleus of the Spanish Churra sheep and experimental procedures carried out in order to evaluate the method were as follows. Udder morphology was determined on 113 Churra breed ewes from three different flocks using the methodology of Labussière et al. (1981) modified according to Mavrogenis et al. (1988) by replacing the measurements of mammary volume and rear surface by those of width and mammary circumference because the latter are easier to measure and define the udder volume. From these data, environmental factors significantly affecting udder traits appeared to be: lactation month, flock, parity and milk yield (Fernández et al., 1995). Phenotypic correlations between traits were estimated as well as the optimum time to perform udder evaluation (between the 30th and 120th day of lactation) all these results allowing for a design of a linear evaluation system orientated towards sheep mechanical milking (de la Fuente et al., 1996). In a second trial 2015 Churra ewes from seven flocks were scored using the proposed method in order to evaluate its objectivity, obtaining a total of 5265 scores. Phenotypic correlations among scores from three different qualifiers are shown in Table 5.

Table 5. Repeatabilities and phenotypic correlations among scores from 3 qualifiers (A, B y C)

		Correlations		
Trait	**r**	**A-B**	**A-C**	**B-C**
Udder depth	0.57	0.81	0.77	0.86
Udder attachment	0.61	0.75	0.77	0.79
Udder shape	0.68	0.87	0.84	0.85
Teat placement	0.73	0.86	0.85	0.85
Teat size	0.60	0.77	0.72	0.79

Heritabilities, repeatabilities and variation coefficients are included in Table 6 (Fernández et al., 1997). These values do not greatly differ from those obtained in other species such as cattle using a linear scale and although heritabilities are not high they allow for a selection program with a non-negligible expected response. This method has been experimentally applied to three Spanish sheep breeds: Churra, Latxa and Manchega (Table 7) (de la Fuente et al., 1998) and it is currently used in Churra sheep aiming at improving aptitude for mechanical milking (de la Fuente and San Primitivo, 1997).

Table 6. Heritabilities, repeatabilities, and coefficient of variation of linear udder traits

Trait	**Heritability**	**SE**	**r**	**CV**
Udder depth	0.16	0.04	0.51	18.32
Udder attachment	0.17	0.05	0.48	27.79
Udder shape	0.24	0.06	0.62	31.23
Teat placement	0.24	0.06	0.64	37.19
Teat size	0.18	0.05	0.54	24.60

Table 7. Mean and standard deviation for udder traits in Churra, Latxa and Manchega breeds

Trait	**Churra (n = 10762)**	**Latxa (n = 2707)**	**Manchega (n = 7171)**
Udder depth	4.64 ± 1.35	5.87 ± 1.42	5.34 ± 1.28
Udder attachment	4.89 ± 1.44	5.64 ± 1.18	5.08 ± 1.29
Udder shape	4.58 ± 1.58	-	4.57 ± 1.31
Teat placement	4.33 ± 1.67	4.77 ± 1.18	4.64 ± 1.51
Teat size	4.36 ± 1.37	5.22 ± 1.19	4.92 ± 1.04

Somatic Cell Count

Mastitis is one of the most economically important health problems in sheep and thus methods allowing for an early diagnosis of the process or sub-clinical mammary infections show high relevance. Among these methods we can cite the milk somatic cell count (SCC) proposed by Gonzalo et al. (1993) that due to its effectiveness and ease of detection is currently used together with milk composition analyses.

Somatic cell count is hardly influenced by hygienic and management practices. However, the very few studies performed in sheep suggest an inherited component in the SCC parameter, which would permit a prediction of response to selection. SCC has a dual significance. In healthy animals SCC may be considered a bromatological milk variable, but SCC from infected udders may be used as an indicator of mastitis.

A few studies have focused on this duality from a genetic point of view through the estimation of genetic parameters separately for healthy and infected animals, as well as for the whole population. An investigation was performed on several breeds in order to define a threshold discriminating healthy from infected ewes, which was established in 250,000-300,000 cells/ml (González et al., 1995). Heritability estimations were obtained for SCC under different considerations in a study with 10 flocks from the selection nucleus of Churra sheep (El-Saied et al. 1998; 1999) and the values obtained were 0.09 for test-day measures and 0.12 for lactation measures (Table 8). These values are in the range found for SCC in cattle (0.09-0.13) (Banos and Shook, 1990; Schutz et al., 1990; Da et al.1992, Zhang et al., 1994). Heritability was also obtained for Churra ewes with a SCC value under the threshold indicating a healthy status (250,000 cells/ml) which gave an estimate of 0.03 that did not significantly differ from zero. All these results suggest that the genetic component of SCC in healthy animals is negligible whereas this is not the case when the estimation is performed on the whole population. Then SCC as an indicator of mastitis may be considered an adequate criterion for selection although with relatively low expected responses.

Table 8. Heritabilities, repeatabilities and their approximate standard errors for SCC

Variable	h^2	SE	r	SE
Log SCC (whole population)				
Lactation measures	0.12	0.03	0.35	0.03
Test day measures	0.09	0.02	0.38	0.01
Log SCC (<250,000 cells/ml)	0.03	0.02	0.10	0.02

In contrast with sheep in which species there are serious limitations derived from the reduced flocks with productive parameters available, genetic parameters of SCC in cattle have been extensively studied. However the results obtained in cattle regarding the genetic correlation between SCC and other milk traits are not coincident (Banos and Shook, 1990; Schutz et al., 1990). Estimations obtained in Churra sheep for the genetic and phenotypic correlations among lactation SCC, milk yield and milk protein percentage are shown in Table 9 (El-Saied et al., 1999). The low genetic correlations between SCC and milk yield as well as between SCC and milk protein percentage, indicate that a selection program to increase milk yield and protein percentage is not expected to result in a genetic change in SCC under the conditions in Churra sheep. The negative correlations found between SCC and milk production have also been found in other investigations in cattle (Ng-Kawi-Hang et al., 1984; Emanuelson et al., 1988) and sheep (Gonzalo et al., 1994; Lagriffoul et al., 1994; Fuertes et al., 1998).

Table 9. Genetic correlations (below diagonal) and phenotypic correlations (above diagonal) among lactation variables

	Milk yield	Log SCC	Protein percentage
Milk yield		-0.16	-0.26
Log SCC	-0.15		0.12
Protein percentage	-0.47	0.03	

In view of the relatively low heritability and the moderate repeatability values of SCC, the inclusion of repeated records seems advisable in order to increase the accuracy of prediction of genetic values in the same way as it is used in cattle (Da et al., 1992; Zhang et al., 1994). An Animal Model with repeatability seems particularly interesting in sheep due to the reduced number of daughters per ram.

It is not possible for the moment to establish a relationship between SCC and genetic resistance to mastitis. Further investigations are required in order to clarify this relationship. However from the results obtained till the present moment SCC heritability seems to be low indicating a great environmental influence and thus response to selection will not be high.

Other Criteria

Feed Efficiency

Cost of feed represents a major expense for most dairy sheep production. In sheep dairy breeding programs, economic gain will be only obtained if an increase in milk yield maintains or increases feed efficiency. The verification of this point was carried out in an investigation performed in Lacaune sheep which results indicated that dairy breeding based only on an increase in milk income appeared as fully acceptable regarding indirect responses in feed efficiency (Marie et al., 1996). This experiment involved a divergent selection on milk dry matter yield (fat + protein) and ad libitum feeding. After four years of experiment the high line´s ewes produced, 22% more milk compared to the low line, without increase in body weight, ingested 7% more feed and targeted more adequately their body reserves towards milk production. Thus Gross Efficiency was improved (0.36 *vs* 0.31). These results indicate that an increase of individual milk yield will be followed by a progress in the economic margin per animal (Barillet et al., 2001).

Disease Resistance

Animal diseases represent a major cost to sheep producers, through production losses and the direct costs of treatment and control. The danger of relying entirely on antibiotics or chemicals was foreseen in the early 1970s, and scientists set about determining the potential for genetic selection of the sheep host to reduce the susceptibility to diseases. A clear understanding of disease and the animal’s defense systems is required for alternative approaches to disease control (Hill, 1999). The onset of disease is often the result of the interaction between an individual animal’s genotype and the environment to which the animal is exposed. If an animal has a genetic predisposition for acquiring a disease, then environmental conditions, including standard disease-prevention methods may be only partly effective in preventing disease. An often-overlooked alternative approach to standard disease control methods would be selective breeding to increase disease resistance in livestock.

Genetic resistance to disease involves many facets of the body's defense system and their interactions and is extremely complex. However there are two cases where the selection has done first results in bacterial diseases as footrot (Raasda, 2000), parasite resistance (Crawford et al., 1997; Coltman et al., 2001). As indicated above there are many investigations about mastitis resistance and SCC as selection criteria in dairy sheep. In the next years further clarifying results will elucidate this situation.

Particularly interesting regarding genetic resistance is scrapie an infectious disease of sheep in which the infectious particle appears to be a particular form (scrapie prion) of a protein molecule found in normal, healthy sheep (prion protein). Current experimental evidence strongly suggests that there are prion protein forms that do not undergo the structural transformation to scrapie prions. These prion proteins differ from those that easily convert to become scrapie prions by single amino acid substitutions. For example, an arginine (R) at amino acid 171 of the prion protein appears to prevent the prion molecule from undergoing the structural change associated with strain C scrapie. In a similar manner, an alanine (A) at amino acid 136 appears to prevent the prion molecule from undergoing the structural change associated with strain A scrapie. Analysis at DNA level can easily determine the resistant/susceptible status of an animal (Hunter, 2000). This knowledge makes entirely possible introducing in a breeding program selection of animals for resistance to spongiform encephalopathy, so that in several generations scrapie can be eliminated from the population (Hunter, 2000). There are many dairy breeds that are starting a genotyping program of elite rams and in the next years, only resistant animals will be eligible as AI sires.

In the next future with the help of molecular techniques, results in this area will be very important in sheep breeding. The improvement of farm animals by selective breeding is a highly effective and sustainable means of improving livestock. Genetic change is cumulative and permanent, so that an improvement gained is maintained without further input. New genetic gain also builds upon past improvement.

New Developments in Reproductive Techniques

Reproductive technologies are of high importance given the constraints of reproductive abilities in any animal breeding schemes.

It is difficult to evaluate the future developments of reproductive technologies in animal breeding programs, but recent advances such as fiber optics and *in vitro* technologies offer new approaches for animal breeding and can assist in addressing problems of infertility or reduced fertility in humans. Modern reproductive technologies include artificial insemination, semen freezing and sexing, embryo transfer and embryo micromanipulation. Furthermore, these techniques have been applied to produce animals that incorporate new genes, which are beneficial to agriculture and to animal and human health. Reproductive technology is a complex item and we will describe here some milestones that can improve animal breeding in the next future.

Improved AI technique

Artificial insemination (AI) is a powerful tool in animal breeding programs, providing a means to obtain rapid genetic progress. AI is widely used in dairy sheep and either fresh or frozen semen can be used to inseminate ewes. In the past, the results obtained using frozen semen were unsatisfactory, especially when the semen was deposited outside the uterus, but through the use of improved diluents, pregnancy rates with frozen semen seem to approximate to those achieved with fresh semen. AI fecundity rate in sheep is lower than in cattle and conception rates of 55-60% are common in most sheep breeds. Recently several scientific advances have begun to put AI within reach of the sheep producer.

The main value of laparoscopy for AI in ewes is that it provides a method for depositing semen directly into the uterus. By doing so it reduces failure of fertilization, which previously occurred after the conventional insemination of frozen/thawed semen in those ewes involved in 'sire reference' breeding schemes. Another aspect that will improve using laparoscopic techniques is embryo recovery and transfer in MOET breeding programs. Indeed, the laparoscopic techniques that were developed in the 1980's are still regarded as a major advance towards a more welfare friendly approach for implementing genetic improvement programs.

One of the mayor problems in artificial insemination is the semen transcervical application. Due to the tightly interlocking nature of the cervix, the access to the uterus via its natural entry point is extremely difficult in the ewe. This is the reason for ignoring it as a uterine entry point and resorting to laparoscopy for direct intrauterine insemination in order to ensure fertilization with frozen/thawed semen or embryo recovering (Robinson et al., 1999). In this regard, observations that there is large between-ewe variation in the occurrence and strength of the cervical response is particularly interesting; it may explain why conception, following cervical insemination, occurs with apparent ease in some ewes but not others. The challenge in this point is to know which factors are controlling this cervix behavior.

Sorted Semen for Production of Lambs of Pre-determined Sex

Research on flow cytometry of sperm for the purpose of predetermining gender of offspring has led to a validated method to separate X from Y chromosome-bearing spermatozoa for use with *in vitro* fertilization and embryo transfer, intratubal insemination or intracytoplasmic sperm injection (Johnson, 1995). Recent experiments have demonstrated that normal lambs can be obtained in vivo following laparoscopic deposition of 100,000 sex sorted spermatozoa in the tip of each two horns of the uterus (Robinson et al., 1999). One of the limiting factors is the capacity of sorting spermatozoa using this technique but the rapid increase already achieved in the speed of sorting sperm suggests that the use of sexed semen in sheep will probably become a commercial reality in the near future.

Cloning

Cloning technology has advanced very rapidly offering exciting opportunities for the improvement of efficiency and sustainability of livestock production (Robl, 1999). The main uses of cloning in animal breeding would be acceleration of genetic progress and rare animal conservation. Genetic progress is dependent on the exploitation of genetic variation and cloning would only have a limited use within breeding programs. Then the main advantage of cloning would be based on the rapid dissemination of genetic progress from elite herds towards the commercial farmer (Wooliams, 1997). Furthermore, cloning techniques will provide new methods for genetic conservation of indigenous breeds that are in an endangered situation under the threat of imported breeds that are being reared in intensive farming systems.

Different variables may affect the work effort required and the probability to produce a clone. Although sheep was the first mammal cloned from an adult cell, no additional sheep have been reported as a result of nuclear transfer using adult cell nuclei. The reason for this is unclear but perhaps is due simply to the focus of most sheep work being on the production of transgenic animals and using fetal cell lines rather than adult cell lines (Westhusin et al., 2001). The efficiency of cloning sheep is similar to other species in terms of cloned embryo production and live offspring produced per embryo transferred (Colman, 2000; Wilmut et al., 1997) and cloning best animals to improve the efficiency of production in sheep will undoubtedly be explored in the near future.

Utilising the Reproductive Potential of Females

Females in livestock species have a reproductive potential greatly in excess of that exploited by natural mating. This is due to two particular features: (1) the presence of a relatively large number of primordial follicles in ovaries and (2) ovarian follicular growth is initiated soon after birth which allows the recovery of viable gametes (oocytes) from females before the puberty. The latter has become the singular outstanding advantage of females compared with males in genetic improvement in species with a long generation interval. Techniques as oocyte pick-up by laparotomy with subsequent in vitro fertilization could be used to increase the production of ewes with high genetic potential and to decrease the generation interval (Kuhholzer et al., 1997; O'Brien et al., 1997; Stangl et al., 1999). The ability to produce embryos in vitro provides the opportunity to apply other technologies such as embryo splitting, embryo sexing, pre-implantation genetic diagnosis etc. Furthermore, with the emergence of genetic markers that will elucidate the molecular basis of economic traits in livestock, it will be possible, in a near future, a genetic selection at an embryo stage and before the investment in pregnancy.

Molecular Tools in Sheep Breeding

Since domestication began, sheep farmers have been manipulating livestock genes through selective breeding. This artificial selection of animals exhibiting desired properties has produced an unwittingly sorting of alleles underlying phenotypes of interest. It is known that most production traits undergoing selection are quantitative traits, that is, they exhibit a continuous distribution and are influenced both by environmental and genetic factors. The genotypic component reflects the joint contribution of multiple "polygenes". Using the quantitative genetics theory, breeders have modeled the animal phenotype as the sum of genetic and environmental components allowing for an increase in most of animal products. This progress in animal performance acts on polygenes without any knowledge about their identity or mode of action.

The advent of DNA molecular technologies specifically PCR and the appearance of microsatellites as an abundant source of highly polymorphic markers has boosted the generation of linkage maps in sheep and other livestock species (Beattie, 1994; Crawford et al., 1995;de Gortari et al., 1998; Maddox et al., 2001). The availability of these genetic maps jointly with other genomic resources (segregating populations, large insert libraries, radiation hybrid maps, comparative maps, preliminary transcript maps, etc.) has opened the possibility to map by linkage analysis and identify by positional cloning economic trait loci in livestock.

Milk production, as the majority of economically relevant production traits shows a continuous distribution and as mentioned above, is controlled by an unknown number of genes and influenced by environmental factors. A Quantitative Trait Locus (QTL) is defined as a region in the genome that harbors one or more genes affecting a quantitative trait.

Identifying major genes or QTL related to economically important traits and selecting animals based on genotype is an efficient tool to improve livestock production and product quality. There are two main strategies designed to identify the genes underlying complex traits, as are milk related traits; the linkage analysis in a whole genome scan and the association test using candidate genes. These two strategies, which are described below, are now in their first steps in dairy sheep breeding, but they will most probably be applied in deep in the near future.

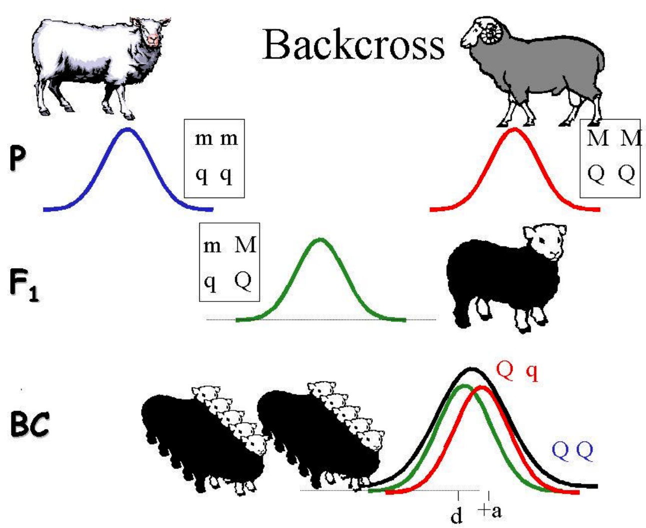
QTL Detection in Dairy Sheep Using a Whole Genome Scan

This procedure is based on linkage mapping using genetic markers and segregating families. A genetic marker is any polymorphic sequence, whose alleles can be distinguished from each other, microsatellites being the most widely used markers in linkage studies. As QTLs could be located anywhere, markers should be spread over the entire genome, so that at least 150 to 250 evenly spaced markers are required for a complete low-density genome scan. Segregating families can be experimental crosses or outbred families.

Experimental Crosses

To map the genes underlying a specific phenotype an experimental cross is performed, by mating divergent parental lines and using the resulting F_1 individuals to generate a large segregating F_2 or a backcross population. The F1 animals show a high heterozygosity at marker loci and, in particular, at those loci that account for phenotypic differences between the two populations. This approach is used to identify the genes contributing to the differences observed for phenotypic traits between two different breeds or divergent selected strains of a breed. This strategy has been extensively used in pigs and cattle (Andersson et al., 1994; Brenneman et al., 1996). In sheep we can cite experimental crosses for detecting complex traits, for example between selected divergent lines for parasite resistance in New Zealand populations (Crawford et al., 1997) or between Lacaune and Sarda breeds for milk production traits. An illustration of a backcross is shown in figure 3.

Figure 3. Intercrosses between divergent populations. Example of a backcross between two divergent sheep breeds



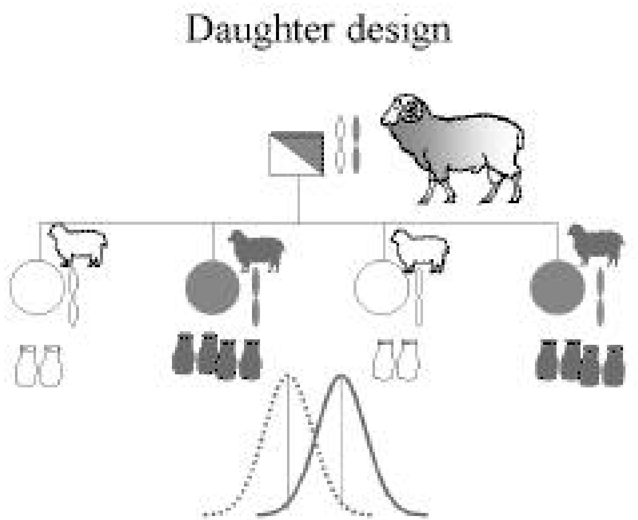
This approach offers several advantages. The cross between phenotypically divergent lines will presumably generate an important allele substitution effect in F2 or backcross populations and the

Outbred Population

The objective in this case is to map the QTL that are underlying the genetic variance observed for traits in a commercial population. These studies profit from two specific features of dairy livestock populations: (1) the development of artificial insemination and semen preservation has made large half-sib families with a common antecessor available. (2) The existence of breeding programs allow for the use of production values corrected for the environmental factors rather than individual production records, the former values showing less complexity due to the reduction of non-genetic noise. Two main schemes, the “daugther design” and the “grand-daughter design” are used for this purpose (Weller et al., 1990).

In the “daughter design” a single sire can have hundreds of descendants with records on different quantitative traits (figure 4). The daughters of a sire heterozygous for a marker are genotyped for a marker and recorded for the quantitative traits. If alternative groups of daughters, sorted by marker allele, shows differences in the quantitative traits indicate a linkage between the marker and a QTL underlying genetic variation on the trait. The use of genetic markers spanning whole genome (genome scan) will indicate the traits segregating for quantitative traits in one family, analysis of a number of families will provide useful information about the genetic variability on a trait in a breed.

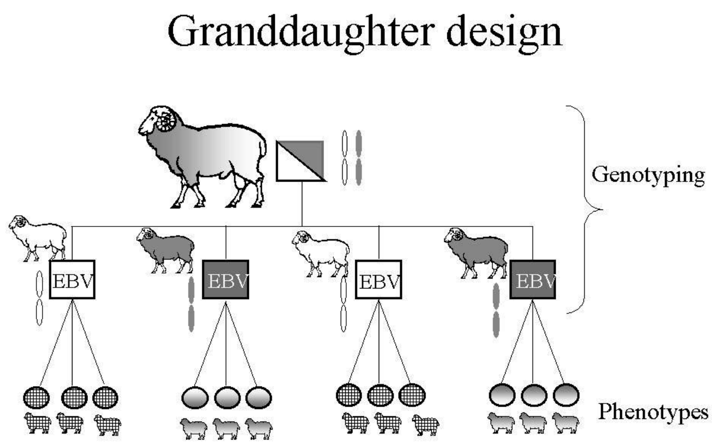
Figure 4. Half-sib families and QTL mapping. Illustration of a daugther design



An alternative analysis is the so-called granddaughter design. In the ‘granddaughter design’ (Weller et al, 1990), the basic idea is to reduce the residual variability of performance. Here the trait is not measured directly on the progeny but it is estimated as the mean performance of granddaughters. The design involves 3 generations as is shown in figure 5. Only generations 1 and 2 are genotyped, whereas performances are measured only at generation 3. For a similar detection power, the number of marker genotypes here is usually threefold lower than in a ‘daughter design’.

Daughter and granddaughter designs have been used mainly in dairy cattle with excellent results (Georges et al., 1995; Coppieters et al., 1998; Ron et al., 2001). In dairy sheep these investigations show larger limitations when compared with dairy cattle. The different production systems applied in each local breed imply lower population sizes with relatively recent implantation of selection schemes. These circumstances does not permit, in most of the cases, a granddaughter design, and the limited size of half-sib families in a daughter design results in a low statistical power of the study. However, many experiments are currently being undertaken searching for QTL in dairy sheep and first results have already been reported (Diez-Tascón et al., 2001).

Figure 5. Half-sib families and QTL mapping. Illustration of a granddaughter design



A genome scan will always find the map location of a trait locus with a major effect, provided that an accurate genetic model has been postulated, a reasonable sample size has been used and that the marker set provides full genome coverage. However, a genome scan will fail to detect trait loci with smaller effects if they do not reach the stringent significance thresholds that must be applied when performing a large number of tests in a full genome scan.

Candidate Gene Approach

Candidate genes are genes that play a role in the development or physiology of a trait of economic importance. The candidate gene approach proposes that a significant proportion of quantitative genetic variation of a given trait is contributed by segregation of functional alleles of one or more of the candidate genes for the trait (Bryne and McMullen, 1996; Rothschild and Soller, 1997). At the DNA level, a candidate gene comprises a contiguous tract of DNA, including introns, exons and upstream and downstream regulatory regions concerned with biosynthesis of a single protein or via alternative processing to produce related proteins. Allelic variation at a candidate gene sequence can cause a change in protein production or efficiency in a metabolic process that will influence a specific trait.

The candidate gene approach can be very powerful and can detect loci even with small effects, provided that the candidate gene represents a true causative gene. However, there are often many candidate genes for the trait of interest and it may be more time-consuming to evaluate all of these than performing a genome scan. Furthermore, the candidate gene approach might fail to identify a major trait locus simply because of the gaps in our knowledge about gene function. Candidate gene tests must also be interpreted with caution because spurious results can occur because of linkage disequilibrium to linked or non-linked causative genes or because the significance thresholds have not been adjusted properly when testing multiple candidate genes.

Once the chromosomal location of a trait locus has been determined, this information can be applied in breeding programs by using Marker-Assisted Selection. However, the ultimate goal when mapping trait loci is the identification of the causative genes and causative mutations. Positional candidate cloning will continue to be the main strategy for this purpose. Positional candidate cloning in farm animals often relies heavily on the exploitation of comparative data and will become even more powerful with the completion of the human map and the generation of informative databases on gene function and gene expression patterns.

First successes of these tools dealt with single gene traits. Many loci controlling monogenic traits have been detected in sheep. Table 10 lists some examples of genes that have been positioned on ovine gene map using linkage strategies and in some cases identified by positional cloning

Table 10. Monogenic traits mapped in sheep through genomic strategies

Locus	Trait	Position	Gene	Reference
FecX	Inverdale fecundity gene	OAR X	*BMP15*	Galloway et al. (2000)
FecB	Booroola fecundity	OAR 6	*BMPR1B*	Mulsant et al. (2001) Wilson et al. (2001) Souza et al. (2001)
FecX2	Woodlands fecundity gene	OAR X	?	Davis et al. (2001)
CLPG	Callipyge	OAR 18	?	Cockett et al. (1996) Charlier et al. (2001)
Spider	Spider Lamb syndrome	OAR 6	*FGFR3*	Cockett et al. (1999)
Horns	Pesence/Absence of Horns	OAR 10	?	Montgomery et al. (1996)
Agouti	Black wool color	OAR 13	?	Parsons et al. (1999)

In the near future results of QTL detection programs, that are underway, will arise and sheep breeding programs will follow the way marked by other species as pigs and cattle. In these species, several breeding companies are currently using marker-assisted selection with markers flanking QTL as a complement to phenotypic selection of breeding animals. It is likely that sheep breeding programs will be influenced by molecular techniques when QTL mapping results can provide useful information about the genes controlling milk production.

Using Molecular Techniques in Traceability of Sheep Products

Individuals differ from each other at different biological levels. At the most basic level, the deoxyribonucleic acid (DNA) of each animal is different. DNA-based markers as microsatellites or SNP (single nucleotide polymorphisms), are currently used in many livestock genome mapping projects as well as in commercial parentage tests. The potential of DNA fingerprints to accurately identify a particular animal will permit product traceability from the animal retail case to the genetic source. A DNA test identifies the genetic make up of each animal which is unique to each animal and it works like a genetic 'fingerprint' (Fries and Durstewitz, 2001).

The advantages of traceability are enhanced integrity and food safety of the sheep product. The traceability tests, along with drug residue tests and DNA based diagnostics for food born and infectious pathogens enhances quality control for hog finishing operations and meat processors. The traceability tests using markers linked to economic trait loci on the terminal cross animals also provides a quality control step for breeding companies utilizing genetic markers in selection programs.

The end result is that a complaint from a supermarket or customer buying a lamb roast can be traced the whole way back to the farm. The system could be based on the farmer supplying a sample of hair from the lamb when it is registered. As DNA is found in all tissues, the product (lamb) can act as its own label. This hair will then be held in the DNA bank for two months after the animal is killed and it will be used for traceability if requested.

In the case of cheese the problem is different and individual traceability is not possible. However there are many projects devoted to the assignment of a product to a specific breed. This aspect could be very useful for products with appellation of origin and for this purpose a combination of microsatellite markers can be used (Arranz et al., 2001). Moreover breed-specific markers such as mitochondrial haplotypes or a combination of breed-specific SNPs are being evaluated for this goal. For this purpose more powerful statistical tools should be developed mainly in Bayesian or Artificial Intelligence frameworks.

Final remark

As a general conclusion from the present paper we may indicate that most dairy sheep breeding programs which are currently being undertaken are based on milk yield criteria, and no or little advantage is taken from other tools which could improve breeding programs efficiency. Certain strategies described here are already available for their practical utilization. This is the case, for example, of recent innovations in reproductive techniques. For their part, among the selection parameters we can point out milk composition traits, udder morphology and somatic cell count (SCC), which are already considered among the selection criteria in a few sheep breeds, situation that most probably will be made extensive to the rest of breeds. Genetic resistance to pathological processes is probably one the most promising areas of investigation. Until now it has led to important findings only in a few cases, among which we can cite “scrapie”, allowing for a selection of favorable genotypes. Other aspects approached in this paper, such as molecular tools, need to be deeply explored before they can be used in practice, but presumably further investigations will make their application possible in a near future. Finally we should remark that besides the economic benefit, all these advancements will facilitate management procedures and this will undoubtedly result in an amelioration of sheep farmers livelihood.

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IS MACHINE STRIPPING NECESSARY FOR EAST FRIESIAN DAIRY EWES?

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Abstract

Due to the large cisternal storage capacity and non-vertical teat placement in most dairy ewes, machine stripping is commonly performed to remove milk not obtained by the machine. However, stripping requires individual manual intervention, lengthens the milking routine, and could inadvertently lead to overmilking of other ewes in the parlor. The objective of the present experiment was to estimate the effect of omission of machine stripping on milk production and parlor throughput. Forty-eight multiparous East Friesian-crossbred ewes, which had been machine milked and stripped twice daily from d 0 to 79 of lactation, were blocked on percentage of stripped milk (relative to total milk: ≤ 15% or > 15%), and randomly assigned to two stripping treatments: normal stripping (S, n = 24), or no stripping (NS, n = 24) for the remainder of lactation. NS ewes yielded 14% less (105.6 ± 4.8 vs. 122.7 ± 4.8 kg, respectively) commercial milk during the experiment, but had similar lactation length, milk composition, and somatic cell count compared to S ewes. Block × treatment interaction was non-significant for all traits. Average machine milk yield (amount of milk obtained without manual intervention) was greater for NS ewes compared to S ewes (0.68 ± 0.02 vs. 0.63 ± 0.02 kg/milking, respectively), but the difference was not statistically significant. Average machine-on time for S ewes was longer than for NS ewes (89.1 ± 2.4 vs. 78.7 ± 2.4 s, respectively) because of stripping, which may have resulted in overmilking of many ewes in the S group. These results collectively suggest that residual milk left in the udder as a result of omission of machine stripping does not negatively influence lactation length or milk quality. Moreover, overmilking is avoided and parlor throughput is improved when machine stripping is not practiced. The loss in milk yield can be compensated for by the addition of more ewes to the milking flock.

Introduction

One of the most important goals of mechanized milking is to obtain the maximum amount of milk that is rich in total solids, in the shortest amount of time without manual intervention. Therefore, the use of machine and/or hand stripping is not common in dairy cattle, nor is it practiced in dairy ewes in the Roquefort region of France with the Lacaune, where the greatest percentage of dairy ewes are machine milked in the world (Barillet and Bocquier, 1993). Conversely, at present, machine stripping still remains part of the normal milking routine for most sheep dairies in the United States and Canada, where primarily the East Friesian and its crossbreeds are being milked. The North American dairy sheep industry is in its infancy, and as a result, adequate research on simplification of the milking routine and its economic ramifications has not yet been undertaken.

Cisternal storage volume in dairy ewes is large, comprising between 40 and 60% of the total milk volume after a normal 12 h milking interval (Marnet and McKusick, 2001). While this can be of benefit to milk secretion because the concentration of feedback inhibitors of lactation stored within the alveoli is reduced (Davis et al., 1998), larger cisterns are correlated with higher teat placement in dairy ewes (Fernández et al., 1995) which lengthens individual machine-on time (Fernández et al., 1997; Jatsch and Sagi, 1979), and requires the udder to be lifted during milking to remove milk trapped below the level of the exit of the teat canal (Jatsch and Sagi, 1979; Labussière, 1988). Therefore, machine and/or hand stripping is often practiced during machine milking of ewes to improve total milk yield and to avoid leaving large quantities of residual milk in the udder. However, stripping increases parlor throughput time (Billon, 1998; Ricordeau et al., 1963) and requires more labor investment (Le Du, 1984). Finally, because the milking technician is required to give individual attention to each ewe during stripping, other ewes that are concurrently being milked could inadvertently be at risk for overmilking if the number of technicians in the parlor is not sufficient. Overmilking has been shown to cause teat-end damage (Peterson, 1964) and can predispose animals to intramammary infection (Mein et al., 1986).

Depending on breed, udder conformation, stage of lactation, parity, and machine vacuum level, the percentage of total milk obtained during machine stripping in dairy ewes generally ranges between 10 and 30% (Labussière, 1984), and can sometimes be as high as 60% (Sagi and Morag, 1974). Stripping volume may also depend on milk ejection because oxytocin concentrations have been shown to rise in response to stripping (Bruckmaier et al., 1997). Therefore some ewes could be habituated to manual massage for milk letdown, which makes stripping obligatory for complete milk removal. There exist no reports on whether or not this habituation could be overcome by omitting machine stripping. Evaluations of the effect of omission of machine and/or hand stripping on milk production have been conducted with dairy sheep breeds such as the Lacaune, Sarda, and Manchega, however results of these data are generally published in French or Spanish (Bosc et al., 1967; Labussière et al., 1984; Molina et al., 1991; Ricordeau and Labussière, 1968), making it difficult for the North American scientific community and dairy sheep farmers to access this information.

The objectives of the present experiment were to compare the effect of stripping or omission of stripping, for dairy ewes with initially low or high stripping percentage, on milk production, milk composition, and lactation length during mid- to late-lactation. A secondary objective was to utilize the results of the present experiment to estimate the economic impact that stripping or omission of stripping, with one or two milking technicians, would have on parlor throughput and incidence of overmilking. Our hypothesis is that the milking routine for the East Friesian, a breed with notable cisternal storage capacity yet adequate teat placement for machine milking, could be simplified by the omission of machine stripping and at the same time, improvements would be made in parlor throughput and incidence of overmilking. Furthermore, we hypothesize that the amount of milk obtained by the machine without or prior to stripping would be greater for ewes that had adapted to a milking routine without manual udder massage.

Materials and methods

Experimental Design. Forty-eight multiparous East Friesian-crossbred dairy ewes were studied from d 80 to the end of lactation at the Spooner Agricultural Research Station of the University of Wisconsin-Madison during the summer of 2000. Ewes with symmetrical udders, similar average milk production (2.25 ± 0.43 kg/d) and stage of lactation (79 ± 10 d) were chosen from the main dairy flock of 350 ewes that are machine milked and machine stripped twice daily. All ewes in the experiment had been weaned from their lambs at approximately 24 h post-partum. On two consecutive days during the week prior to the experiment, udder morphology traits and individual morning milk production (machine milk and machine stripped milk) were measured. Average udder circumference, cistern height, teat placement score, and stripping percentage were 44.9 ± 3.5 cm, 2.54 ± .97 cm, and 5.55 ± 1.65 (scale of 1 to 9, 1 = horizontal, 5 = 45º, 9 = vertical), and 15.8 ± 7.3 %, respectively. Ewes were blocked into two groups on their average percentage of stripped milk (≤ 15% or > 15%), and randomly assigned to two stripping treatments for the remainder of lactation: normal stripping (S, n = 24), or no stripping (NS, n = 24). Treatment groups were housed separately in two neighboring pens and fed a 16% crude protein concentrate and alfalfa hay.

Data Collection. Machine milking took place at 0600 and 1800 in a 2 x 12 high-line Casse system milking parlor with 6 milking units and two milking technicians. The milking machine (Alfa Laval Agri Inc., Kansas City, USA) was set to provide 180 pulsations per minute in a 50:50 ratio with a vacuum level of 36 kPa. Individual ewe milk production (machine milk and stripped milk), milking time, and milk flow emission kinetics were recorded during a morning milking every 20 d with milk collection jars and a data logger designed for recording milk flow (Le Du and Dano, 1984). For S ewes, stripping commenced within 5 s after the cessation of machine milk flow (< 100 ml/min) and stripping ended when the milking technician deemed it necessary to remove the teat cups; both times were noted electronically with a data logger. Machine stripping was performed by the same milking technician by first lifting the udder at the intramammary groove while applying gentle downward traction to the teat cups, and then by brief manual massage of both udder halves to remove the remaining milk. Machine milk yield and time, and stripping yield and time were calculated from the milk flow data recorded by the data logger. Additionally, milk production was recorded and milk samples were collected monthly throughout the entire lactation. Milk composition analyses for percentage of fat and protein, and Fossomatic somatic cell count (SCC) were performed by a State of Wisconsin certified laboratory. An estimation of milk production and percentages of milk fat and protein within a lactation period were calculated according to Thomas et al. (2000). Somatic cell count was transformed to logarithms of base ten. Ewes were removed from the experiment and dried-off when their daily milk production on a test day fell below 0.4 kg/d.

Throughput Simulation. Parlor throughput time, milking efficiency, frequency of overmilking, and economic returns for the two treatments were estimated from a simulated milking system where ewes were milked in groups of 12 ewes in a 1 x 12 Casse system parlor with 6 milking units and one or two milking technicians. Fixed times, which had been measured previously in this flock for a group of 12 ewes, included: parlor entry time (45 s), parlor exit time (includes teat-dipping, 30 s), and the time to remove the teat cups and replace them on a neighboring ewe (7 s/ewe). All fixed times are in agreement with those cited for Lacaune dairy ewes (Le Du, 1984). Milking procedure time for a group of 12 ewes was calculated by simulation using the results from the present experiment for individual S and NS ewes, respectively: machine milking time (72 and 79 s), stripping time (18 and 0 s), and machine-on time (90 and 79 s) (see Table 2). Ewes in the simulation were numbered 1 through 12 as they would in order in the stanchions. With one milking technician, teat cups would be placed in order on ewes 1, 3, 5, 7, 9, and 11, followed by removal no earlier than the average milking time, and then placement in order on ewes 2, 4, 6, 8, 10, and 12. With two milking technicians, the first technician would place teat cups on ewes 1, 3, and 5 followed by placement on ewes 2,4, and 6. Simultaneously, the second technician would place teat cups on ewes 7, 9, and 11 followed by placement on ewes 8, 10, and 12. Overmilking of an individual ewe was noted when the machine-on time exceeded that of the average milking time. Milk was sold for $1.32/kg. Additional labor and expenses, relative to the S system and one milking technician, included $9.00/hr for labor and $0.37/ewe per milking for ewe purchase price, management, and feed costs (Berger, 1998).

Statistical Analyses. Pre-experimental, experimental, and total lactation data for lactation traits (Table 1) and machine milking and stripping traits (Table 2) were analyzed separately. Reports on parlor throughput, economic returns, and frequency of overmilking were not analyzed statistically and are only provided to give the reader a reasonable estimation from a hypothetical simulation. Least squares means analysis of variance was conducted with the general linear models procedure of SAS (1999). The experimental design was a split plot on time for the measurements taken every 20 d during the morning milking. The model included the main plot effects of: block (pre-experimental stripping percentage: ≤ 15% or > 15%), treatment (NS or S), block × treatment, and ewe within block × treatment, and the sub-plot effects of: time (d-100, 120, 140, and 160), two-way interactions with time, and residual error. Least squares means for treatment, block, and block × treatment were tested against ewe within block × treatment as the error term; time and all interactions with time were tested against residual error. All lactation trait data (Table 1) and the pre-experimental machine milking and stripping data were analyzed with the following model: block (pre-experimental stripping percentage: ≤ 15% or > 15%), treatment (S or NS), and the two-way interaction. Pre-experimental SCC and percentage of milk fat were used as a continuous covariable in the analyses of SCC and percentage of milk fat, respectively, during the experimental period and for the entire lactation.

Results

Milk Production. Lactation trait data are summarized in Table 1 and Figure 1. Milk yield for NS ewes during the experimental period was 14% less (-17.1 kg, $P < 0.01$) compared to S ewes, however, overall lactation yields were not statistically different (Table 1). Average daily milk yield (Figure 1) for S ewes was consistently higher ($P < 0.05$), compared to NS ewes, through d 140 during the experimental period. Both treatment groups lactated for a similar number of days (182.5 d) and had similar overall milk protein content (4.78 %, Table 1). After correcting for slight differences in percentage of milk fat and SCC during the pre-experimental period, milk fat content and SCC were not different between treatment groups for the entire lactation (5.58 % milk fat and 4.77 log units, respectively, Table 1). Block × treatment interaction was not significant for any lactation trait.

Machine milk yield (the amount of milk obtained without or prior to stripping) was higher for NS ewes than for S ewes at all test days during the experimental period (Figure 1), however, only the difference at 120 d of lactation was statistically significant, and the average superiority of the NS ewes over the S ewes for machine milk yield (Table 2) during the experimental period (0.68 vs. 0.63 kg/milking, respectively) was not statistically significant. Total morning milk yield was lower ($P < 0.01$) for NS ewes compared to S ewes (0.68 vs. 0.80 kg, respectively), of which machine stripped milk accounted for 23.6 % of the total milk volume for the latter (Table 2). Machine milking time (the time to obtain machine milk) was not different between treatment groups, however, total machine-on time tended to be longer ($P < 0.10$) for S ewes compared to NS ewes (89.1 vs. 78.7 s, respectively, Table 2). Block × treatment interaction was not significant for any machine milk or stripping trait. Machine milk emission kinetics (milk flow latency, maximum milk flow rate, average milk flow rate) were not different between treatment groups at any stage of lactation (data not shown).

Parlor Throughput. Estimations of parlor throughput, milk production, relative economic returns, and frequency of overmilking are presented in Table 3 from a simulation for S and NS ewes milked with one or two milking technicians. Parlor throughput was lowest when stripping was performed with only one milking technician (103 ewes/hr), and increased with the addition of one milking technician (138 ewes/hr) or when stripping was not performed by either one or two milking technicians (153 and 166 ewes/hr, respectively). Collectively, parlor throughput and milking efficiency increased by 31 and 13%, respectively, when stripping was omitted compared to when stripping was performed. Relative receipts generated per hour were lowest for S ewes with one milking technician ($108.77) and highest for S ewes with two milking technicians ($123.78) compared to NS ewes with either one or two milking technicians ($118.78 and $116.72, respectively). Some degree of overmilking of S ewes always occurred regardless of number of technicians (11 of 12 ewes and 4 of 12 ewes for one and two milking technicians, respectively). Overmilking never occurred for NS ewes, even with only one milking technician.

Discussion

Milk Production. We have shown that when machine stripping is omitted from the milking routine during mid-lactation in East Friesian-crossbred dairy ewes, total commercial milk available for marketing is approximately 14% less per ewe than when machine stripping is practiced. This is in agreement with the 12 to 16% reduction reported for dairy ewes (Bosc et al., 1967; Labussière et al., 1984; Ricordeau and Labussière, 1968) and the 5 to 15% reduction reported for dairy cows (Ebendorff et al., 1990). However, omission of machine stripping did not reduce lactation length or deleteriously affect milk composition or milk quality, which has previously been a concern in dairy ewes (Bosc et al., 1967) and dairy cows (Ebendorff et al., 1987). Moreover, failure to demonstrate a significant block × treatment interaction for any lactation trait demonstrates that the loss in milk production is similar for ewes with low or high initial stripping percentage when stripping is omitted from the milking routine.

The East Friesian has been classified as a breed with large cisternal storage capacity (Bruckmaier et al., 1997; McKusick et al., 1999), which enables the udder to more effectively store milk between milkings (Knight and Dewhurst, 1994). A possible advantage of large cisternal storage capacity is that a higher proportion of the milk could be stored away from the alveoli, thereby reducing the concentration of feedback inhibitors of lactation (Davis et al., 1998) as well as alveolar pressure due to overdistention (Labussière, 1988). One disadvantage for dairy ewes with large cisternal storage capacity is that machine stripping would be obligatory because the machine milk fraction decreases and the stripping fraction increases as the udder halves become less differentiated and teat placement is more horizontal (Sagi and Morag, 1974). This does not seem to be the case in the present experiment because the correlations between stripping percentage and external measurements of the cistern (distance between the exit of the teat canal and the bottom of the udder) or a subjective score for teat placement, were non-significant (data not shown).

Milk composition was not affected by omission of machine stripping in the present experiment. Failure to demonstrate differences in milk composition, particularly in milk fat, implies that an adequate milk ejection reflex was present even though machine stripping was not practiced. The great majority of milk fat is stored within the alveoli between milkings (Labussière,

1988) and active expulsion of fat from the alveoli to the cistern (milk ejection) is required for complete milk fat removal during machine milking of dairy ewes (McKusick et al., 2001). Additionally, the fact that machine milk yield increased (although non-significantly) when stripping was omitted from the milking routine may suggest that some ewes had been habituated to manual massage during at least part of the milk removal process; omission of stripping may have resulted in dishabituation of these ewes to hand contact for milk ejection. These observations are further supported by the fact that lactation lengths were similar for both treatment groups because decreased lactation persistency would be expected if ewes had retained milk in the alveoli as a result of failed milk ejection. Bruckmaier et al. (1997) found that for Lacaune ewes, oxytocin concentrations peaked at 1 min during machine milking and also during machine stripping, however, for East Friesian ewes, oxytocin increased above baseline levels only during machine stripping. They conclude that East Friesian ewes are more dependent on manual stimulation of the udder for complete milk removal than Lacaune ewes. The findings of the present experiment disagree with those of Bruckmaier et al. (1997) because neither a decrease in milk fat content nor in lactation length was observed when manual stimulation was not practiced during milking. It appears that East Friesian crossbred ewes are well adapted to machine milking and that milk ejection and milk synthesis are not compromised by omission of stripping.

Even though machine stripping for S ewes required 17.5 s/ewe of individual manual attention from the milking technician, overall machine-on time increased by only 10 s/ewe compared to NS ewes. This is probably due to the increase in machine milk yield, and therefore machine milking time, for NS ewes compared to S ewes. The average volume of milk obtained by machine stripping for S ewes corresponded to 0.18 kg or 23% of the total milk volume, which is consistent with other reports on dairy ewes (Labussière, 1984). Stripping volume remains constant from mid-lactation to the end of lactation in dairy ewes, however stripping percentage increases as lactation progresses (Ricordeau et al., 1963; Ricordeau and Labussière, 1968) due to a relative decrease in daily milk production. Machine milking efficiency (kilograms of milk obtained per hour) is decreased when stripping is practiced because stripping increases individual milking time and increases machine-on time by 27% in the ewe (Ricordeau et al., 1963) and by 20 to 40% in the cow (Clough, 1964). The results of the present experiment would suggest that machine milking efficiency is actually improved by omission of stripping because more milk is obtained by the machine and therefore helps to explain why the loss in milk yield for NS ewes compared to S ewes is only 14% compared to 23% (the stripping percentage of S ewes).

Parlor Throughput. Results from the present experiment were used to estimate the impact of stripping or omission of stripping with one or two milking technicians on parlor throughput, incidence of overmilking, and financial returns. The simulation estimated a parlor throughput of 138 ewes/hr when stripping is practiced by two milking technicians (the normal milking procedure for this flock of ewes). Estimated parlor throughput corresponded to the actual observed parlor throughput for this flock during mid- to late-lactation (125 to 150 ewes/hr, Berger and Thomas, 1997) and to other reports for dairy ewes (100 to 140 ewes/hr, Billon, 1998; 137 ewes/hr, Le Du, 1984). The results of the present simulation, thus, appear to be representative of the normal milking routine.

Parlor throughput, milking efficiency, and relative receipts generated per hour decreased when stripping was performed by only one milking technician compared with two milking technicians. This would be expected because the milking technician must give individual attention to each ewe during stripping and approximately 35 fewer ewes are milked per hour. When stripping is omitted from the milking routine, we estimate that parlor throughput should increase by 15 to 28 ewes/h with one or two milking technicians, respectively, compared to stripping with two milking technicians. We estimate that relative receipts would not differ greatly ($118.78, $116.72, and $123.78, respectively) because the decrease in milk yield associated with the omission of stripping is compensated for by the additional number of ewes milked per hour. Furthermore, for a milking routine with no stripping, the addition of a second milking technician and extra ewes does not appear to be any more financially advantageous than using one milking technician.

When the milking routine includes stripping, the incidence of overmilking is between 33 and 92% (4 of 12 ewes and 11 of 12 ewes) for two or one milking technicians, respectively. Overmilking occurs because stripping requires the individual attention of the milking technician and therefore stripping for some ewes commences well after the machine milk yield has been obtained by the machine. When stripping is omitted from the milking routine, it is estimated that overmilking would not occur (0 of 12 ewes). Overmilking has been shown to increase the incidence of intramammary infection in dairy cows (Mein et al., 1986) by compromising the teat end's ability to resist bacterial penetration to the mammary gland (Peterson, 1964), resulting in decreased milk production and economic loss. Additionally, we have observed a consistent and habitual pattern in the way dairy ewes position themselves in the parlor prior to milking. Because the simulation estimated longer machine-on times for distinct positions within the parlor (data not shown), the same ewes could be consistently overmilked from day to day. Although economic loss as a result of overmilking associated with stripping was not estimated in the simulation, it is likely that the system with one milking technician and omission of stripping would be even more financially advantageous by comparison to a milking routine that included stripping.

Conclusions

We estimate that the omission of machine stripping in East Friesian dairy ewes will result in a 14% reduction in commercial milk available for marketing. However, milk composition, lactation length, and somatic cell count are not affected. It appears that a milking routine without machine stripping improves parlor throughput and decreases the incidence of overmilking. Moreover, milking efficiency and financial returns could be improved by adding additional ewes to the flock in order to compensate for the expected loss in milk production when the milking routine is simplified to not include stripping.

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Table 1. Least squares means ± SEM for lactation traits of the two treatment groups prior to and during the experiment, and for the entire lactation.

Trait	Treatment[1]	Prior to experiment	Experiment	Total lactation
Lactation period length, d	S	79.4 ± 2.1	102.6 ± 2.3	182.0 ± 3.4
	NS	78.4 ± 2.1	104.5 ± 2.3	183.0 ± 3.4
Milk yield, kg	S	177.6 ± 6.8	122.7 ± 4.8[a]	300.2 ± 10.5
	NS	175.2 ± 6.8	105.6 ± 4.8[b]	280.8 ± 10.5
Average milk yield, kg/d	S	2.28 ± 0.09	1.21 ± 0.05[a]	1.67 ± 0.06
	NS	2.23 ± 0.09	1.01 ± 0.05[b]	1.53 ± 0.06
Milk fat, %	S	5.51 ± 0.16[c]	5.71 ± 0.10	5.57 ± 0.05
	NS	5.15 ± 0.16[d]	5.73 ± 0.10	5.58 ± 0.05
Milk protein, %	S	4.56 ± 0.07	4.91 ± 0.07	4.78 ± 0.06
	NS	4.55 ± 0.07	4.90 ± 0.07	4.77 ± 0.06
SCC, log units	S	4.72 ± 0.08[c]	4.91 ± 0.08	4.80 ± 0.04
	NS	4.52 ± 0.08[d]	4.76 ± 0.08	4.73 ± 0.04

[a,b]Means for a trait within a column with different subscripts differ ($P < 0.05$).
[c,d]Means for a trait within a column with different subscripts differ ($P < 0.10$).
[1]Treatment from d 80 to the end of lactation: S = machine milking and machine stripping (n = 24); NS = machine milking with no machine stripping (n = 24).

Table 2. **Least squares means ± SEM for morning machine milking and machine stripping traits of the two treatment groups immediately prior to and during the experiment.**

Trait	Treatment[1]	Prior to experiment	Experiment
Machine milk, kg	S	1.19 ± .06	0.63 ± 0.02
	NS	1.13 ± .06	0.68 ± 0.02
Machine stripped milk, kg	S	0.20 ± 0.01	0.18 ± 0.01
	NS	0.21 ± 0.01	-
Machine stripped milk, %	S	15.1 ± 1.2	23.6 ± 1.0
	NS	16.5 ± 1.2	-
Total milk, kg	S	1.39 ± 0.06	0.80 ± 0.02[a]
	NS	1.34 ± 0.06	0.68 ± 0.02[b]
Machine milking time, s	S	114.5 ± 5.8	71.7 ± 2.4
	NS	115.1 ± 5.8	78.7 ± 2.4
Machine stripping time, s	S	20.9 ± 2.4	17.5 ± 0.7
	NS	23.1 ± 2.0	-
Machine-on time, s	S	130.5 ± 8.3	89.1 ± 2.4[c]
	NS	136.4 ± 6.9	78.7 ± 2.4[d]

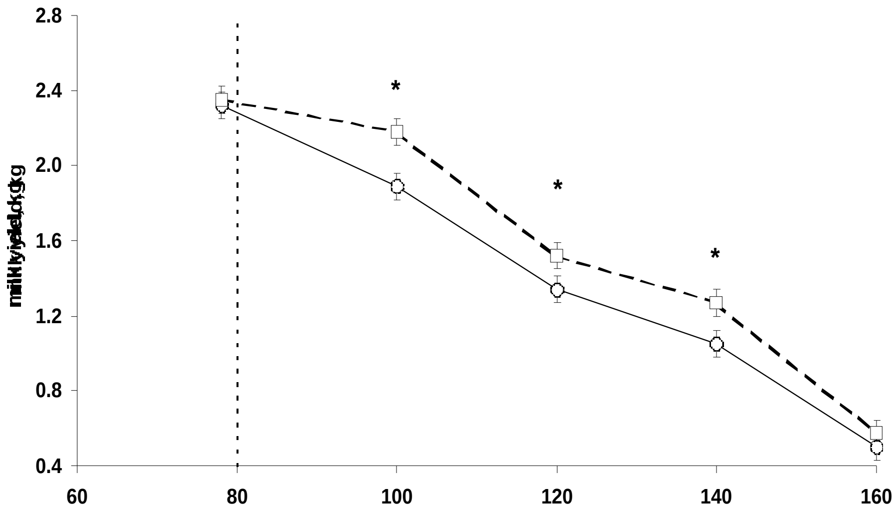
[a,b]Means for a trait within a column with different subscripts differ ($P < 0.05$).
[c,d]Means for a trait within a column with different subscripts differ ($P < 0.10$).
[1]Treatment from d 80 to the end of lactation: S = machine milking and machine stripping (n = 24); NS = machine milking with no machine stripping (n = 24).

Table 3. Simulation of parlor throughput, milking efficiency, relative economic returns, and overmilking rate for East Friesian-crossbred dairy ewes in mid- to late-lactation milked in a 1 x 12 Casse system parlor with or without stripping, and by one or two milking technicians.

Factor	Stripping treatment: S	S	NS	NS
No. Technicians	1	2	1	2
Parlor entry time[1], s	45	45	45	45
Milking procedure time[1], s	344	237	207	186
Parlor exit time[1], s	30	30	30	30
Parlor time[1], s	419	312	282	261
Parlor time[1], min	6.98	5.20	4.70	4.35
Parlor throughput, ewes/hr	103	138	153	166
Milk yield, kg/ewe	0.80	0.80	0.68	0.68
Milking efficiency, kg/hr	82.4	110.4	104.0	112.9
Total receipts[2], $/hr	108.77	145.73	137.28	149.03
Additional expenses[3], $/hr	-	21.95	18.50	32.31
Relative receipts[4], $/hr	108.77	123.78	118.78	116.72
Ewes overmilked, no.	11/12	4/12	0/12	0/12

[1]For a group of 12 ewes.
[2]Receipts from milk sales = $1.32/kg.
[3]Additional expenses relative to the S system with one milking technician: Labor costs = $9.00/hr; ewe purchase, management, and feed costs = $0.37 per ewe.
[4]Total receipts – additional expenses.

A



B

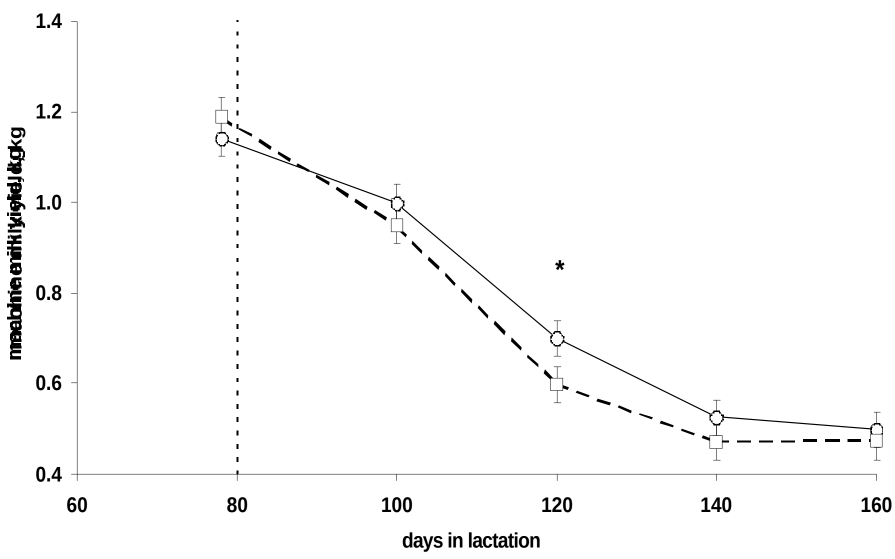


Figure 1. Test-day commercial milk yield (panel A) and morning machine milk yield (the amount of milk obtained without or prior to stripping, panel B), for the two treatment groups: NS ewes (○ , n = 24) were not machine stripped from d 80 to the end of lactation; S ewes (□, n = 24) were machine stripped. The dotted line indicates the start of the experiment. * indicates a significant difference among treatments ($P <$ 0.05)

EFFECT OF REDUCING THE FREQUENCY OF MILKING ON MILK PRODUCTION, MILK COMPOSITION, AND LACTATION LENGTH IN EAST FRIESIAN DAIRY EWES

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Abstract

Efforts to improve milking efficiency of dairy ruminants have concentrated on improving overall milk yield, or alternatively, on decreasing labor input yet still being able to obtain reasonable milk yields. Because dairy ewes are capable of storing the majority of their total milk yield within the cistern, longer intervals between milkings might be a reasonable management tool for this dairy species. Forty-eight third parity East Friesian crossbred dairy ewes were randomly allocated to two milking frequency treatments from d 90 to the end of lactation: 12H ewes were machine milked twice daily at 0600 and 1800 (n = 24); 16H ewes were milked three times every 48 h at 0600, 2200, and 1400, respectively (n = 24). Milk production and composition were measured every 15 d. For ewes managed with a 16 h milking interval, there was a 25% reduction in the number of milkings compared to ewes milked twice daily (180 vs. 135 milkings, respectively). However, there were no significant differences between 16H or 12H treatments in milk yield (118 kg), milk fat percentage or yield (5.50% and 6.3 kg, respectively), milk protein percentage or yield (4.78% and 5.5 kg, respectively), somatic cell count (4.67 log units), or lactation length (178 d). We conclude that East Friesian dairy ewes are well suited for mid-lactation management practices that include less frequent milking (up to 16 h). Longer milking intervals reduces labor input and provides more time to producers for other on- or off-farm activities.

Introduction

Efforts to improve milking efficiency in dairy ruminants have been focused on increasing the amount of milk secreted, or conversely, by limiting the amount of labor required to remove milk from the mammary gland (e.g. by reducing the number of daily milkings). Some dairy cow farmers, for example in New Zealand and France, practice once-daily milking in early lactation to reduce metabolic stress (Davis et al., 1999; Rémond et al., 1999), or in late lactation to accommodate or improve quality of farming life (Davis et al., 1999). However, once-daily machine milking, at least in dairy cows, results in significant losses in milk production on the order of 10 to 50% compared to twice daily milking (see review by Davis et al., 1999).

Physiologically, milking routines should be in accordance with intramammary filling rate and cisternal capacity to store milk: overfilling of the udder results in increased intramammary pressure, distention of the alveoli, and increases in amounts of feedback inhibitors of lactation, all of which can compromise subsequent milk synthesis (Labussière, 1993; Peaker, 1980; Wilde et al., 1995). Conversely, under-filling of the udder has been shown to reduce milk flow rate during milking, resulting in less efficient milk removal (Bruckmaier, 2001).

Because of traditional or routine farming practices (i.e. milking before and after the work day), twice-daily milking is most common for domestic dairy ruminants. However, it is possible that longer milking intervals might be tolerated by some species, such as the dairy ewe and goat, which have larger cisternal storage capacity (up to 75% of total milk yield, Marnet and McKusick, 2001) compared to cows (20 to 30%, Bruckmaier, 2001). Increases in milking frequency would thus only be advantageous for species such as the dairy cow that store the majority of milk in the alveoli, while decreases in milking frequency would be more advantageous for the ewe and goat which store relatively more milk within the cistern. In other words compared to the cow, dairy ewes might not suffer the same degree of loss in milk production or in lactation length with less frequent milking. Moreover, simplification of the milking routine would presumably result in significant savings in labor and expenses.

In dairy ewes, little research has been conducted on appropriate milking intervals. Researchers in France and Sardinia with dairy ewes have tested the effect of omitting one or both of the Sunday milkings to enable farmers to spend more time with their family and other off-farm activities; they reported losses of 5 to 25% in milk production (Casu and Labussière, 1972; Labussière et al., 1974; Labussière, 1988). The effect of consistently longer milking intervals (i.e. 24 h) on commercial milk production and lactation length is not known. Intermediate to once- or twice-daily milking, is a milking routine that comprises three milkings in 48 h. However, there are no reliable reports on 16-h milking intervals in dairy ewes, and only one published study in dairy cows where yield losses of 7 to 18% were reported (Woolford et al., 1985).

We hypothesize that a milking interval of 16 h would be appropriate for dairy ewes because of their increased cisternal storage capacity, and the fact that a 16-h time period lends itself to organization of the milking routine to include three milkings every 48 h (e.g. 0600, 2200, and 1400). The objectives of the present experiment were to estimate the differences in milk production, milk composition, somatic cell count (SCC), and lactation length for East Friesian dairy ewes managed with either a 12- or 16-h milking interval from mid- to late-lactation.

Materials and methods

Forty-eight third parity East Friesian crossbred dairy ewes were studied from d 90 to the end of lactation at the Spooner Agricultural Research Station of the University of Wisconsin-Madison during the summer of 2001. Ewes with symmetrical udders, similar average daily milk production (1.8 ± 0.4 kg/ewe, mean ± SD) and stage of lactation (88 ± 7 d, mean ± SD) were chosen from the main dairy flock of 350 ewes that are normally machine milked twice daily. All ewes in the experiment had been weaned from their lambs at approximately 24 h post-partum. Ewes were randomly assigned to two milking frequency treatments for the remainder of lactation: twice daily machine milking at 0600 and 1800 (12H, n = 24), or three milkings in 48 h at 0600, 2200, and 1400, respectively (16H, n = 24). Treatment groups were housed separately in two neighboring pens and fed a 16% crude protein concentrate and alfalfa hay.

Machine milking took place in a 2 x 12 high-line Casse system milking parlor with 12 milking units and two milking technicians. The milking machine (Alfa Laval Agri Inc., Kansas City) was set to provide 180 pulsations per minute in a 50:50 ratio with a vacuum level of 36 kPa.

Individual ewe milk production (morning, evening, and/or afternoon) was recorded and morning milk samples were collected every 2 wk throughout the experiment. Milk composition analyses for percentage of fat and protein, and Fossomatic somatic cell count (SCC) were performed by a State of Wisconsin certified laboratory. Parlor time (the time for entry, machine milking, and parlor exit) was recorded every other day with a stopwatch during the morning milking for each treatment group of 24 ewes. Adjusted 24-h milk production was calculated on each test day by adding the 0600 and 1800 production for the 12H ewes, and by adding the 0600, 2200, and 1400 production and then dividing by two, for the 16H ewes. An estimation of total milk production, percentages of milk fat and protein, and total milk fat and protein yield for the 90-d experimental period was calculated according to Thomas et al. (2000). SCC was transformed to logarithms of base ten and averaged over the 90-d experiment. Ewes were removed from the experiment and dried-off when their daily milk production on a test day fell below 0.4 kg/d.

Least squares means analysis of variance was conducted with the general linear models procedure of SAS (1999). The experimental design was a split plot on time for measurements taken every 15 d (Figure 1). The model included the main plot effects of: treatment (12H or 16H) and ewe within treatment; and the sub-plot effects of: day (d-90, 105, 120, 135, 150, 165, and 180), treatment x day, and residual error. Least squares means for treatment were tested against ewe within treatment as the error term; treatment x day interaction was tested against residual error. For data presented in Table 1, a simple one-way ANOVA was used to estimate the effect of treatment.

Results

During the experimental period (d 90 to the end of lactation), 16H ewes were machine milked 45 fewer times than 12H ewes (Table 1), and most lactation traits did not differ between treatments. Ewes milked every 12 h compared to ewes milked every 16 h during mid- to late-lactation had similar lactation length (178.4 d), milk production (118.5 kg), milk fat percentage and yield (5.50% and 6.3 kg, respectively), milk protein percentage and yield (4.78% and 5.5 kg, respectively), and SCC (4.67 log units) (Table 1). Throughout the experiment 16H ewes had similar adjusted 24-h milk yield compared to 12H ewes (Figure 1), however, morning milk yield was 28% higher ($P < 0.01$) for 16H vs. 12H ewes (Table 1 and Figure 1).

Discussion

The results of the present experiment demonstrate a clear advantage in milking efficiency for East Friesian dairy ewes managed with a milking interval of 16 h during mid- to late-lactation (last 90 d of a 180 d lactation), because there is a 25% reduction in the number of milkings, yet no compromise in milk yield, milk composition, or lactation length, compared to ewes managed with the normal 12-h milking interval. Most reports concerning the effect of once-daily milking in ewes have shown significant losses in milk production and hypothesize that lactation length would also be reduced (Casu and Labussière, 1972; Knight and Gosling, 1994; Morag, 1968). Apparently, a 16-h milking is more appropriate for dairy ewes, compared to a 24-h milking interval, because we observed no detrimental effect on lactation traits. Moreover, a 25% reduction in total labor was realized with the 16-h milking interval, which permits dairy sheep producers more time to devote to other farming practices and/or to other activities off the farm.

Had the experiment been conducted during early lactation, it is likely that less frequent milking would have significantly reduced lactation performance of these East Friesian dairy ewes. Less frequent milking during early lactation results in reduced milk yield in dairy cows

(Rémond et al., 1999; Walsh, 1976), goats (Wilde and Knight, 1990), and ewes (Knight and Gosling, 1994), and could compromise lactation persistency (Walsh, 1976) because of decreased alveolar diameter (Li et al., 1999) and/or reduced functional udder capacity (Carruthers et al., 1993). Udders of dairy ewes that are managed with a mixed weaning system of suckling and once-daily machine milking in early lactation have large secretory capacity, however, as soon as weaning takes place, milk production drops by 30 to 40% (McKusick et al., 2001; Labussière and Pétrequin, 1969) due to less frequent udder evacuation. Therefore, less frequent milking or longer milking intervals for dairy ewes in early lactation would not be a wise management decision.

Conclusions

Milking every 16 h during mid-lactation appears to be a reasonable compromise to normal twice-daily milking routines for dairy ewes, and does not result in any deleterious effects on milk yield, milk composition, somatic cell count, or lactation length. The advantage of a longer milking interval is that the cistern is allowed to fill more efficiently and yet a milking routine can still be established based on a 16 h interval. Moreover, significant reductions in labor and time spent in the milking parlor will result in a higher standard of living and enable the farmer to spend more time with other on- or off-farm activities.

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Table 1. Least squares means ± SEM for milk production and composition traits of an individual ewe in the two treatment groups during the experiment (d 90 to the end of lactation).

	Treatment[1]	
Trait	12H	16H
Total number of milkings	180	135
Lactation length, d	179.3 ± 1.2	177.5 ± 1.1
Morning milk production, kg	0.65 ± 0.03[b]	0.83 ± 0.03[a]
Parlor time[2], min	12.7 ± 0.4	12.4 ± 0.4
Adj. 24-h milk production, kg	1.34 ± 0.06	1.35 ± 0.06
Total milk production, kg	119.1 ± 5.3	118.0 ± 5.2
Avg. milk fat, %	5.48 ± 0.16	5.51 ± 0.15
Total milk fat yield, kg	6.3 ± 0.3	6.2 ± 0.3
Avg. milk protein, %	4.74 ± 0.08	4.82 ± 0.08
Total milk protein yield, kg	5.5 ± 0.2	5.5 ± 0.2
Somatic cell count, log units	4.69 ± 0.04	4.64 ± 0.04

[a,b]Means within a row with different subscripts differ ($P < 0.05$).

[1]During the experiment, 12H ewes (n = 24) were milked twice daily (0600 and 1800) and 16H ewes (n = 24) were milked every 16 h (0600, 2200, and 1400).

[2]Time for parlor entry, machine milking, and parlor exit for a treatment group of 24 ewes during a morning milking.

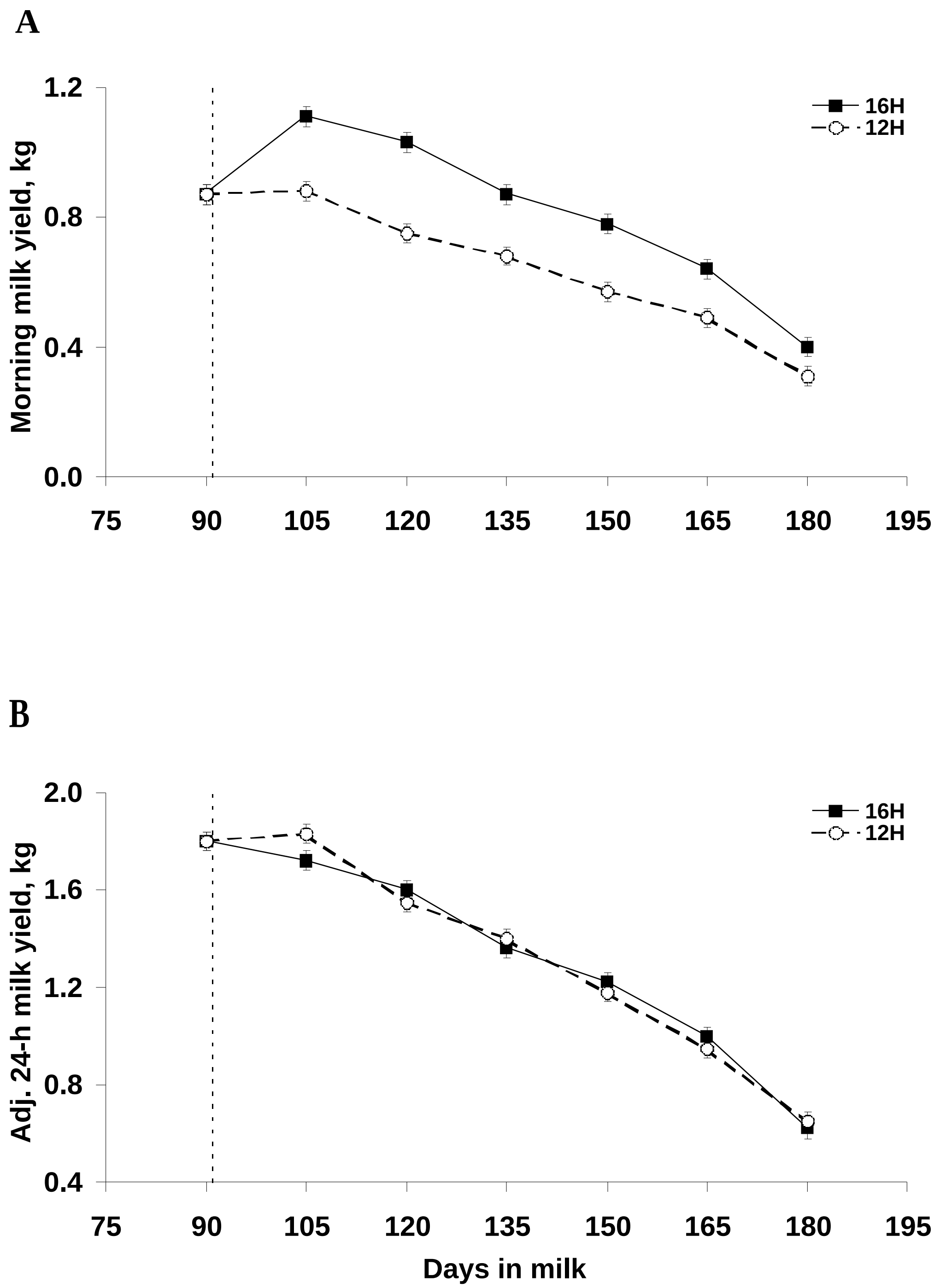


Figure 1. Morning (panel A) and adjusted 24-h milk yield (panel B) for the two treatment groups (12H = ewes milked twice daily at 0600 and 1800, n = 24; 16H = ewes milked every 16 h at 0600, 2200, and 1400, respectively, n = 24). The dotted vertical line indicates the start of the experiment.

USING LIGHT IN A DAIRY SHEEP OPERATION

Ken Kleinpeter

Manager, The Old Chatham Sheepherding Company
Old Chatham, New York

Summary:

In 1999 The Old Chatham Sheepherding Company started experimenting with a light control protocol to increase our supply of fresh milk in the Fall months. The goal was to increase the number of "out of season lambings" in our East Friesian crossbred flock, and to extend the lactations of those ewes that did lamb in the fall. We have found that while the light control protocol is very effective in increasing the number of ewes which lamb in the Fall, the data on extended Fall lactations is inconclusive.

Introduction:

Due to seasonal breeding characteristics, and relatively short lactations of sheep, in most parts of the world sheep dairies are seasonal enterprises. Products made from the milk are mostly aged cheeses that can be made while the ewes are lactating and sold throughout the year. Fresh products made from sheep milk are only available in season.

This system has worked for centuries in most of the world where sheep are milked, but because of different market conditions and consumer expectations in the United States, it may not be appropriate for all sheep dairy operations here. This is especially true for businesses like ours at the Old Chatham Sheepherding Company whose product line consists mostly or entirely of fresh products like yogurt, soft fresh cheeses, and other soft- ripened cheese that have limited shelf life.

It is far too difficult to get shelf space in the highly competitive markets in the United States, to risk losing it by being out of production for several months a year. Furthermore, the average American consumer who is offered thousands of choices in the marketplace, is not accustomed to products only being available seasonally, and will often move on to competitive products if a product is not available for part of the year.

Given these realities, most sheep dairy producers in the United States have two choices: make only aged cheeses, or go to year around production. (I am less familiar with the market in Canada, though I expect conditions are not much different there.)

Due to our decision from the beginning of our business in 1988 to not compete directly with imported hard cheeses and concentrate instead on fresh and soft-ripened cheeses, we have milked our flock year round for more than 13 years now. The purpose of this presentation is to give a brief review of our efforts to maintain production in the "out of season" months over the years, and to report on what has turned out to be by far the most successful of these efforts: light control.

Background and History:

Most sheep producers are aware that while most breeds of sheep are seasonal breeders, there is a continuum in different breeds and individuals within breeds ranging from very short breeding seasons to practically year round breeding. Our East Friesian flock is somewhere in the middle of that continuum with a natural breeding season that ranges from mid-August to mid-February. Therefore, we can easily extend our lambing period from early January to mid -June. Historically, however, under natural conditions, we could expect only between 15 to 25 percent of ewes exposed to rams between March and June to lamb in the Fall.

Because of this, in our early years, we experienced chronic shortages of fresh milk from September though December, and surplus production in April though June or July. Not only did this cause chaos in our marketing efforts, it also caused our lambing and milking barns to be over-taxed for part of the year and under-utilized in another part of the year.

In the past, we experimented with hormone treatments to increase Fall lambing. While hormone treatments did improve the out of season lambing numbers over natural breeding, the results varied from year to year, ranging from 30 percent to 70 percent success rates. Additionally, hormones are costly in terms of both money and labor. The cost is about eight dollars per ewe, and the treatment regimen requires each ewe treated to be handled individually twice. And, most importantly, the use of hormones did not fit philosophically into our otherwise organic management of the farm.

Protocol:

This was not a scientific experiment. We made no effort to compare one protocol with another, to maintain control groups or to compare light control with a number of other methods in the same year to evaluate results. We haven’t even done our project exactly the same way each year. We simply chose a protocol we thought might work, and we tried it. However, because we do have good records going back a number of years we were able to compare our results using the light control with results from hormone treatment and natural breeding.

We discovered a number of different light treatment protocols when we first started looking into trying it for our farm. However, many of the protocols were developed by researchers who needed lambs all year around for their research, and most involved year-long schedules that required climate-controlled buildings where day could be turned to night and night into day. These protocols worked very well, but are not practical for most farms.

We settled on a protocol that only required lengthening day lengths, which is much easier than shortening day lengths. Simply put, we started groups under lights the first week of January, and kept them under 20-hour days for 60 days. We were advised by some that a 16-hour day would work, and by others that 24 hours of light would work. Some said the dark period had to be complete and total darkness, meaning even a streetlight within 50 yards of the building would compromise the results, others disagreed. We decided to keep the lights on from 4 AM until midnight and made every effort to keep the dark period from midnight until 4 AM as dark as possible. Since the barn we use is far from other light sources, this has not proved difficult.

After 60 days under the lights, the ewes were moved outside into normal day lengths. Rams were introduced about four weeks later and the ewes started cycling within a week or so. We have found that some ewes will start cycling right away, and some will cycle as much as six to eight weeks later.

The rams are put under the same light treatment protocol, but in a completely different building. We feel it is important for the ewes to be out of sight and smell of the rams until they are exposed to them at the end of the protocol. This way we also take advantage of the "ram effect" that has been well documented.

Lights Used:

We have used three different barns with somewhat different light levels successfully, so it seems that varying brightness levels of light in the barns can produce good results. We have not tried changing the light intensity to compare results. It is possible different light levels would produce better results than we have experienced. A research project comparing light levels would probably produce some useful information on this subject.

In all of our barns we have 100-watt metal halide fixtures. This type of fixture is relatively expensive to buy and install, but they are very energy efficient, providing about 450 watts of light per 100 watts of electricity used. Although the lights are installed a bit differently in each barn, on average they are about 14 feet above the barn floor and are spaced about 25 feet apart. At night, the barns are not extremely bright inside, but there is enough light to read a book or newspaper without much strain.

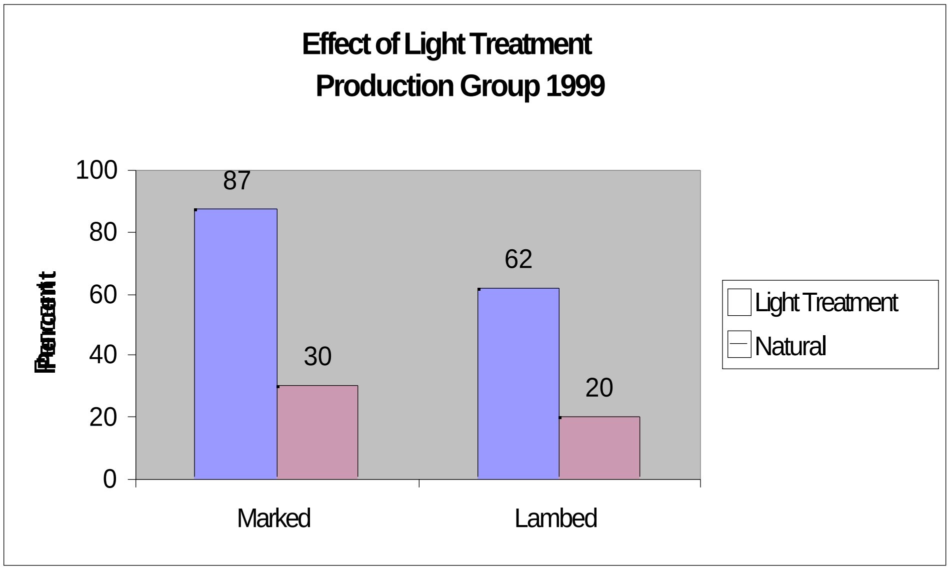
Results:

We are now into our third year of light treatment, and because we have done things a bit differently every year, it will be most straightforward if each year's results are presented independently. We started cautiously in 1999, because we had no idea how the system would work. Ewes selected for the light control group were held back from breeding during the normal Fall season, so if the light treatment protocol didn't work, we would have lost production of those ewes for the season.

In discussing our results, it is necessary to digress a bit to explain one aspect of the way we manage our flock. For the past five years, our flock has been divided into two groups, the "Elite Group" and the "Production Group". The Elite Group consists of our highest milk-producing ewes. This group is blood tested three times a year to screen for disease, and it is the source of all replacement stock for our use or for sale. The two groups are kept separate in every phase of the operation. No replacement stock is kept from the Production Group.

Practically, this means during breeding ewes in the Production Group can be exposed to a number of rams simultaneously, because it is not important for us to know the sire of lambs from that group. Of course the opposite is true for the Elite Group. Ewes from the Elite Group can only be exposed to one ram at a time, because it is critical to our selection program to know the sire of replacement stock. This turns out to be important for the light control protocol because, as you will see later, we have had different success rates in the two groups.

In 1999 we started only one group of 50 ewes in the first week of January. In the first week of March the group was turned out to a winter paddock, and five weeks later, the rams were introduced. These ewes were all from our production group, so we were able to put a number of rams in the group. Within six weeks, 87 percent of the ewes had been marked, and 62 percent of those ewes eventually lambed sometime in the fall, which we defined as September 1st through December 31st.



The discrepancy between ewes marked and ewes lambing is something we have noticed every year, but the discrepancy does vary a bit from year to year. It could partially be influenced by weather conditions, and partially because not all ewes conceive from the first breeding (this holds true even in the normal breeding season). In the natural breeding season, ewes that don't conceive on the first breeding will usually cycle again but this is probably not the case with the "out of season" breedings. It could be that some light control ewes don't conceive the first time, and then don't cycle again. This is known to happen in ewes treated with hormones for out of season breeding, and it may well apply to light control protocols as well.

This is also an area that merits further research, because if the number of successful Fall lambing could be moved closer to the number of marks, it would greatly increase the efficacy of the light control protocol.

In the Fall of 1998, before starting the formal light control protocol, we made a decision to put our lactating ewes on a 20-hour light schedule. We did this primarily to see if we could extend the lactations of the ewes that lambed in mid to late summer and in the Fall. We have noticed over the years that Fall lactations have tended to be shorter and less productive than Spring lactations, and that mid to late summer lambing ewes tended to sharply drop in milk production as the days grew shorter.

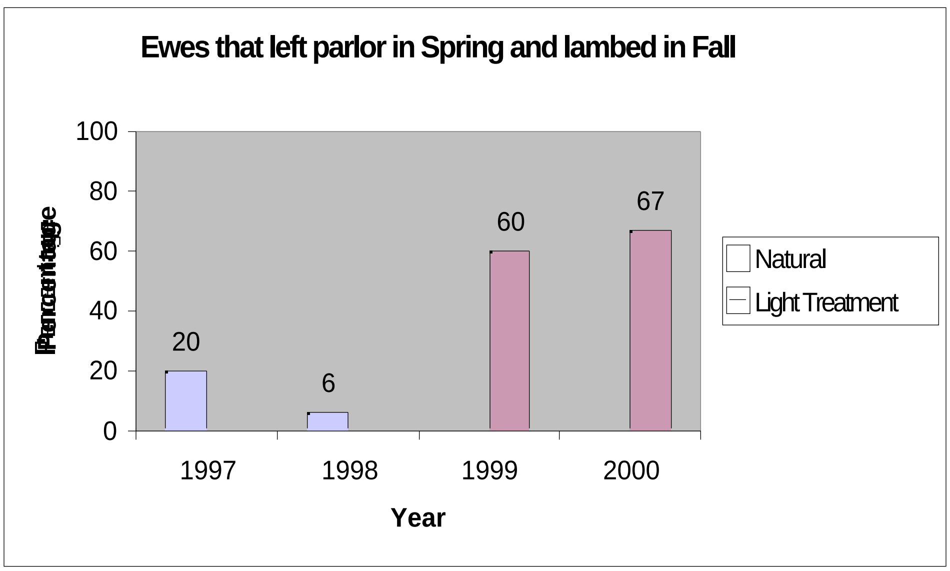
While, subjectively, we believe that leaving the lights on in the milking barn has resulted in more productive Fall lactations, it is hard to separate the effect of our ongoing selection program from the effects of the light control. Fall lactations are no longer greatly less productive than Spring lactations. However, we have experienced increasingly productive average lactations every year since we began, so the more productive fall lactations may not be only a result of the lights.

Leaving lights on in the milking barn did yield some surprising results. We quickly noticed a significant percentage of ewes that ended their lactations in the Spring, after lactating for two to five months under 20-hour days in the milking barn, quickly bred back after they were dried off. This we can surely attribute to the lights, because the results of the two years since we started the milking barn light treatment, 1999 and 2000 were so dramatically different than the two years, 1997 and 1998 before we started light treatment.

In 1999, 119 ewes ended their lactations between February 1st and June 1st. Individual ewes in that group had lactated for as few as 75 days up to as many as 391 days. As they were taken from the parlor, they were added to the breeding group that included the light control ewes from January of that year. Of these ewes, 82 percent were marked, and 60 percent lambed that Fall, indicating that the 20-hour day length worked for out of season breeding, even when the ewes were lactating while exposed to extended day lengths.

In 2000, 155 ewes ended their lactations between February 1st and June 1st, and were folded into the appropriate light control breeding groups. Of those 155 ewes, 67 percent lambed that Fall.

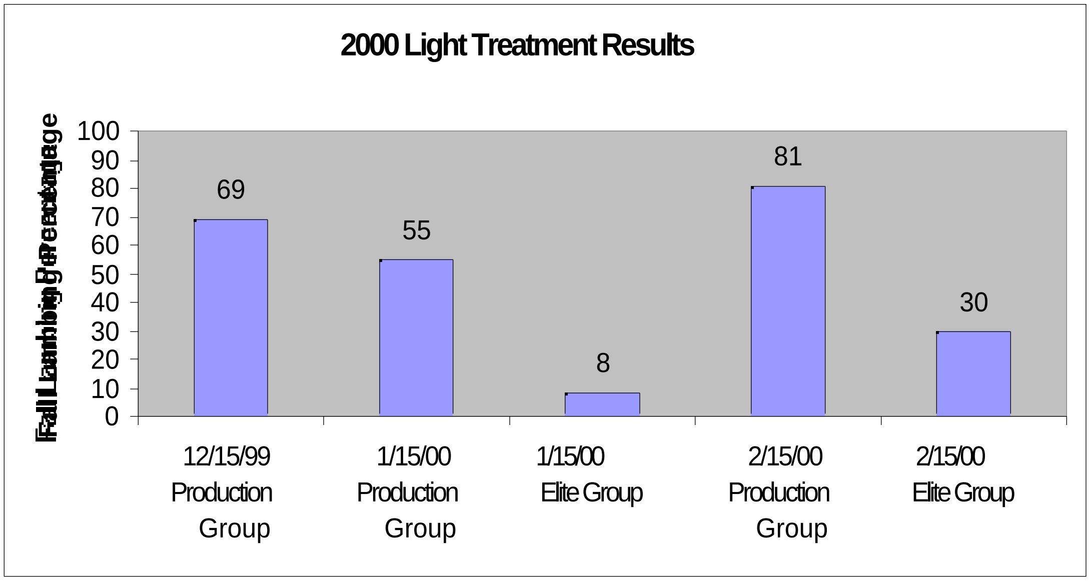
In 1997, before starting the light treatment protocol, thirty percent of ewes that ended their lactations between those dates lambed in the Fall and in 1998 only six percent of ewes with lactations ended between February 1st and June 1st lambed in the Fall.



For the 2000 Fall lambing season we started 225 ewes in the light treatment protocol, in five different groups. Forty production ewes started the 20-hour days on December 15th in 1999; 43 production ewes and 45 elite ewes (mostly replacements) were started in separate groups on January 15th 2000; and 24 elite ewes (also mostly replacements) and 73 production ewes, in separate groups, were started on February 15th, 2000. Each of these groups was taken out of the light control barn as their 60-day periods were completed.

The results were as follows:

- The 12/15/1999 Production Group: 69 percent of the 40 ewes lambed in the fall of 2000
- The 1/15/2000 Production Group: 55 percent of the 43 ewes lambed in the fall of 2000.
- The 1/15/2000 Elite Group: 8 percent of the 45 ewes lambed in the fall of 2000.



- The 2/15/2000 Production Group: 81 percent of the 73 ewes lambed in the fall of 2000.
- The 2/15/2000 Elite Group: 30 percent of the 24 ewes lambed.

Discussion:

In looking over these results, it is quite clear that our success rate in the Elite Groups was much lower than for the Production Groups. There are two different variables for the Elite Groups when compared to the Production Groups. The Elite Groups were comprised mostly of replacement ewes, and while the ewe to ram ratio was never more than 10 to 1 in any of the groups, there was only one ram each in the Elite Groups. The production Groups had ten or more rams each.

It is not clear which of the variables contributed more to the lower success rate in the Elite Groups, but we suspect it was the lowered ram effect of having only one ram per group. For 2002 we plan to try a group of Elite replacement ewes that will be exposed to a number of rams simultaneously.

As this paper was prepared in late September, our 2001 Fall lambing results were not complete. However, judging from the pregnancy checking we did in August, and the ewes that have lambed so far, we are expecting that about 68 percent of the 125 production ewes that were in light treatment will lamb. It also seems clear that about 66 percent of the ewes which left the parlor between February 1st and June 1st this year, will also lamb this Fall. Unfortunately, only about 30 percent of the 75 elite light treatment ewes have scanned pregnant or have lambed.

Having completed our third year of using light control, we are now confident that we can consistently get between 60 and 70 percent of ewes exposed to the protocol to lamb in the Fall if we can expose them to a group of rams. As mentioned earlier, these light treatment results are better, more consistent, and considerably less expensive in time and money than those we achieved with the hormone treatments we experimented with over the years.

However, there are downsides. To start light control groups in January, February and March, ewes have to be held out of the normal breeding season. So even with a 70 percent success rate, we still have 30 percent of the ewes that don’t lamb in the fall, and so we miss a season of production from those ewes. Because it is so important for us to have adequate fresh milk in the Fall, when demand for our products is the highest, we have accepted this downside.

Based on the unexpected results of having lactating ewes respond as well as non-lactating ewes to the protocol, we will again tinker with the system in 2002. Having used the light treatment for the past three years, we now have a good segment of our flock on a Fall lambing schedule. These ewes lamb sometime in the Fall, lactate for several months under 20-hour days in the milking barn, and leave the milking barn sometimes between February and June. We know we can expect about 68 percent of these ewes to breed back in April, May or June, and lamb again in the Fall. Those that don't breed for Fall lambing then breed back in the early Fall, so we don't miss a year of production on those ewes.

Practically, this means we can now hold back fewer ewes from Fall breeding for a separate light control group. In fact, we'll probably hold back no more than 100 production ewes for a February light control group this year. Production ewes that end their lactations in January and February will be folded into that group and they will all go out in early April for breeding in May and June. Ewes that end their lactations April through June will simply be folded into the light control breeding groups.

Also for 2002 the only Elite Group light control ewes will be replacements that were not quite old enough to breed in the fall. We will not plan to keep replacements from this group, so they will be exposed to a number of rams. Hopefully our results using this method will be better than the Elite Group results have been in the past. However, since the group will only consist of replacements that were not ready to breed in the Fall, any ewe that conceives will be a bonus.

Conclusion:

Despite some drawbacks, the use of light control in our operation has been a great success for us, and we believe any producer who is contemplating year-round production should strongly consider trying it. Most importantly, it has meant we no longer have to ration orders to important customers in the Fall, something we had to do as recently as 1998. And, since we can now spread our lambing over the whole year, our labor and our facilities are much more efficiently utilized.

We also believe our protocol and/or variants of it should be studied more extensively in a more scientific manner to see if our results can be improved on.

THE EFFECT OF GROWTH RATE ON MAMMARY GLAND DEVELOPMENT IN EWE LAMBS: A REVIEW

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Summary

Over the past twenty years, research has established that there is a negative relationship between prepubertal growth rate and lifetime milk production in sheep and cattle. In cattle, reduced mammary development as a result of high growth rate can result in 10 to 17% less daily milk production during the 1st, 2nd, and 3rd lactation, compared to animals raised at slower growth rates. We as dairy sheep producers place great emphasis on growing our replacement ewe lambs quickly, to ensure that they will be of adequate size to reach puberty and conceive as lambs, thereby giving birth and lactating for the first time as yearlings. By doing this, we may be producing ewes with less capacity for milk production and, in effect, shooting ourselves in the foot: spending money on feed supplements for ewe lambs who then become less-productive milkers precisely because they grew so well as lambs. It is therefore paramount that attention be given to determining the proper growth rate in dairy ewe lambs.

The negative effect of high gain occurs during a critical period: from about 1 month to 5 months of age in the ewe lamb. In this period the lamb's mammary gland is producing great masses of "ductules", the small ducts that in pregnancy will grow into the milk-secreting alveoli and the milk-transporting ductal network. Any process that limits the development of these ductules will thus also limit the mature gland's capacity to produce and transport milk.

The effect of nutrition on prepubertal mammary growth is largely due to the inverse relationship between feeding level and growth hormone (GH) concentrations. When animals are fed at lower levels of energy, GH release is relatively higher, compared to animals on high-energy, ad-lib diets. GH acts via other hormones to stimulate cell division, provoking growth and proliferation of the ductules, and it makes energy available for the rapidly-dividing cells in the ductules. If nutrition is too restricted, however, there will be inadequate growth of the mammary fat pad, which is essential for mammogenesis. The fat pad provides the framework for mammary gland development and is also a source of local hormones critical to the growing gland. If energy intake is too low, and the fat pad too small, mammary growth can be inhibited because the proliferating system of ducts will literally run out of fat pad area in which to expand.

Recent trials in dairy heifers suggest that optimal gain — that which results in the greatest milk yield — is about 65 to 75% of maximum daily gain. Although there have been no equivalent trials with sheep, research has shown that growth rates in the young ewe lamb must not be too low, limiting fat pad area and seriously delaying puberty (thus lowering reproductive efficiency), nor too high, resulting in lower milk production. The objectives of this paper are to review the current state of available knowledge concerning the effect of nutrition on mammary growth in the young ruminant female, and the subsequent effects on lactation performance.

Prepubertal Mammogenesis

The portion of the mammary gland that contains the secretory alveoli and the ducts that transport the milk secretions is called the "parenchyma"; parenchymal tissues are composed of epithelial cells. In the ewe lamb, development of the mammary epithelium is restricted to undifferentiated cell production: the proliferation of a network of ducts through the mammary fat pad. During pregnancy these epithelial cells will further proliferate and differentiate into either ducts or the specialized milk-producing cells of the alveoli. The parenchyma is surrounded and supported by the "stroma", also called the fat pad. The fat pad is composed primarily of connective tissue and adipose tissue, as well as vascular and lymphatic systems, and nerves and myoepithelial cells.

In the ruminant, postnatal development of the mammary parenchyma proceeds through specific proliferative stages. At birth the basic glandular structures have been formed, with a single primary duct arising from the teat. In the calf/baby lamb period (until 2 to 3 months in the calf, and probably until 1 to 2 months in the lamb), mammary epithelial growth is *isometric* — growing at a rate similar to that of the whole body — and is limited to the development of secondary and tertiary ducts in the zone adjoining the gland cistern, and to growth of non-epithelial connective and adipose tissues (Sejrsen and Purup, 1997).

At some point in the second month of life, the lamb's mammary gland enters an *allometric* phase of growth — epithelial cell numbers are increasing at a rate faster than that of the whole body. During this time, extensive outpocketing of epithelial tissue arises from the secondary and tertiary ducts around the gland cistern. Hovey et al. (1999) has described these outpockets as clusters of ductules arising from the termini of more sizable ducts (Figure 1). The ductules advance as dense masses, replacing surrounding adipose tissue as they progress. DNA is being actively synthesized at the periphery of these masses of ductules, indicating rapid cell proliferation. During this period the fat pad is also growing, adding adipose tissue and the structurally-supporting connective tissues (Sejrsen et al., 2000).

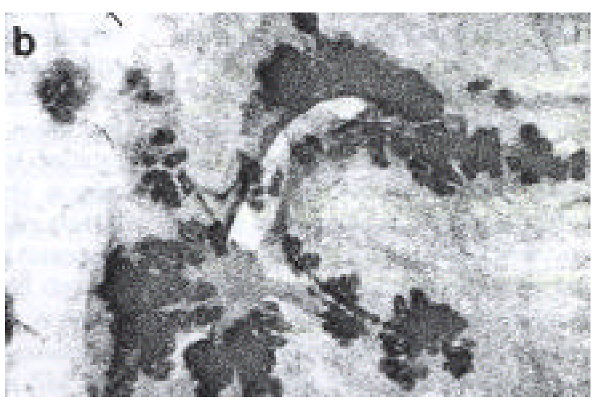

Figure 1. Whole mount of a terminal ductal unit from the mammary gland of a prepubertal ewe lamb. Dense clusters of epithelial ductules can be seen arising from hollow ducts, particularly at their terminus. From Hovey et al., 1999.

After puberty, the mammary gland reverts to isometric growth, with growth again paralleling that of the whole body.

Pregnancy causes the mammary gland to undergo another period of extensive development andallometric growth (Sejrsen et al., 2000). In the ewe, mammary growth in early pregnancy consists of rapid ductal growth. In late pregnancy, differentiated epithelial cells form alveoli, which are anchored to collagen. DNA analysis of cell numbers of epithelial and connective tissue in Romney sheep showed that 20% of gland growth occurred between birth and puberty, 78% during pregnancy, and 2% during lactation (Anderson, 1975).

Total milk yield is proportional to total epithelial cell numbers (Hovey et al., 1999). As revealed by the Romney ewe study above, 98% of epithelial cell numbers are established by parturition. Between parturition and peak lactation, secretory cells hypertrophy and become more fully differentiated. Forsyth (1995) studied the relationship between milk yield and alveolar cell activity and persistence in dairy cattle. She found that after peak lactation, activity per individual cell is maintained, and that alveolar cell loss is the primary cause of milk yield decline. In the modern dairy cow, peak yield accounts for 66 to 80% of the variance in total yield, and persistency (days in milk) accounts for only 8 to 12 % of the variance. Peak yield is primarily determined by secretory cell numbers. Therefore any process that negatively impacts epithelial cell numbers will negatively impact total milk yield.

The Fat Pad

The mammary fat pad is a matrix of connective and adipose tissue that also houses the gland's vascular and lymphatic systems. It has three major functions critical to mammogenesis: first, its connective tissue network provides the structural support for the parenchyma; second, it serves as an active lipid store for the growing and/or differentiating epithelia; and third, in a function only now being understood, it locally regulates mammary development by mediating hormone action and synthesizing growth factors.

As shown in the recent work by Hovey et al. (1999), the fat pad's adipose tissue is extensively interlaced with rope-like cords of connective tissue fibroblasts. In the lactating adult, these cords will give structural support to the fluid-filled udder. In the developing animal, the connective tissue meshwork, interspersed between adipocytes, directs the spread of parenchymal growth: ductules are seen lying embedded within veins of connective tissue (Figure 2). As the growing ducts advance through the adipose/collagen matrix, fibroblasts proliferate in response to the oncoming ductules, continuously ensheathing the ductules in multiple layers of fibrous tissue.

Although the proliferating epithelial cells do not directly abut the fat pad's adipocytes, the adipose tissue acts as a lipid depot for the dividing cells. Lipid-depleted adipocytes are seen in the area of ductal infiltration. Furthermore, Hovey et al. (1999) found that adipocyte-derived fatty acids markedly increased the response of mammary epithelial cells to growth factors in vitro.The actions of many hormones are mediated by the mammary fat pad, and the fat pad is also a major site for the synthesis of local growth factors. Growth hormone (GH), a dominant mammogenic hormone, has binding sites in adipose tissue in the prepubertal ewe lamb. Insulin-like growth factor-1 is stroma-derived in the mammary gland, and there appear to be epidermal growth factor receptors within the fat pad as well as on epithelial cells (Hovey et al., 1999).

The mammary fat pad is therefore not simply an inert supporting material. It plays an integral and critical role in directing, stimulating, and regulating mammogenesis.

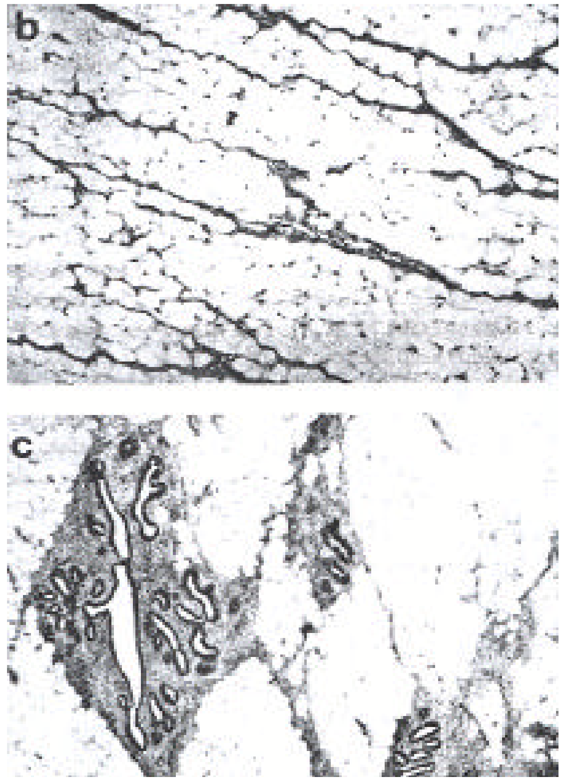

Figure 2. Sections of mammary fat pad from a prepubertal ewe lamb. (a) A meshwork of fibrous connective tissue cords can be seen throughout the adipose tissue. (b) As the epithelial tissue expands into the fat pad, ductules advance ensheathed within cords of connective tissue. From Hovey et al., 1999.

Level of Nutrition and Milk Yield

A large number of trials have shown that high levels of nutrition in the prepubertal ruminant can limit mammary gland development, resulting in reduced milk yield in subsequent lactations.

Umberger et al. (1985) reared Suffolk- and Dorset-cross ewe lambs from early weaning (20kg) to puberty on either pasture plus ad-lib grain ("F" ewes; 0.20 kg/d gain) or on pasture plus limited grain ("T" ewes; 0.12 kg/d gain). After breeding at 9 months, treatments were reversed for half of each group. Milk was collected at 20, 40, and 60 days of the ewes' first lactation, and daily milk yields were estimated for the 60-day period. Alveoli were also counted from ewes sacrificed in each group (alveoli per $4.23mm^2$). Results showed that slower-growing ewe lambs had more alveoli (402 vs 334 alveoli per unit area) and produced more milk (1.56 vs 1.29 kg/d). Reversing the feeding level after the start of breeding did not affect milk yield or alveoli numbers.

In dairy heifers, the negative relationship between prepubertal daily gain and milk yield has been well documented. In a recent study, Hohenboken et al. (1995) reported that as prepubertal daily gain was reduced from a high level (H: 0.79kg/d) to a moderate level (M: 0.67 kg/d) to a low level (L: 0.52 kg/d), first-lactation milk yield increased: compared with H heifers, those on M and L rearing intensities had 9% and 14% more milk, respectively. Also, consistent with their lower milk production, H heifers were less efficient in nutrition utilization during lactation. Compared with L and M groups, H heifers lost less weight during early lactation, passed into positive energy balance sooner after parturition, and gained more weight to the end of lactation.

Many trials have examined the mammary parenchymal tissue of animals reared on different levels of food intake, and related observed mammary development to the subsequent milk yield of similarly-raised adults.

From a histological perspective, prepubertal daily gain is positively correlated with total mammary gland weight and the percentage of adipose tissue in the gland, but negatively correlated with measures of epithelial cells and connective tissue. Sejrsen et al. (1982) found that heifers on a restricted diet (0.64 kg/d gain) had less total gland weight than heifers on a high-energy, ad-lib diet (1.3 kg/d). Restricted heifers, however, had 61% less extra-parenchymal adipose tissue and 30% more absolute parenchyma, which occupied a greater proportion of the available fat pad area. Within the parenchyma itself, the restricted heifers had more DNA content (reflecting epithelial cell numbers: 1562 mg vs 1061 mg), more hydroxyproline (reflecting connective tissue mass: 2288 mg vs 1466 mg), and more parenchymal lipid (3140 mg vs 2340 mg).

This effect on mammogenesis appears to be permanent, and has been shown to persist over several lactations in both beef cattle and dairy cattle. After four lactations, dairy cows fed a moderately-restricted diet (0.75 kg/d) as heifers still had 68% more secretory tissue and 16% less adipose tissue than cows that had been fed to near-maximum gain (1.1 kg/d) as heifers (Harrison et al., 1988). Similarly, beef cows reared at a low daily gain had significantly higher 30-day milk yields and weaned significantly heavier calves in their 1st, 2nd, and 3rd lactations, compared to contemporaries reared at a high daily gain (Johnsson and Obst, 1984).

The negative effect of high plane of nutrition on mammary gland development appears to cease at or around puberty. In the non-pregnant dairy animal, there is no consistent growth of mammary secretory tissue after the 2nd estrous cycle (Sejrsen et al., 1982), and there is no correlation between rate of gain and secretory tissue mass in postpubertal dairy cattle (Sejrsen et al., 1982; Harrison et al., 1983), in beef cattle (Johnsson and Obst, 1984), or in sheep (Umberger et al., 1985; Johnsson and Hart, 1985; Anderson, 1975).

Table 1. Milk yield, estimated at 30 days of lactation, over 3 lactations from beef heifers fed to grow at high (H), moderate (M), or low (L) rates.

		Rearing treatments					
		HM	*HL*	*MM*	*LH*	*LM*	Stat.signif
Daily gain, kg	2-8 months	0.91	.91	0.67	0.55	0.55	***
	8-14 months	0.57	.14	0.58	0.97	0.55	***
Liveweight, kg	8 months	235	235	185	164	164	***
	14 months	331	259	284	323	258	***
Puberty	Live weight, kg	244	237	238	234	233	NS
	Age, mo	9.0	9.1	11.6	11.0	12.1	***
Relative milk yield	1st lactation	100	120	105	139	154	**
	2nd lactation	100	131	135	130	135	*
	3rd lactation	100	127	141	145	149	**

After Johnsson and Obst, 1984

Using February-born Hampshire Down-cross ewe lambs, Johnsson and Hart (1985) were able to quantify the effects of nutrition on allometric growth rates. With these slower-maturing, highly-seasonal lambs, the trial revealed two distinct periods of allometric parenchymal growth before the lambs reached puberty in October and November. Between 4 and 20 weeks of age, lambs were fed for either low or high gain (L or H; Table 2). Then, between 20 and 36 weeks, lambs were either maintained at low gain, switched to high gain, or switched to low gain (LL, LH, or HL). As with the Hereford heifers, mammogenesis in lambs was greater in the early prepubertal period: overall, total parenchymal DNA increased 19-fold between 4 and 20 weeks, whereas total parenchymal DNA increased only 3-fold between 20 and 36 weeks.

The trial also showed that a high plane of nutrition reduces the *rate* of allometric growth in early puberty. Between 4 and 20 weeks, mammary growth was rapid and significantly affected by liveweight gain: mammary parenchyma increased 3.7 times faster than liveweight in L lambs, but only 2.4 times faster in H lambs. Between 20 and 36 weeks, however, the response to feeding level appeared to be determined by nutrition in the previous period. In ad-lib fed lambs (H), restriction of diet after 20 weeks (HL) promoted allometric growth: 2.6 times that of liveweight. In restricted lambs (L), mammary development after 20 weeks occurred in proportion to liveweight gain: 1.4 times that of liveweight for LH lambs, 1.6 for LL lambs.

Table 2. Mammary fat pad and parenchymal tissue development in ewe lambs fed to grow at low or high rates at 4 to 20 weeks and 20 to 36 weeks

	Rearing treatment					
	L	*H*	*LL*	*LH*	*HL*	Stat.
	4 to 20 weeks		*20 to 36 weeks*			Signif.
Daily gain, kg	0.12	0.22	0.11	0.21	0.11	
Age at slaughter, wks	20	20	36	36	36	
Live wt, kg	23.7	33.2	36.1	48.9	47.7	*
Trimmed fat pad, g	14.7	30.0	46.0	86.7	70.3	*
% Fat pad occupied	65	27	53	46	44	*
Parenchyma (dried, fat-free tissue), mg	844	623	1580	2496	1883	*
Total epithelial DNA, mg	32	26	61	91	73	*
Live weight at puberty, kg			33.4	43.3	45.7	***
Age at puberty, days			233	240	235	NS

After Johnsson and Hart, 1985

The exception to this was the early puberty reached by a few lambs in the H group, which ended allometric mammary development at 18 weeks and resulted in reduced mammary gland size.

There was also a significant difference in the proportion of fat pad occupied by parenchyma. At 20 weeks, parenchyma in L lambs had occupied 65% of available fat pad area, while H lambs had 27% occupied. And although LH lambs had 25% more parenchymal DNA than HL lambs at similar liveweights (48 kg at 36 weeks), the final proportion of fat pad occupied at 36 weeks was similar (46 and 44%, respectively).

From these results the authors concluded that 1) the allometric phase of prepubertal mammogenesis is primarily a function of age and largely reverts to isometric growth before normal puberty; 2) after 20 weeks, the size of available fat pad may limit further lateral expansion in restricted-gain lambs; and 3) precocious puberty attained within the major phase of allometric growth can lead to marked decrease in mammary gland size.

The effect of nutritional plane on prepubertal mammogenesis is similar across breeds in sheep and cattle. Hohenboken et al. (1995) reported that there was no difference in sensitivity of subsequent milk yield to high prepubertal gain across four Danish dairy or dual-purpose cattle breeds. In sheep, this relationship has been demonstrated in trials with Dorset-, Suffolk-, Hampshire-, and Finn-cross ewe lambs (Umberger et al., 1985; McCann et al., 1989; Johnsson and Hart, 1985; McFadden et al., 1990).

Hormonal Influences on Prepubertal Mammogenesis

Researchers now recognize that the impaired mammary development of rapidly-reared prepubertal ruminants is caused by altered secretions of hormones, growth factors, and binding proteins, all of which regulate mammary development (Sejrsen et al., 1997). Although the exact physiological mechanisms are not understood, it is agreed that high feeding levels inhibit circulating growth hormone (GH) concentrations in the blood, and that there is a positive correlation between serum GH and prepubertal mammary growth (Sejrsen et al., 1983, Johnsson et al., 1985). This has also been confirmed by trials showing that exogenous administration of GH produces increased parenchymal tissue growth in lambs (McFadden et al., 1990; Johnsson et al., 1986) and heifers (Sejrsen et al., 1997).

Johnsson et al. (1985) examined the effects of daily nutrition on GH plasma concentrations at various ages before puberty and the associated mammogenesis. Blood samples were taken from ewe lambs at 10, 14, 18, 26, and 36 weeks of age. As described earlier, lambs were fed to either a high (H) or low (L) daily gain from 4 to 36 weeks. Results showed that GH response to fresh daily feed was significantly higher in L lambs than H lambs at 10, 14, and 18 weeks, and that GH concentrations and mammary development were positively correlated. As the lambs' ages increased after 20 weeks, both the mean level of serum GH and the sensitivity of GH concentrations to feed intake declined (Figure 3).

Growth hormone levels have also been positively correlated with ductal growth during the allometric period in heifers (Sejrsen et al., 1983). Serum GH concentrations were depressed in prepubertal heifers on ad-lib feed, but were not affected by rearing rate after puberty. And, as with lambs, serum GH concentration was negatively correlated with extraparenchmal adipose tissue mass, indicating a lipolytic role of GH.

It is believed that the mammogenic actions of GH may be mediated by the stromal cells of the fat pad. In the prepubertal ewe, adipose tissue binds GH, and probably stimulates the production and secretion of insulin-like growth factor-1 (Hovey et al., 1999). IGF-1 is a direct and potent mitogen for undifferentiated ruminant epithelial cells (Weber et al., 1999), and also, in gestation, for differentiated cells, stimulating DNA synthesis in ductal epithelial cells, secretory alveolar cells, and myoepithelial cells (Forsyth, 1995).

It is important to note that IGF-1 is highly mitogenic for undifferentiated mammary epithelial cells *at low concentrations*. Weber et al. (1999) reported that in vitro, additional IGF-1 caused epithelial cells to secrete binding proteins (IGFBP-2 and IGFBP -3) that bind IGF-1 with high affinity and regulate its bioactivity. It is suspected, therefore, that high feed levels in the prepubertal ruminant result in high concentrations of IGF-1, which in turn trigger production of binding proteins that render the mammary tissue insensitive to circulating IGF-1 (Sejrsen et al, 2000)

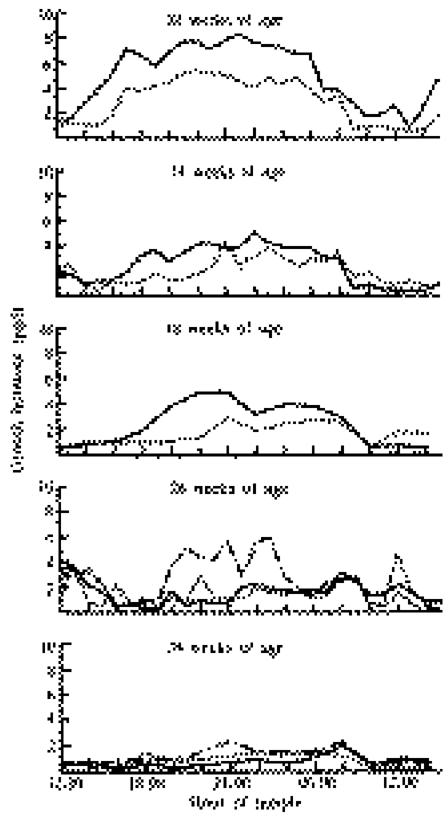

Figure 3. 24-hour plasma GH response to daily feeding of lambs on either HL (**…..**), LH (**__**), or LL (**_._**) feed levels. For all treatments, feeding occurred between 8.00 and 9.00 am.

From Johnsson et al., 1985.

A large number of other growth factors are involved in the regulation of mammogenesis, as either stimulators or inhibitors. Normal cells require more than one growth factor for mitotic cell cycle progression (Forsyth, 1995), and may require a sequential series of growth factor actions. Growth hormone is a dominant player in mammogenesis. How this hormone controls the growth factors, which in turn mediate hormonal actions, is still largely unknown.

In summary, restricted energy intake in the prepubertal ewe lamb allows full release of GH to 1) stimulate IGF-1 production and consequent mitogenic activity in mammary epithelia, and, through the lipolytic role of GH, to 2) make energy from adipocytes available to the rapidly-dividing ductal epithelia. Conversely, unrestricted energy intake in the prepubertal ewe inhibits GH release which, via an unknown mechanism, allows high concentrations of IGF-1 to trigger production of IGF binding proteins, thereby rendering the mammary gland less sensitive to mitogenic stimuli.

Onset of Puberty and Reproductive Performance

Puberty is the culmination of a gradual maturation process that begins before birth and is primarily determined by body weight and photoperiod (season). Within breeds of sheep or cattle, the main source of variation in age at the onset of puberty is level of feeding (Sejrsen and Purup, 1997).

Within seasonal limits, attainment of puberty appears to be determined by body weight rather than age. In both sheep and cattle trials, the restricted planes of nutrition were sufficient for the skeletal and body development required for sexual maturity (Stelwagen and Grieve, 1990; Johnsson and Hart, 1985)

While studying the effects of daily gain on mammary development, researchers have also observed effects of daily gain, particularly restricted gain, on reproductive performance. Overall, gain restricted to improve mammary development had no clear adverse impact on conception or lambing rate. Umberger et al. (1985), for instance, reported no difference in conception rate between prebreeding treatments, but found an increased lambing rate (1.41 vs 1.11) in ewe lambs on the higher level of feed. Conversely, McCann et al. (1989) found that ewe lambs on the higher feed level had improved conception (92% vs 88%) but no better lambing rate.

Effect of Diet Formulation

It appears to be dietary energy level, rather than ration formulation or total intake, that influences growth hormone release and subsequent mammary development. In heifers, the negative impact of feeding level is not affected by roughage type (corn silage vs grass silage vs barley straw; Hohenboken et al., 1995); by energy source (fiber vs starch; Houseknecht et al., 1988); by protein level or protein source (Sejrsen and Purup, 1997); or by concentrate/roughage ratio (Sejrsen et al., 2000).

Beef heifer weanlings were fed either high-energy-fiber (HEF), high-energy-starch (HES), or low-energy-fiber (LE) diets (Houseknecht et al., 1988; Table 3). Protein levels were similar across treatments; daily gain, as intended, was lower with the low-energy diet. The LE diet produced significantly higher levels of GH, while both HE diets produced higher levels of IGF-1, showing that serum GH and IGF-1 concentrations are influenced by dietary energy level rather than energy source.

Table 3. Growth hormone (GH) and insulin-like growth factor (IGF)-1 response to differing energy intakes and sources in beef heifers

	Rearing treatments			
	High energy - starch *(corn/soybean meal)*	High energy - fiber *(soy hulls/soybean meal)*	Low energy - fiber *(soy hulls/soybean meal)*	*Statistical significance*
ME, Mcal/kg	18.84	17.16	10.17	
CP, %	13.3	13.1	14.1	
NDF, %	34.7	63.8	61.4	
Daily gain, kg	0.92	0.88	0.42	*
GH, ng/ml	6.4	8.3	13.8	**
IGF-1, ng/ml	92.6	92.2	63.3	**

From Houseknecht et al., 1988

Specific effects of some nutrients cannot be ruled out, however, particularly the addition of polyunsaturated fats (PUF) to the diet. At five months of age, lambs on an ad-lib diet with a PUF supplement (sunflower seeds) had more parenchymal and fat pad development than either the non-supplemented ad-lib or the restricted-diet lambs (McFadden et al., 1990). Furthermore, Hovey et al. (1999) noted that a diet deficient in essential fatty acids impaired ductal growth, and that unsaturated fatty acids have been found to enhance the proliferative effects of mammary growth factors in vitro.

Optimum Growth Rate and the Influence of Genetics

What is the "optimal" growth rate in a prepubertal ruminant? What growth rate will be large enough not to limit necessary fat pad development but not so large as to depress growth hormone release and consequent mammary ductal proliferation?

Numerous trials with dairy heifers have revealed a curvilinear relationship between prepubertal growth rate and first lactation milk yield (see Sejrsen et al., 2000; Johnsson, 1988). Hohenboken, et al. (1995) found that when groups of Danish Friesian heifers were fed to achieve gains ranging between 0.50 kg/d and 0.90 kg/d, maximum milk yield was produced in groups gaining between 0.60 and 0.70 kg/d, or about 70-75% of maximum gain (Figure 4). By comparison, a group of British Friesians achieved 1.18 kg/d gain on an ad-lib diet (Harrison et al., 1988), and optimal parenchymal growth occurred at 0.57 kg/d, or about 50% of maximal gain. In trials with ewe lambs, improved mammary development occurred when lambs on restricted diets gained 74%, 53%, and 60% of the gain achieved on less-restricted diets (McCann et al., 1989, Johnsson and Hart, 1985, Umberger et al., 1985, respectively).

The genetic capacity for growth and milk yield has a large influence on determining the optimum gain for an individual or group. Hohenboken, et al. (1995), for instance, found that although the negative effect of feeding level existed and was similar across three dairy breeds, the optimum or injurious feeding level differed between breeds. Negative effects occurred when daily gain exceeded 0.35 kg/d in Jerseys, 0.55 kg/d in Danish Reds, and 0.65 kg/d in Danish Friesians. Heifers from the larger breeds ate more, grew faster, were heavier at calving, and produced more milk than Jerseys.

In a trial involving Hampshire Down-cross ewe lambs (Johnsson et al., 1985), large variation in GH secretory patterns and mammary development were observed within the same treatment. They suggested that during prepubertal allometric growth, restricted feeding will not affect mammary development of genetically poor animals, but will allow better development of glands in animals with higher genetic potential. This implies that there may be a separate, independent, mechanism for the genetic expression of mammary parenchymal growth.

Figure 4. Effect of prepubertal feeding level on subsequent milk yield in Danish Friesian heifers. Each point represents the mean of 17-18 heifers. Data from Hohenboken et al., 1995; figure from Sejrsen et al., 2000.

Similarly, calves, heifers, and cows sired by bulls with high genetic potential for milk production were found to have higher circulating levels of blood GH than animals sired by bulls from a random population (Akers, 1985).

Sejrsen et al. (2000) noted that at the same level of feeding, the genetic capacity for higher milk production is positively correlated with the genetic capacity for higher growth. Therefore, for groups with greater milk yield potential, optimum daily gain would be higher, and for an individual with higher milk yield potential, gain above the optimum would have less negative impact on lifetime milk production. And, within a prepubertal group or breed, at an optimum feed level, a higher genetically-based growth rate will be reflected in higher milk yield (Figure 5), whereas a higher growth rate due to increased feeding will be reflected in reduced milk yield potential.

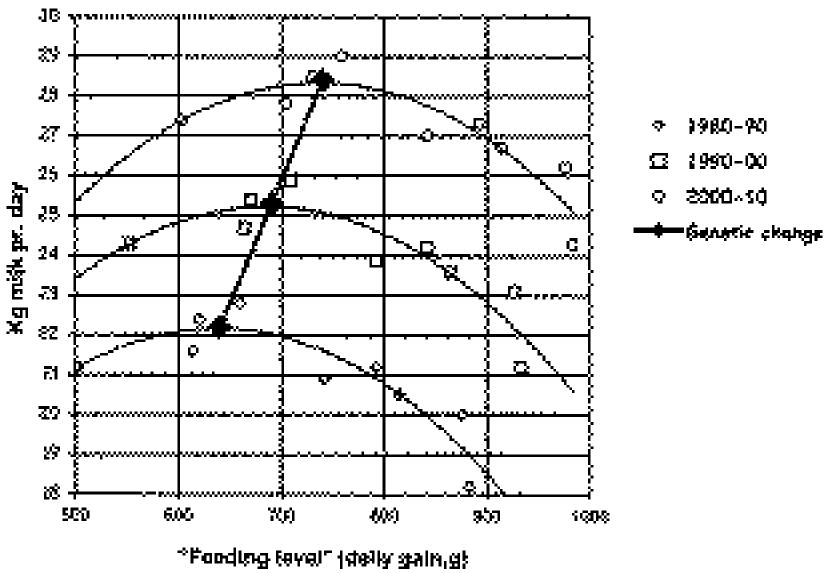

Figure 5. Illustration of the expected change in optimal daily gain with the increased genetic potential in milk yield in Danish dairy cattle from the 1980's to the 2000's. The relationship between feeding level and milk yield is unchanged and the higher optimal daily gain is achieved at the same feeding level. From Sejrsen et al., 2000.

Conclusions

Milk production is limited by the number of secretory cells in the udder. Diets excessive in energy, prior to puberty, inhibit the growth of the mammary epithelial tissue that will later sprout the milk-producing alveolar cells, and thus also limit lifetime milk yield. It is therefore recommended that dairy sheep producers should restrict the energy intake of replacement ewe lambs to about 65 to 75% of their ad-libitum intake. This will increase the rate of mammary growth and increase the total amount of epithelial tissue that will later develop into milk-secreting alveolar cells.

The negative impact of high-energy diets on ewe lambs is greatest starting at about 4 to 6 weeks of age and declines over the next few months of age, due to both the reduced concentration of circulating growth hormone and the lessening influence of growth hormone on mammary tissue. At the end of this phase of rapid duct extension, the absolute amount of ductal tissue, the degree of ductal penetration into the mammary fat pad, and the final size of the fat pad, will be primary determinants of the ultimate size of the adult lactating mammary gland.

Early puberty, especially before 20 weeks of age, may substantially reduce mammary gland development in rapidly-reared ewe lambs by curtailing both the rate and the duration of the allometric growth phase. Increased feed levels after 20 weeks have less influence on mammary development and can improve liveweight at breeding.

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EFFECT OF FREEZING ON MILK QUALITY

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Abstract

Raw whole ovine (sheep) milk was frozen at -15°C and -27°C and microbiological and physico-chemical properties were evaluated periodically. Total bacteria decreased at a faster rate in milk stored at -15°C than at -27°C. Acid degree values for milk stored at -15°C were significantly higher than that stored at -27°C. Samples stored at -15°C exhibited protein destabilization after 6 months of storage while those stored at -27°C were stable throughout the 12 month storage period.

Frozen ovine milk was evaluated in several products including cheese and yogurt. Yogurt produced from milk frozen at -27°C exhibited good sensory and functional characteristics while that produced from milk frozen at -12°C for 3 mo or more exhibited poor gel strength.

(**Key words**: ovine, sheep, milk, freezing, whey)

Introduction

The U.S. dairy sheep industry is still in the early stages of development. In the mid-1980's, Dr. Boylan of the University of Minnesota conducted a number of studies in the hopes of helping promote a dairy sheep industry in the U.S. (Boylan, 1984, Boylan, 1986). Working with cheese researchers at the University of Minnesota, they evaluated the potential for producing Feta, Manchego, and Bleu cheese from ovine milk (Boylan, 1986). Additional developmental work in the upper Midwest was conducted by Dr. Steinkamp of LaPaysanne, Inc. (Steinkamp, 1994). The first commercial dairy sheep flocks were established about 10 years ago and their numbers have grown to approximately 100 at the present time.

In 1996, the University of Wisconsin-Madison accepted the mission of furthering research on dairy sheep production and management. Since then, Dr. David Thomas of the Animal Sciences Department and Yves Berger of the UW Agricultural Research Stations have been conducting extensive research on the genetics and management systems impacting ovine milk production (Thomas et al., 1999, 2000). Research on handling and processing ovine milk has also been conducted by faculty within the University of Wisconsin Food Science Department (Casper et al., 1998, 1999; Ha and Lindsay, 1991; Jaeggi et al., 2000; Kilic, 1999; Ponce de Leon-Gonzalez, 1999; Rauschenberger et al., 2000; Wendorff, 1998, 2001).

With seasonal production and low levels of milk production per ewe, raw milk typically is frozen at the farm until sufficient quantities are accrued for further processing. In the first several years of ovine milk production in Wisconsin, commercial cheese plants experienced some problems with milk quality and stability with frozen raw ovine milk supplied by the dairy sheep cooperative. Some of our research studies concentrated on the projected shelf-life of the frozen raw ovine milk and factors impacting raw milk quality during frozen storage. This paper will review factors affecting quality of frozen raw ovine milk and impacts on processed products produced from frozen milk.

DISCUSSION

Stability of Frozen Raw Milk

Mid-lactation ovine milk was obtained from the University of Wisconsin Experimental Station at Spooner, WI. The milk was immediately cooled to 4°C and transported to the laboratory in Madison. Gross composition of the milk is shown in Table 1. The raw milk was packaged in sterile 170 ml polyethylene containers and 13.5 kg polyethylene pails with a 2-mil polyethylene liner. One set of containers and pails was frozen and stored in a home freezer at -15°C. The other set of containers and pails was frozen and stored in a commercial freezer at -27°C. A sample container and pail were removed from each freezer after 3, 6, 9 and 12 months of storage and thawed in a cooler at 4°C. When thawed, samples were analyzed for total bacteria, coliform bacteria, acid degree value (ADV) and intact protein. Intact protein was defined as the total protein content of milk minus the protein present in sediment at the bottom of container or pail.

Both total bacteria and coliforms decreased at a faster rate in milk stored at -15°C than milk stored at -27°C (Table 2). Milk that was frozen at -15°C developed larger ice crystals than milk that was flash-frozen at -27°C. Those larger ice crystals formed at higher freezing temperatures tend to be more destructive to bacteria than smaller ice crystals formed in flash-freezing at lower temperatures (Jay, 2000). It has also been reported that gram-negative rods tend to be more susceptible to freezing damage than cocci (Georgala and Hurst, 1963). ADVs for milk stored at -15°C were significantly higher than for those samples stored at -27°C (Table 3). In spite of the increases in ADV with storage, samples did not exhibit a rancid flavor within the 12 months of storage. Several researchers (Antifantakis et al., 1980; Needs, 1992) have reported an increase in free fatty acids with frozen storage of ovine milk. Needs (1992) reported a significant loss of residual lipase activity in ovine milk after 6 months of storage at -12°C and -20°C. However, Voutsinas et al. (1995) reported no significant differences in lipolysis or lipid oxidation when concentrated ovine milk was stored at -20°C for up to 6 months.

After 6 mo of frozen storage at -15°C, thawed milk samples exhibited protein destabilization with flocculated protein settling at the base of containers. After 9 mo of storage, over 20% of the protein was lost in the sediment (Table 3). Samples stored at -27°C exhibited good protein stability throughout the 12 mo of storage. Storage stability results were comparable for the 170 ml containers and the 13.5 kg pails throughout the study. Previous researchers have reported good protein stability in frozen ovine milk if stored below -20°C (Antifantakis et al., 1980; Bastian, 1994, Young, 1985). Young (1987) did observe separation and recombination problems in ovine milk stored at -12°C for 12 months. Koschak et al. (1981) reported that frozen bovine milk and milk concentrates stored at -20°C or lower remain stable for long periods of time but stability decreases greatly as the temperature is raised above -20°C.

Protein stability of frozen bovine milk has been extensively researched over several decades. The destabilization of proteins in bovine milk during frozen storage was primarily due to the casein fraction (Desai et al., 1961). Several factors impacting casein destabilization included; time and temperature of storage (Tracy et al., 1950; Koschak et al., 1981); milk concentration (Bell and Mucha, 1952); lactose crystallization (Desai et al., 1961); and prefreezing heat treatment, (Braatz, 1961). El-Negoumy and Boyd (1965) concluded that free calcium in milk was the primary cause of protein instability in frozen bovine milk. Several pretreatments were recommended to improve protein stability in frozen milk concentrates: lactose hydrolysis (Stimpson, 1954), prefreezing heat treatment to resolubilize lactose (Braatz, 1961), and addition of sodium hexametaphosphate (Riddle, 1965). To determine if any of these pretreatments might aid in stabilizing the protein in ovine milk during frozen storage, mid-lactation ovine milk was processed by one of the following treatments and frozen at -12°C:

1) addition of 4 g of sodium hexametaphosphate per L of raw milk.
2) heat the milk to 68.5°C for 25 min prior to freezing.
3) a combination of pretreatments (1) and (2).
4) enzymatic hydrolysis of at least 30% of the lactose in milk.
5) control, no pretreatment.

Samples were frozen in 170 ml polyethylene containers. A comparative control sample was also frozen and stored at -27°C for 12 mo. A sample container of each pretreatment and control was removed from the -12°C freezer after 3, 6, 9 and 12 months of storage and thawed in a cooler at 4°C. When thawed, samples were analyzed for acid degree value (ADV) and intact protein. Complete results are being reported in Abstract 346 at this Annual Meeting (Rauschenberger et al., 2000). In summary, lactose hydrolysis and treatments with the addition of hexametaphosphate did help stabilize the proteins in milk frozen and stored at -12°C for up to 12 mo. The results from these pretreatments indicate that higher calcium in ovine milk most likely contributed to the instability of the milk frozen at -12°C. These results were similar to those observed in bovine milk concentrates (Muir, 1984). Since the addition of hexametaphosphate has been reported to contribute a salty flavor to milk and cause potential destabilization of the fat (Muir, 1984), this may not be a viable pretreatment to use in freezing ovine milk in a home freezer at -12°C. At -27°C, stabilizing effects of high viscosity and low kinetic energy limit lactose crystallization and protein aggregation (Johnson, 1970).

Quality of Yogurt from Frozen Milk

Since the majority of ovine milk is seasonally produced, yogurt manufacturers are dependent on treatments, such as freezing, to extend the milk supply throughout the year. Several researchers (Antifantakis et al., 1980; Voutsinas, et al., 1996) have reported that good quality yogurt could be produced from frozen ovine milk. However, several yogurt manufacturers in the U.S. have reported quality problems when producing yogurt from frozen ovine milk. The objective of this study was to determine the effects of frozen storage of ovine milk on the quality of yogurt.

Mid-lactation ovine milk was obtained from the University of Wisconsin Experimental Station at Spooner, WI. The milk was immediately cooled to 4°C and transported to the laboratory in Madison. The raw milk was packaged in 2.1 L polyethylene containers. One set of containers were frozen and stored in a home freezer at-12°C. Another sample was frozen and stored in a commercial freezer at -27°C for comparative purposes. A sample container was removed from the -12°C freezer after 1, 3, 6, 9 and 12 months of storage and thawed in a cooler at 4°C. When thawed, milk was heat-treated at 82°C for 30 min and cooled to 44°C. Milk was inoculated with 0.02% commercial yogurt culture of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* (YC-470, Chr. Hansen, Inc., Milwaukee, WI) and 0.02% culture of *Lactobacillus acidophilus* (LA-K, Chr. Hansen, Inc., Milwaukee, WI). The fermentation was continued until the pH of the yogurt reached 4.6. The yogurt was immediately cooled to 4°C with ice water and placed in a 4°C cooler. The pHs of the yogurts, at 24 hr, ranged from 4.3 to 4.4. Samples were analyzed for titratable acidity, syneresis, water holding capacity and gel strength.

Syneresis and water holding capacity of yogurts made from frozen milk, throughout the 12 mo study, were not significantly different than that of the of yogurt made from the initial fresh milk. Titratable acidity of the yogurts produced from frozen milk after 3 mo of storage were significantly lower than yogurt made from fresh milk (Table 4). Since pH values for the yogurts were similar throughout the study, buffering capacity of the frozen milks was reduced due to loss of salts or proteins. Visual evidence of protein destabilization was observed after 6 mo of storage at -12°C. However, the protein could be resuspended and stabilized with the pasteurization treatment. Gel strength was significantly reduced in yogurts made from milk after 9 mo of frozen storage at -12°C (Table 4). Destabilized protein, in milk stored at –12°C, apparently interfered with the binding of milk proteins in the formation of the yogurt gel. Yogurt produced from milk stored at -27°C for 12 mo was comparable to that produced from fresh milk (Table 5).

Results of this study indicate that good quality yogurt can be produced from frozen ovine milk if frozen and stored at -27°C for up to 12 months. Antifantakis et al. (1980) and Young (1987) also obtained acceptable quality yogurt from ovine milk frozen and stored at -20° to -30°C for up to 11 months. Young (1987) reported an unacceptable clot in yogurt from milk stored at -12°C for 12 mo. Voutsinas et al. (1996) reported that good quality yogurt could be produced from whole ovine milk that was concentrated and stored frozen at -20°C for 6-8 mo. However, yogurts produced from frozen, concentrated ovine skim milk were of inferior quality compared to the initial fresh milk.

Summary

The future potential for production of high quality specialty products from ovine milk is very promising. However, proper handling of the milk is critical to the overall quality and yield of processed products. Ovine milk should be rapidly frozen and stored at -27°C or lower for maximum protein stability. If limited to frozen storage in home freezers (-12°C), frozen storage should be limited to 3 mo maximum.

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TABLE 1. Gross composition of ovine milk at start of storage study[1]

Component	%, wt/wt
Total solids	16.1
Fat	5.9
Protein	5.1
Ash	0.8
Lactose (by difference)	4.3

[1] duplicate determinations

TABLE 2. Microbial population for frozen ovine milk stored at -15°C and -27°C up to 12 months

Time of	SPC (CFU/ml)		Coliforms (CFU/ml)	
Storage (mo)	-15°C	-27°C	-15°C	-27°C
0	8200 [a]	8200 [a]	44 [a]	44 [a]
1	4100 [a]	4100 [a]	26 [a]	10 [a]
2	2500 [a]	3200 [a]	21 [a]	9 [a]
3	3400 [a]	3700 [a]	12 [a]	12 [a]
6	2200 [a]	2800 [a]	<1 [b]	8 [a]
9	340 [b]	2700 [a]	<1 [b]	8 [a]
12	610 [b]	1800 [a]	<1 [b]	5 [a]

[a,b] Means for SPC or coliforms within the same row without a common letter differ (*P* <0.05)

TABLE 3. Acid degree value (ADV) and intact protein content for frozen ovine milk stored at -15°C and -27°C up to 12 months

Time of	ADV (ml of 1N KOH/100 g of fat)		Intact protein (%)	
Storage (mo)	-15°C	-27°C	-15°C	-27°C
0	.22 [a]	.22 [a]	5.1 [a]	5.1 [a]
1	.25 [a]	.26 [a]	5.1 [a]	5.1 [a]
2	.42 [a]	.32 [b]	5.0 [a]	5.0 [a]
3	.35 [a]	.29 [a]	5.0 [a]	5.0 [a]
6	.41 [a]	.31 [b]	5.0 [a]	4.9 [a]
9	.42 [a]	.28 [b]	3.4 [b]	4.9 [a]
12	.49 [a]	.35 [b]	3.9 [b]	5.0 [a]

[a,b] Means for ADV or intact protein within the same row without a common letter differ (*P* <0.05)

TABLE 4. Titratable acidity and firmness of yogurt produced from ovine milk frozen and stored at -12°C

Time of storage (mo)	Titratable acidity (%, as lactic acid)	Gel firmness (g)
0	1.25 [a]	125 [a]
3	0.99 [b]	99 [a]
6	0.93 [b]	83 [b]
9	0.87 [b]	59 [b]
12	0.90 [b]	72 [b]

[a,b] Means within the same column without a common superscript differ (*P* < 0.05).

TABLE 5. Characteristics of yogurts produced from ovine milk frozen and stored at –12°C and -27°C for 12 mo

Characteristic	Initial milk	Stored at -12°C	Stored at -27°C
Titratable acidity, %	1.25 [a]	0.90 [b]	1.18 [a]
Syneresis, %	75.1 [a]	79.7 [a]	77.5 [a]
Water holding capacity, %	28.5 [a]	25.7 [a]	30.4 [a]
Firmness, g	125 [a]	72 [b]	109 [a]

[a,b] Means within the same row without a common letter differ (*P* <0.05).

LATEST DEVELOPMENT IN THE USE OF RAW MILK FOR CHEESEMAKING

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Introduction

Since 1949, cheesemakers could use one of two methods to assure the safety of cheese that they produced: 1) pasteurize milk intended for cheesemaking or 2) hold the finished cheese at a temperature of not less than 35°F for at least 60 days (US FDA, 2000). Research over the years has shown that various pathogens can survive well beyond the mandatory 60 day aging period in various cheeses (Table 1). In April 1997, FDA ask the National Advisory Committee on Microbiological Criteria for Foods if a revision of the policy requiring a minimum 60 day aging period for raw milk hard cheeses was necessary to ensure the safety of hard cheeses for U.S. consumers (Donnelly, 2001). Some of this concern was initiated when Wisconsin temporarily lost the TB-free status due to TB-contaminated animals being transported in from Upper Michigan (Anonymous, 1995). Additional concerns came from a report by Reitsma and Henning (1996) detailing the survival of *E. coli* 0157:H7 in aged Cheddar cheese. The Institute of Food Science and Technology (IFST) in the UK also issued a caution on the potential health hazards posed by pathogenic bacteria in raw milk cheeses, especially soft and semi-soft cheeses (IFST, 2000). In 1999, FDA initiated challenge studies with *E. coli* 0157:H7 in raw milk Cheddar cheese to determine the effectiveness of the aging period in eliminating the potential pathogen. At the same time, they started a comprehensive review on the safety of raw milk cheeses.

The American Cheese Society, in conjunction with Oldways Preservation and Exchange Trust and the Cheese Importers of America, were very concerned with the potential that FDA may ban raw milk cheeses. In March 2000, they formed the Cheese of Choice Coalition to work with FDA to preserve their ability to manufacture and import raw milk cheeses under the existing food regulations. In November 2000, they hired Dr. Catherine Donnelly of the University of Vermont to assist in a thorough review of the past safety of raw milk cheeses. She recently presented her findings at this year's American Cheese Society meeting in Louisville, KY (Donnelly, 2001). Following is a summary of her findings:

Reviews on Safety of Raw Milk Cheeses

Johnson et al. (1990) conducted a comprehensive review of epidemiological literature from 1948-1988. They identified only six outbreaks of illness transmitted via cheese produced in the U.S. during this period. The use of raw milk was a factor in one outbreak each in the U.S. and Canada. No outbreaks were reported for hard Italian cheeses, such as Parmesan, Romano and Provolone. In rare instances, Swiss and Cheddar cheeses were linked in outbreaks.

Altekruse et al. (1998) reviewed all cheese associated outbreaks reported to the CDC during the period 1973-1992. There were 32 cheese-related outbreaks, 11 of which could be attributed to contamination at the farm during manufacturing or processing. Of the 11 outbreaks, 5 were related to consumption of Mexican-style soft cheese whereas only 1 outbreak was related to Cheddar cheese. The authors suggested that aging alone may not be a sufficient pathogen control step to eliminate *Salmonella*, *Listeria*, and *E. coli* 0157:H7 from cheese.

Recent Outbreaks involving Cheddar Cheese

Four outbreaks occurring in the late 1990s were reported in the U.K. Three of these cases involved *E. coli* 0157:H7 and the fourth case was caused by *Salmonella* (Donnelly, 2001). All four outbreaks were caused by incomplete pasteurization or use of raw milk for cheesemaking. An outbreak of *E. coli* 0157:H7 was the result of using raw milk to produce Cheddar cheese curds that were sold fresh from the plant (Durch et al., 2000).

While outbreaks of illness have resulted from presence of *L. monocytogenes* in soft ripened and Hispanic-style cheeses, no outbreaks of listeriosis have been reported as a result of *Listeria* surviving in cheese aged for a minimum of 60 days.

Challenge Studies

Reitsma and Henning (1996) examined the survival of *E. coli* 0157:H7 during manufacture and aging of Cheddar cheese. They used milk with two levels of *E.coli*, 1000 cfu/ml and 1 cfu/ml. The cheese with 1000 cfu/ml in the milk showed a 2-log reduction after 60 days of aging but still contained *E. coli* after 158 days of aging. The cheese with 1 cfu/ml in the milk had no detectable *E. coli* after 60 days of aging.

Conclusions from Review

Aged hard cheeses made from raw milk are microbiologically safe when manufactured under conditions that use milk screening procedures, good manufacturing practices and HACCP. Legitimate concerns can be raised regarding the safety of soft and semisoft cheeses manufactured from raw milk, as well as high moisture, low salt aged cheeses. They recommend a strategy that involves routine testing of incoming lots of raw milk and working with producers when infected animals are identified to allow treatment and confinement of animals to control infectious disease.

Pathogens in Raw Milk

Surveys of various groups of producers have shown low levels of individual pathogens in raw milk at the farm (Table 2). Some levels of pathogenic bacteria may be low but Jayarao and Henning (1999) pointed out that 32% of milk at the farm contained at least one pathogen. When milk from a number of farms is commingled, e.g., at a commercial cheese plant, levels of pathogens in loads of milk are significantly increased (Ingham et al., 1997). If using commingled milk for commercial cheese production, a cheesemaker must assume that the load of milk most likely will contain pathogens, especially *S. aureus.*

Current FDA Studies on Raw Milk Cheeses

FDA is currently running studies to determine how effective the 60 day aging period is for reducing potential pathogens in Cheddar cheese. Hard cheese was made from unpasteurized milk inoculated with 10^3 and 10^5 *E. coli* 0157:H7 and aged under standard aging conditions of 7°C (45°F). Populations of *E. coli* were reduced by 1 log at 60 days and 1-2 logs at 90 days of aging (Schlesser et al., 2001). Populations of *E. coli* in cheese aged for 180 and 240 days were reduced by 2-logs and 3-logs, respectively. Additional studies are now being conducted with *Salmonella* as the test pathogen.

Potential Future Regulations covering Raw Milk Cheeses

With the current information available to FDA on potential presence of pathogens in raw milk and the limited reduction of pathogens during the standard 60 day aging period, FDA will be proposing new regulations within the next 2 years. The U.S. FDA has recently stated, “a review of the literature relating to the potential for growth of pathogens in hard cheeses that are aged for at least 60 days shows that such growth is not likely to occur because of the combined effect of decreased pH, decreased water activity, and possibly other factors inherent to these cheeses" (USFDA, 1999). However, in the recently released HHS and USDA *Listeria* risk assessment and *Listeria* action plan, USDA and FDA advise pregnant women, older adults and people with weakened immune systems that "cheeses that may be eaten include hard cheeses; semi-soft cheeses such as Mozzarella; pasteurized processed cheeses such as slices and spreads; cream cheese; and cottage cheese." However, persons residing in these risk groups are advised "do not drink raw (unpasteurized) milk or eat foods that contain unpasteurized milk." (USDA, 2001). Following are potential regulations that may be proposed:

Full pasteurization of all cheese milk

This was the first fear that most cheesemakers had when the question of safety of raw milk cheeses was first raised in 1995-96. However, with the statement made in 1999 concerning the safety of hard cheeses (listed above, USFDA, 2001) and the dialogue going between the FDA and American Cheese Society, indications are that FDA may be willing to accept raw milk hard cheeses that are aged for 60 days. FDA will most likely require some additional regulations concerning the potential presence of pathogens in raw milk used for cheesemaking. Soft ripened and semisoft ripened cheeses will be required to be manufactured from pasteurized milk.

Raw milk hard cheeses with HACCP at the farm (Amer. Cheese Soc. Plan)

This is the current recommendation for future production of raw milk hard cheeses being proposed by the Cheese of Choice Coalition. Critical control points in the HACCP program at the farm would include antibiotic testing, temperature requirements on cooling and holding of the raw milk and routine testing of incoming lots of raw milk for pathogens to ensure safety of raw milk cheeses. The difficult aspect of this proposal involves the cost and time of analysis for pathogens in the raw milk. What pathogens do you test for and do all lots of milk have to be tested for pathogens? Assuming that you get some reduction of pathogens during the 60 day aging period, will FDA allow a minimum level of pathogens (for instance, <10/g) to be established in the raw milk. Since testing for pathogens will take some time, what do you do with the cheese that was produced from raw milk that does contain some confirmed pathogens? Do you then have to have analysis of the finished aged cheese to confirm that the product is indeed safe?

ACS covers Cheddar, Swiss, Parmesan and Romano in their review of safety on aged raw milk cheeses. Their recommendation is to allow aged hard cheeses to be produced from raw milk but have not defined "hard cheeses". Would that be limited to cheeses with less than 42% moisture or an a_w of less than 0.95? Semisoft and soft cheeses would require pasteurized milk for their production.

Raw milk cheeses produced with HACCP at the farm (Oregon Plan)

In 1993, there were several outbreaks of *E. coli* 0157:H7 in Oregon linked to raw milk (Anonymous, 1993). Rather than ban raw milk sales in Oregon, the state regulatory agency stated that raw milk for sale would have to meet the Grade A Pasteurized Milk Standards of <20,000/ml SPC and <10/ml coliforms. If the 10 coliform/ml limit was used as a critical control point (CCP), then there would never be more than 10 *E. coli*/ml in the cheese milk. Since FDA (Schlesser et al., 2001) has shown that a 1 log reduction of *E. coli* is experienced with 60 days of aging, a raw milk with <10/ml coliforms should produce a cheese with undetectable *E. coli* 0157:H7. The coliform analysis would be much quicker and cheaper than performing pathogen testing on raw milk at the farm. This may give us some measure of the safety potential for *E. coli* but other pathogens, e.g., *Listeria* do not necessarily correlate with coliform counts (C.W. Donnelly, personal communication). Other microbiological hurdles would have to be in place.

Heat treatment of all milk for aged cheeses

Johnson et al. (1990) proposed a heat treatment of milk for cheesemaking of 148°F for 16 sec or equivalent to reduce the potential for pathogens in milk used for cheese. Many of our commercial plants are producing "raw milk cheeses" using heat treatments of 154-158°F for 15 sec on their milk for cheesemaking. This heat treatment eliminates most of the potential pathogens and yet does not eliminate all the secondary microflora in the milk that contribute to the full flavor of raw milk cheeses. Over 95% of raw milk aged cheeses in Wisconsin are produced from heat-treated milk. There is some concern that the current labeling of raw milk cheeses does not differentiate between heat-treated milk and true raw milk cheeses. This may be addressed in future labeling requirements for true raw milk cheeses, similar to unpasteurized fruit juices (Anonymous, 1998).

Warning label on all raw milk cheeses

In 1996, severe outbreaks of *E. coli* 0157:H7 in fruit juices and apple cider prompted FDA to establish requirements for warning labels on unpasteurized juices. This label is required on all juices not produced under a system validated to reduce *E. coli* 0157:H7 by 5 logs (Anonymous, 1998). The warning label must state: "WARNING: this product has not been pasteurized and, therefore, may contain harmful bacteria that can cause serious illness in children, the elderly, and persons with weakened immune systems". This warning label on unpasteurized juices has established a president that FDA could follow on raw milk cheeses.

The cider makers have found that most of the supermarkets and chains now handle only pasteurized juices. Smaller cider makers selling at farmers markets, etc, have found that their customers have adjusted to the warning labels and markets have stabilized. Within the next couple years, FDA will require all cider makers selling product wholesale to pasteurize their cider. Small processors will be allowed to sell unpasteurized juices, with warning labels, to retail customers only.

Some version of this labeling requirement may be proposed for raw milk cheeses by FDA. The question will be what cheeses FDA may allow to be produced from raw milk. Since the Cheese of Choice Coalition is concentrating on preserving raw milk hard cheeses, I would anticipate that FDA may propose that soft ripened and semisoft ripened cheeses would be required to be produced from pasteurized milk. If somehow, FDA would allow raw milk to be used for soft or semisoft cheeses, there would definitely be a requirement for warning labels to protect the consumer.

Conclusion

FDA is responsible for overseeing the safety of our food supply. They are aware that the 60 day aging period does not effectively eliminate pathogens from all varieties of cheese. There have been numerous recalls of soft and semisoft cheeses in the past few years due to presence of pathogens, e.g., *Listeria* and *E. coli* 0157:H7. In the next 2 years, FDA will be revising the regulations covering the potential production of raw milk cheeses. What the final regulation will look like is hard to guess at this point. However, with the fruitful discussions that are ongoing between the Cheese of Choice Coalition and FDA, there is hope that there may be some allowance for raw milk hard cheeses. In the end, FDA will still want to ensure the safety of all cheeses consumed by U.S. consumers.

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THE AUSTRALIAN SHEEP DAIRY INDUSTRY: HISTORY, CURRENT STATUS AND RESEARCH INITIATIVES

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Introduction

Australia has a large ethnic population of European origin and imports some $8 million worth of sheep milk products every year (Dawe and Langford, 1987). About 8,000 tons per year of sheep milk products could find a market in Australia and to match this demand 250,000 ewes would have to be milked in 100-150 dairies (Dawe, 1990). Sheep dairying is not completely new for Australia: between 1963 and 1975 two sheep dairies operated in Victoria and in 1972 Peter Tavella started a sheep dairy and a cheese factory at Leeton, New South Wales (Dawe and Langford, 1987). In the same area, also S.T. Dawe and C.M. Langford were researching on sheep dairying at the Leeton Research Station of the Department of Agriculture. The lack of interest and the wrong economic environment caused, according to Dawe (1990), the unsuccessful outcome of the Tavella enterprise. In 1985 an export market for 4-6 week old lambs was established with Italy, and this revived the sheep dairy industry (Dawe, 1990). However, due to organisational problems the suckling lamb market failed (S.T. Dawe, Pers. comm.).

Jumbuck Dairy operated very successfully between 1989 and 1993. A decision to move their operations to new South wales turned out to be fatal for the company (I. Temby, Pers. comm.).

The Australian sheep milking industry is still relatively small, but it is growing. In 1987 there were only five sheep dairies operating in Australia. This number has now risen to 20 dairies mainly concentrated in Victoria, milking a total of 5000 to 10000 ewes. At the moment, returns from sheep milk are about $100-150 per ewe per year, which is high if compared with the traditional production of wool and prime lambs. However, there are high costs associated with the purchase of the milking machinery, with the milking operations and with the rearing of the lambs, which make the milking of sheep barely profitable.

Sheep milking has a distinctive advantage over other new animal industries: sheep farmers would not need to change much of the infrastructure because they would be still farming the same animals, and little new expertise would also be required.

Sheep milk has high farm gate returns of 1.20-1.50/litre and there are local and export markets for sheep milk products. The recent GATT agreement should stop the EEC from protecting their sheep milk products, so that Australia will have a chance to compete on the international market (Bencini and Dawe, 1998).

Despite this, the sheep milking industry is still in its infancy and many sheep dairies have appeared and disappeared over time. Three major reasons for this were identified at The University of Western Australia where we have been conducting research to address these problems for the last 10 years. These are outlined below.

The lack of productive dairy sheep

Australia does not have specialised breeds of dairy sheep. The pioneering sheep dairy farmers of the 60s, 70s and 80s were milking local breeds of sheep that produce less than 100 litres of milk per lactation, and this level of production is not profitable (Bencini and Dawe, 1998). Farmers may have been mislead, in part, by results produced at Leeton Research Station were some sheep produced 150 litres per lactation (Dawe, 1990). Many farmers converted to sheep milking based on yields of one litre per head per day, which are in fact rarely achieved when starting a sheep dairy with unselected sheep. With time and heavy culling, the yield of the local breeds can be lifted to one litre per day and above. These are for instance the yields recorded on local crossbred sheep at Cloverdene sheep dairy. Cloverdene has been selecting for milk production since 1992, when they started their operation. How much of this gain is due to genetic improvement and how much to environmental factors is not known.

Because milk production is only expressed by ewes, genetic improvement for milk production can only be achieved through a progeny-testing scheme similar to those used in dairy cattle and overseas dairy sheep. Although this idea has been contemplated by ‘Lambplan’ (R. Banks, Pers. comm.) and by the Rural Industries Research & Development Corporation (RIRDC), the sheep milking industry at present does not have the resources to undertake such a program.

A solution to the problem of low productivity of the local breeds could be the importation of specialised dairy breeds of sheep from overseas. Recently two breeds of sheep that have the highest production of milk in the world, the Awassi and the East Friesian (Epstein, 1985; Anifantakis, 1986) have been imported into Australia. These two breeds have the potential to increase yields and make sheep milking economically viable. However, in both cases, only small numbers of animals were actually imported, and their dairy potential under Australian conditions had not been measured before. As sheep from these new breeds are expensive, farmers are likely to milk the crosses of these breeds with local sheep.

The Awassi fat tail sheep has been milked for thousands of years in the Middle East and has recently been improved for milk production, with reported productions of 1000 litres of milk per lactation (Epstein, 1982). The Awassi sheep were imported into Western Australia as frozen embryos in 1986 and came from a flock that had been highly selected for milk production in Israel and was subsequently imported to Cyprus (Lightfoot, 1987). A different importation of Awassi sheep occurred in New South Wales. These Awassi sheep came directly from a high producing flock in Israel to Flock House Agricultural Centre in New Zealand, from where they were transferred in Australia within four years.

The company Silverstream imported East Friesian sheep to New Zealand in 1991. After a period of quarantine they were made available for sale in Australia. The East Friesian is the highest milk producing dairy sheep in Europe, with yields of over 600 litres per lactation (Kervina et al, 1981; Casu and Sanna, 1990). It has been imported in many countries to produce crosses with local breeds, thereby originating the Assaf in Israel, the Frisonarta in Greece, the FLS in France, and the Friserra in Portugal (Flamant and Barillet, 1982). However, crosses with the Awassi have shown no adaptation to the harsh environment of Israel (Eyal and Goot, 1969; Mills, 1989) and Sardinian farmers complain about similar adaptation problems with the East Friesian x Sarda crosses (personal observation). Other attempts to introduce the East Friesian sheep in the Mediterranean region have failed, as the breed is not adaptable to harsh conditions and to flock management (Flamant and Morand-Fehr, 1982). The genetic improvement of the local breeds is attracting more attention since they appear to be better suited to their environments (Treacher, 1987).

The University of Western Australia Sheep milking research project aims at evaluating the dairy potential of the Awassi and East Friesian sheep and their crosses with local breeds to establish which cross has the best potential for dairy production.

The lack of typical Australian sheep milk products

The second problem faced by the Australian sheep milk industry is the fact that because sheep milking is not a tradition in our country, we do not have typical Australian sheep milk products. The majority of manufacturers entering the industry were aware of the importation of sheep milk products from overseas for the local ethnic communities. Therefore, their first attempts concentrated on imitating imported overseas cheeses such as the famous Pecorino and Fetta. However, these cheeses are protected by tariffs and DOC trademarks, or suffer from serious competition from cheap cow's milk imitations. Moreover, some of these cheeses (e.g. the Pecorino) require long maturation times involving high storage costs and risk of spoilage during storage.

These cheeses also have very strong flavours and they are imported and consumed within the local ethnic communities who are used to their strong taste. Australian consumers, by contrast, like milder products (e.g. Colby instead of matured Cheddar; Burton, 1990).

In overseas countries where milking sheep is an ancient tradition, most of the sheep milk produced is transformed into cheese and some into yogurt (Bencini and Pulina, 1997). It is probably for this reason that manufacturers entering the industry initially produced only cheese and yogurt. However, novelty products, fresh products, and healthy and low fat products nowa-days also attract consumers.

We believe that a viable sheep milking industry could only be established by developing typical Australian sheep milk products. These will eventually not only replace some of the importations, but also will be exported similarly to Australian wines. Our research project aims at developing new sheep milk dairy products including specialty cheeses, yogurt and ice cream that should be acceptable to Australian consumers and to investigate potential markets for these products.

Lambs

The third problem faced by the sheep milking industry is that of the disposal of lambs. If lambs are left with their mothers the amount of milk they drink even with early weaning is such that the whole operation becomes unprofitable. Many farmers have concluded that it is better to kill the male lambs at birth and keep the females for replacement, either artificially feeding them or by allowing their mothers to wean them. This solution has animal welfare implication and is disliked by many farmers (T. Dennis, Pers. comm.). Moreover, sheep milking is relatively new with consumers that are curious and occasionally reluctant to accept even the idea of milking a sheep. It is possible that consumers could be turned off by the idea that newborn lambs are killed to produce the milk. Some farmers attempted feeding the lambs artificially, similarly to what is done in the dairy cattle industry. However, artificial feeding is extremely expensive and labour intensive. Lambs tend to get sick and die, which increases dramatically the cost of the operation.

Overseas countries that have a tradition for milking sheep also have markets for young milk-fed lambs. For example in Italy, male milk-fed lambs are slaughtered at 4 weeks of age and 6-8 kg body weight. It is very common to see a whole lamb carcass sold in butcher shops fetching prices of $25-35/kg. The females to be used for replacement are kept with their mothers for longer, but the sale of young male lambs allows the shepherds to start milking the flock relatively early in lactation. In Australia the traditional lamb consumed is the prime lamb (once called fat lamb), a 20-30 kg beast that has been weaned by its mother and has eaten grass. By the time a prime lamb is ready for market its mother has stopped lactating and would be of no use for milking.

Therefore, our research effort concentrated on investigating economically viable methods to wean the lambs and markets for milk-fed lambs.

Dairy potential of Awassi sheep

Our research has shown that first cross Awassi x Merino sheep produce more milk than local Merino sheep (Figure 1).

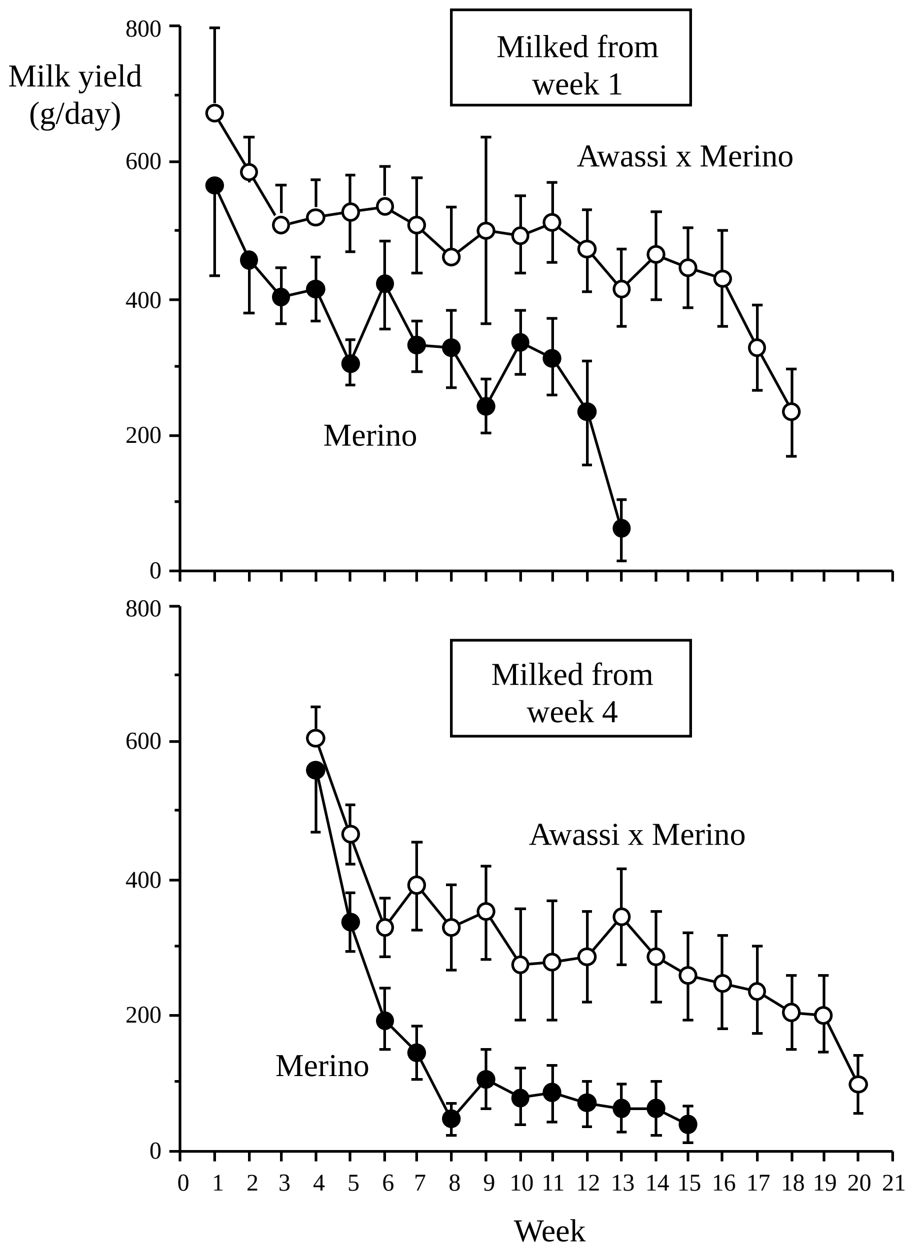

Figure 1. Lactation curves of Awassi x Merino (n=45) and Merino (n=22) ewes milked immediately after lambing (AxM, n=22; M, n=6) or after four weeks of nursing their own lambs (AxM, n= 23; M, n=16).

Heterosis did not seem to intervene on the milk production of the sheep and the production of Awassi x Merino ewes was intermediate between those of the two parent breeds. For this reason we also compared the production of milk from higher Awassi crosses (Table 1).

Table 1. Daily milk production (g/day), total lactation yield (kg) and total lactation length (weeks) of Awassi crossbred ewes.

Cross (n)	Daily production	Lactation yield	Lactation length
1/2 (16)	383±26.0	33.4±7.83	21±2.1
3/4 (13)	515±42.9	45.0±12.87	21±2.6
7/8 (11)	557±38.7	50.3±16.06	22±3.4
15/16 (7)	606±56.5	65.3±16.17	25±3.5

Although back-crossing to the Awassi increased milk production, it appears that the years spent in Cyprus under harsh conditions as well as the seven years spent in quarantine in Australia were sufficient to undo all the genetic improvement achieved by the Israeli on the Awassi sheep. After these first experiments we have milked a lot more sheep and the results are still showing that the Awassi that was imported in Western Australia is not capable of the 1000 litres of milk per lactation quoted by Epstein (1982). Anecdotal evidence suggests that the Awassi sheep imported to new South Wales produce more milk that the Western Australian Awassi, but the results are still unpublished. Within each flock we have observed exceptional individuals producing large quantities of milk. Therefore it is possible to recommence selection for dairy production.

Currently we are milking East Friesian x Awassi and East Friesian x Merino ewes. Preliminary results indicate that the East Friesian x Awassi ewes produce more milk than Awassi ewes, while the East Friesian x Merino ewes produce less milk than Awassi ewes (Table 2).

Table 2. Milk production (g/day) on 20 September 2001, of Awassi, Awassi x Merino, East Friesian x Awassi, East Friesian x Merino

Breed (n)	Daily production	Standard Error
Awassi (18)	745	112.0
Awassi x Merino (5)	483	80.1
East Friesian x Awassi (9)	1222	184.9
East Friesian x Merino (15)	525	67.3
Merino (19)	386	55.2

Dairy products development

Our project addressed the lack of specialised dairy products made with sheep milk by developing new sheep milk products that were initially tested on small groups of people to assess their acceptability to Australian consumers. This resulted in the development of methodologies for the production of two new cheeses. One of these is a soft spreadable cream cheese that has virtually no maturation time. It was developed to respond to the need of manufacturers for a fresh product that would provide the 'cash flow' for the enterprise. The other is a semi-mature cheese that has to be aged for about one month. Both cheeses were tested on a large group of consumers through a survey in a popular supermarket chain. Both cheeses were rated highly by potential consumers, who were disappointed to hear they could not purchase our products. The survey revealed that 86% of consumers were prepared to buy both cheeses at a price of $21/kg (±1.02) for the semi mature and $32/kg (±0.8) for the spreadable cheese, confirming the existence of domestic markets and a consumers willingness to pay high prices for sheep milk products.

Another product developed within our project was sheep milk ice-cream in collaboration with our industry partners, the Peters & Brownes Group, who are major exporters of ice-cream to Japan. We investigated the effect of fat concentration on the quality of sheep milk ice-cream. Batches of sheep milk ice-cream containing different concentrations of fat were produced and tested by an expert panel at the R&D Laboratory of the Peters & Brownes Group. The batches were scored poorly by the panel regardless of the fat content. By contrast, they were considered generally good by Animal Science staff. Since members of both organisations may have been biased against or in favour of the sheep milk ice-cream, this conflicting result was further investigated by conducting a blind test on a small number of potential consumers. Consumers were unable to distinguish sheep milk ice cream from cows milk ice cream, supporting the possibility that the experts at P&B were prejudiced against the sheep milk ice cream. However, the participants stated that they were not prepared to pay more money to purchase the sheep milk ice cream. This was to be expected, since according to the participants there was no difference in taste between the two products.

Producers had also reported problems in processing sheep milk harvested in early lactation. We investigated the presence of colostrum immunoglobulins that are essential for the welfare of the lambs, but that could be the cause of the reported processing problems. To test this hypothesis sheep were separated from their lambs and milked immediately after lambing and samples of milk were collected daily and analysed for the presence of colostrum immunoglobulins by Capillary Electrophoresis. We found that colostrum immunoglobulins persisted in the milk of some ewes for up to nine days after separation from the lambs. Sheep dairy producers that milk the sheep immediately after they have given birth should therefore discard the milk for at least one week.

There was also the possibility that processing problems in early lactation could be due to the presence of an unbalanced ratio of fatty acids in the milk fat as in early lactation the sheep could mobilise body reserves to synthetise the milk fat. In this case the milk fat would contain more unsaturated long chain fatty acids as this is the form in which the mammary gland cells transform the fatty acids that come from body fat tissue. Short/medium chain fatty acids increased from 33 to 40% with the progression of lactation, supporting the hypothesis.

Lambs

The problem of weaning lambs when their mothers are milked in a dairy situation is extremely serious for the industry. Artificial feeding is expensive, but if lambs are weaned by their mothers, they drink so much milk that the whole operation becomes unprofitable. So far, the solution adopted by many farmers has been to kill the lambs at birth. However, this is an undesirable outcome for animal welfare reasons and because many producers dislike this practice (T. Dennis, Pers. comm.).

We investigated methods of weaning the lambs and markets for milk-fed lambs to make them a second source of profit for the sheep milking enterprise.

Our studies confirmed that the artificial feeding of lambs is too expensive to be contemplated by a sheep milking enterprise. It was only through the generous intervention of our industry partners, the YHH Holdings, that we managed to feed artificially our first group of lambs at a cost of $60 per head. Subsequently we tested the share milking method, which has been reported to be economically viable to rear lambs while milking sheep (Knight et al, 1993). We tested a method in which the ewes were left with their lambs for one to two weeks. Then they were milked regularly twice a day, but they were allowed to nurse their lambs during the day. Our studies showed that share milking not only allows the production of both milk and lambs, but also it results in greater production of milk and longer lactations than those observed in sheep that were separated from their lambs at four weeks of age. We have also developed a very efficient system to separate the lambs from the ewes, by using a selective drafting gate that allows only lambs to move through.

An honours students also investigated the meat production potential for milk-fed lambs. She compared the carcase composition of lambs that were nursed by their mothers with that of lambs whose mothers were shared milked until slaughter (at 15 kg body weight). This work showed that although share milked lambs had slower growth rates than their counterparts, their carcases did not differ in composition. Both groups of lambs were extremely lean, which could be used by the industry to promote milk-fed lamb as a healthy product.

One of the requirements of our agreement with the RIRDC was that we conducted an economic evaluation of sheep milking as part of our project. A collaboration with the Agricultural Economics Group in our Faculty resulted in the development of the "Sheep dairying gross margin calculator", a user friendly spread sheet that allows producers to calculate gross margins for a sheep milking enterprise.

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GROUP BREEDING SCHEME: A FEASIBLE SELECTION PROGRAM

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Introduction

Every flock owner practices some sort of selection on his/her flock by keeping ewe lambs or ram lambs from their best ewes for the trait(s) they have chosen. In traditional sheep flocks the selection criteria most often chosen by producers are prolificacy, growth, out of season lambing, easy care sheep, etc… In a dairy sheep flock, selection is done on milk production, milk composition, udder morphology, milk let down, etc… In other words we all want the perfect sheep that is high producing with the least amount of work at the least cost. Real genetic progress in individual small to medium size flocks is, generally, not forthcoming because of ill chosen traits to improve (or too many), small number of animals to choose from and inaccuracy of the estimated genetic value of the animal selected. A quick reminder of genetic principles might help understand the reasons for the poor or no results from an individual flock selection program.

Genetic review

Two terms are absolutely indispensable to understand:

Heritability. Heritability (h^2) is the proportion of phenotypic differences between animals which is due to additive genetic differences. Simply put, it is the proportion of parent superiority observed in the progeny. In general reproductive traits have a low heritability while growth, carcass traits, fiber traits and milk production have a medium heritability. The following table gives a few examples of heritabilites in sheep:

Prolificacy	10%
Lamb survival	5%
90-day weight	25%
Loin eye area	50%
Fiber diameter	40%
Milk yield	30%
Milk Fat percentage	35%
Milk Protein percentage	40%

The higher the heritability, the quicker the selection will be. In sheep, dairy traits have a moderate heritability, which means that significant genetic improvement can be achieved.

Selection differential. The selection differential is a simple concept and refers to the difference between the selected animals and the average of the entire flock as shown in Figure 1 where the average milk production is 120 liters and the average milk production of the selected animals is 150 liters. The selection differential will be 30 liters.

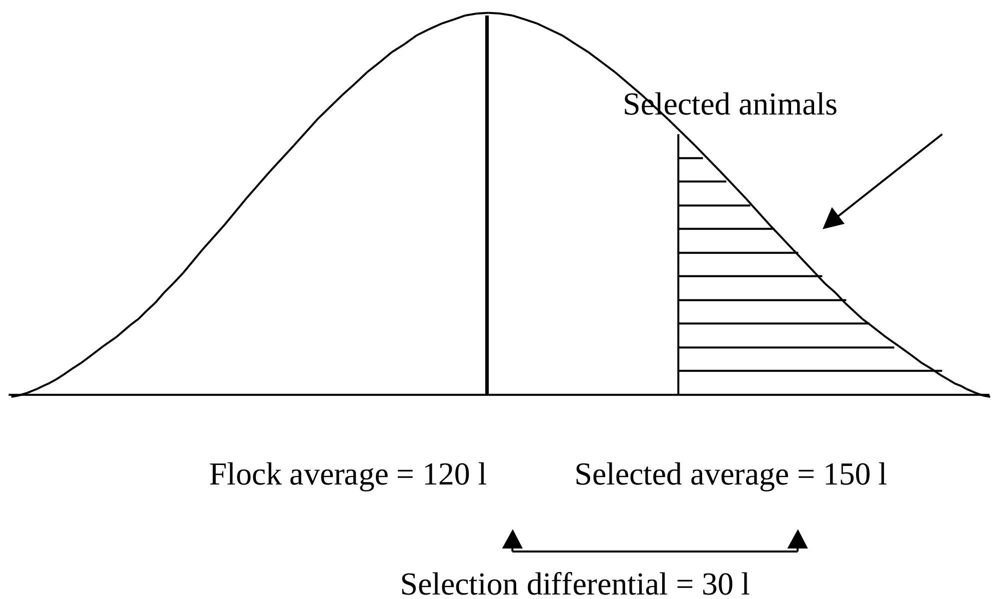

Figure 1: Selection differential

Combining the heritability and the selection differential, the theoretical genetic improvement per generation would be:

$$\Delta G = h^2 \text{ x } Sd$$

In the example the genetic improvement of dairy yield of the flock would be:

$$\Delta G = .30 \text{ x } 30$$

$$\Delta G = 9 \text{ liters}$$

Considering that in sheep the generation interval is about 3 years, the genetic improvement per year would be:

$$\Delta G / L = h^2 \text{ x } Sd /3 = .30 \text{ x } 30/3 = 3 \text{ liters}$$

Reducing the generation interval by using ram lambs and by breeding young ewes at 7 months of age, will greatly improved the annual genetic improvement.

However, the formula is rather simplistic and geneticists in charge of selection programs prefer to use the following equation:

$$\Delta G / L = h \text{ x } \sigma_a \text{ x } I / \text{Generation interval}$$

Where:

h = square root of heritability, which represents the accuracy of selection. The accuracy of selection is greatly improved if all environmental factors (non genetics) can be removed. Many production traits need to be adjusted for, let's say, age of dam, sex, type of birth, birth weight, type of rearing, etc… Without using adjusting factors, gross mistakes can be made and little genetic progress will be realized. The accuracy of selection will also be improved if the performance of all relatives of the animal to be selected are taken into consideration. This is the purpose of EPDs (Estimated Progeny Difference) calculated by NSIP in the US and by ROP in Canada.

σ_a = amount of genetic variation between animals. The larger the variation the better and easier the selection. Without variation in a population, selection would become impossible. Generally there is no problem with not having enough variation.

I = intensity of selection. Let's say that a producer has 100 ewes producing 150 lambs of which 75 are females. Just to replace older ewes, unhealthy ewes, dead ewes, he will need to keep around 25 ewe lambs or 33% of his ewe lamb crop. According to tables, the intensity of selection is 1.1, which is very little. On the ram side he needs to keep only 3 rams or 4% of his ram lamb crop representing an intensity of selection of 2.15. In this case ram selection is twice as powerful as ewe selection. However, how can a producer select an animal that does not express the trait he is selecting for such as milk production? The only information available will be the performance of his ascendants (Dam, grand Dam etc..) and EPDs can be calculated. However the most important information, performance of half sibs or performance of his progeny, are missing. The accuracy of selection is therefore greatly reduced.

The purpose of this short preamble was to demonstrate that the selection practiced by individual producers is often inaccurate and disappointing because:

- The number of animals to choose from is too small resulting in no or very little intensity of selection.
- The accuracy of selection is very small because of the impossibility to eliminate all or most of the environmental factors.
- The producer has no mean to compare the performance of his animals to the performance of his neighbor's animals. If he needs to purchase replacement animals (ewes or rams) he has no resource to see if the animals he is purchasing are, on average, better than his.

For rapid genetic improvement, the goal of the dairy sheep industry should be to develop a national or regional breeding program which includes recording of milk production of ewes, centralized processing of milk production records and estimation of EPDs, planned mating of ewes and rams with superior EPDs, progeny testing of promising young rams and the rapid spread of superior genetics through the population by the use of artificial insemination with semen from proven rams.

This is the U.S. dairy cattle model that is so successful and it is the system used on the Lacaune breed in France on which genetic gain has been an average of 2.4% for the last 30 years.

The North American sheep dairy industry, however, does not have the financial means of the dairy cattle industry and is certainly not backed up by government funding as the French system is. Alternative solutions have to be found and a Group Breeding Scheme could very well be what the industry needs.

Group Breeding Scheme

A Group Breeding Scheme is a group of producers with a common selection goal where breeding stock is selected and shared among the members of the group. By increasing the number of animals in the selection pool, using EPDs and sharing the best rams, the group of producers increases the rate of genetic gain over purchasing sheep from outside flocks or from selecting solely within their own flock.

A Group Breeding Scheme uses a team of common sires over a group of flocks in order to create genetic links between member flocks. With genetic links between flocks, it becomes possible to compare animals between flocks regardless of the environmental differences between flocks, management, nutrition or other non-genetic effects, and EPDs can be calculated. An EPD is an estimate of the genetic value of an animal calculated from performance information from all relatives of that individual and is the most accurate estimate of genetic value possible. An EPD calculation for a prospective ewe or ram replacement would use the milk yields (or any other trait) of the individual's dam, maternal grand-dam, paternal grand-dam, full-sisters, half-sisters, and any other female relatives with milk production records. Rams with the highest EPD become reference rams and are used on a certain percentage of ewes (generally the ones with the highest EPDs) of each member flock either with natural mating or, better yet, with artificial insemination. The conditions of use of the rams and rewards to the owner of the rams (payment, time of use, cost, etc…) need to be sorted out by the group of producers.

EPD calculations require relatively sophisticated statistical techniques and fairly large computing resources. EPDs are currently calculated by the National Sheep Improvement Program (US) and by the Record of Performance Program (Canada) on a few meat breeds. It would be up to a group of sheep dairy producers to form an association and to work with NSIP (or another entity) for the calculation of milk production EPD

A Sire Reference Scheme is not a new concept since most selection schemes use the similar principles of a nucleus population and diffusion of genetic improvement throughout the base population. New Zealand, however was the pioneer in the use of group breeding schemes in sheep and achieved rather good results on meat and wool breeds. Some similar breeding programs are being developed in other countries (Spain for instance) on commercial dairy sheep operations.

How does a Group Breeding Scheme work?

First step. A group of producers with a set of common goals get together with the purpose of genetically improving their flock. By-laws should be clearly defined to which all members should abide. Rewards to the producers of the best rams used by the group should be spelled out to eliminate all possible controversies. Selection criteria should be well chosen and agreed upon by all members. Generally, in dairy sheep production, milk yield is the primary selection criterion. However, since practically all sheep milk is transformed into cheese, fat and protein percentages are extremely important for cheese yield and high quality products. In North America a good level of production has been obtained by crossbreeding with the East Friesian. However, this higher level of production has resulted in lower fat and protein percentages in the milk because of the negative correlation between production and components. It would seem essential that fat and protein content should be included as selection criteria as soon as possible.

Second step. All members enroll in NSIP or ROP or any other entity that would be able to calculate EPDs. Members keep accurate records on pedigree, milk production, milk composition and on any other traits that the group decided upon. Recording of milk production should be standardized and performed by a third party such as the Dairy Herd Improvement Program. ICAR (International Committee for Animal Recording) has set definite rules for the recording of ewe milk production.

Third step. During the first 2-3 years, a set of common sires, chosen as best as possible, is used on all member flocks in order to create genetic links between flocks, which is the essential condition for the possible comparison of animals between flocks. Meanwhile intra-flock EPDs are calculated on ewes of each flock in order to determine the best 20% ewes, which would form a sort of loose nucleus in each flock. The percentage of ewes to form the nucleus is determined according to the number of ewes involved in the breeding group and will be the same for each flock. The higher the number of ewes in the group, the lower the percentage needed for the nucleus, resulting in a higher intensity of selection. The advantages of a nucleus are two folds:

- Only the ewes of the nucleus need to have a strict record keeping system, lowering the overall cost.
- Artificial insemination can be done only on the nucleus ewes.
- As soon as the genetic link is created, the real genetic improvement will start.

Fourth step. The semen of the best between-flock EPD young rams is collected and used fresh or frozen for the insemination of the nucleus or “elite” ewes of each flock. The number of rams to use will depend on the number of “elite” ewes in the group. The rest of the ewes (or base flock) can be bred naturally by any rams of the producer’s choice (generally with second best EPD’s). “Elite” ewes are replaced by the best EPD ewe lambs born from elite ewes. The second best ewe lambs are used to replace ewes of the base flock. The best ram lambs from the elite group join the ram pool and are progeny tested. Some of them would become “proven” rams, the others are sold.

Subsequent years. Half of the “elite” ewes of each flock are inseminated with “proven” rams and 1/2 are inseminated with promising young rams for progeny testing.

Therefore, a typical pyramidal structure is formed in each flock as shown in figure 2. Another possible system would be for all producers to pool their best ewes together in one flock to form a nucleus flock. This “elite” flock can be managed by one of the members who would also take care of the pool of rams. All “proven” rams and promising young rams as well as some replacement ewes will come from this nucleus flock. This system works extremely well and requires the least amount of work from each member. The producer member taking care of the nucleus flock is compensated for his extra work and expenses by a higher milk production of this elite group.

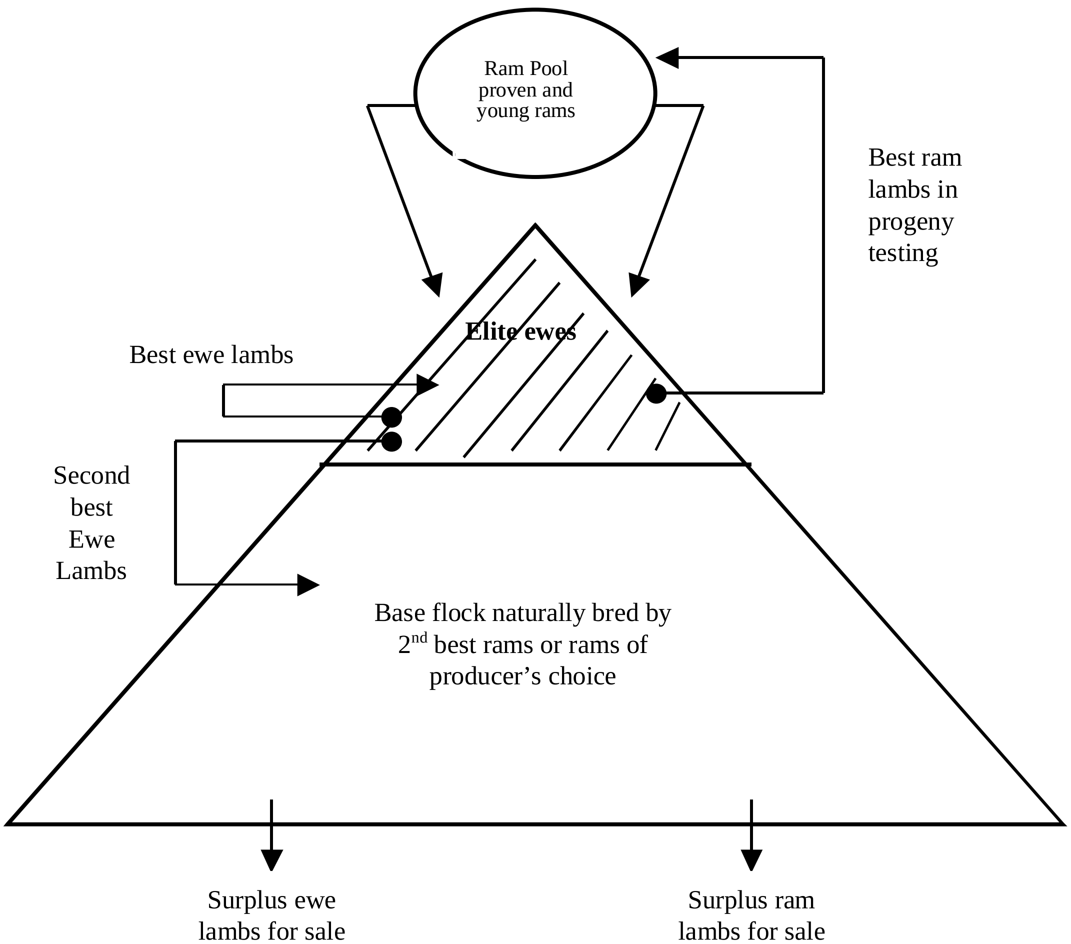

Figure 2: Structure and movement of animals in one member flock

The structure and movement of animals for the whole breeding group is shown in Figure 3. The best EPD rams are shared by all members of the group. Young rams are progeny tested in all member flocks. Artificial insemination (fresh or frozen) is used.

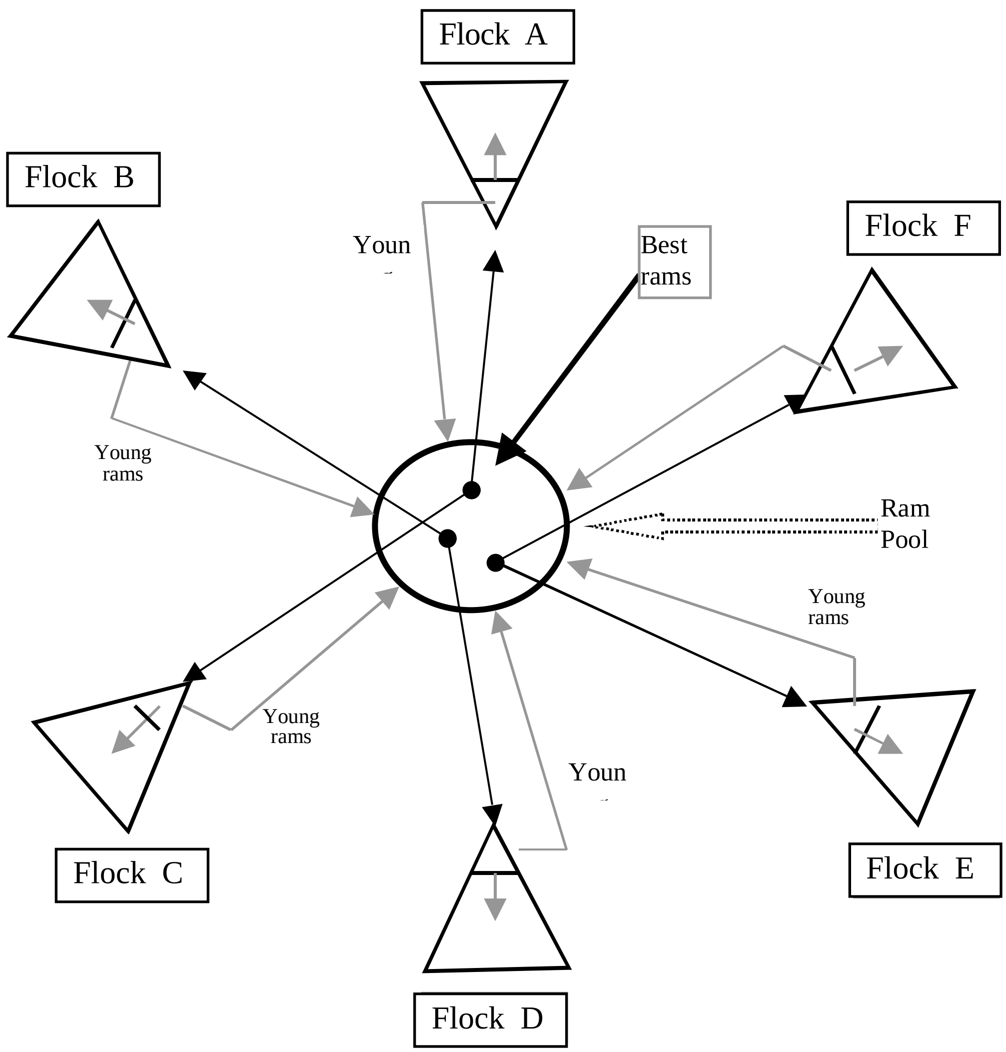

Figure 3. Design of a group breeding scheme.

Advantages of a Group Breeding Scheme

- A Group Breeding Scheme can be easily started by a group of producers already involved in a small cooperative (milk marketing) or any other association.
- The maximum genetic gain is realized in the "elite" group. The genetic gain is rapidly passed to the base population and all member flocks improve at the same rate.
- Manageable population size (a few hundred to a few thousand) if the group stays at a reasonable size.
- Only a small percentage of ewes need to be recorded with great accuracy, reducing expenses, time and labor.
- Financial rewards for the members through the sale of surplus breeding animals based on accurate genetic value.

Disadvantages of a Group Breeding Scheme

- A group Breeding Scheme, by definition, involves only a small population.
- The progeny testing of promising young rams lengthens the generation interval. However this is true for all types of selection program. Progeny testing greatly increase the accuracy of EPDs.
- Very little improvement will be realized until genetic links between flocks are established (2-3 years).
- Members of the group need to be very involved. The Group Breeding Scheme is totally managed by the members and by no one else.
- At the present time neither NSIP or ROP calculate EPDs for milk production. Intense lobbying needs to be done.
- Some costs are involved: milk production recording, analysis of milk samples for composition, enrollment in NSIP (or other), semen collection, artificial insemination, more rams kept for progeny testing, etc…

Conclusion

So far milk production of the "dairy ewes" in North America has increased dramatically due to the introduction of East Friesian germ plasm but at the same time milk composition has deteriorated. Moreover, a crossbreeding system, in the long run, is difficultl to sustain without inching toward a pure breed, which might not be desirable because of increasing unfavorable effects such as lack of adaptation to the environment. Therefore, a selection program based on milk production AND milk composition appears necessary in the long run. Because of a manageable size, low cost and high efficiency (when well run) Group Breeding Schemes could very well be the solution.

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CAN THE OVARY INFLUENCE MILK PRODUCTION IN DAIRY EWES?

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Abstract

In dairy ewes with large cisternal storage capacity, such as the East Friesian, we hypothesize that milk transfer between milkings from the alveoli to the cisterns, and therefore overall milk production and composition, might be improved by the hormonal milieu created by the presence of corpora lutea (CL). Furthermore, we wanted to evaluate this effect with the number of CL that would be typically present during the estrous season and without the potential stimulatory effect of estradiol (E2) on milk production. Mid-lactation East Friesian crossbred ewes (n = 24) were synchronized for estrus with intravaginal progesterone (CIDR), PGF$_{2\alpha}$, and gonadotropins. Following ovulation, CL were counted via laparoscopy on d 4, and the ewes were studied during three time periods (pre-treatment: d 0 to 5; treatment: d 6 to 18; post-treatment: d 19 to 25). On d 5, ewes received a treatment of either saline (CLY, n = 12) or PGF$_{2\alpha}$ (CLN, n = 12) to allow CL persistence or regression, respectively. Additionally, all ewes received two CIDRs during the treatment period to provide high concentrations of plasma progesterone (P4). All ewes received PGF2$_{2\alpha}$ on d 18. Milk yield and milk flow rate were recorded daily, milk samples were obtained periodically for analyses of milk fat and protein, and jugular blood samples were collected for P4 and E2 immunoassay. During the treatment period, CLY ewes had higher daily milk yield (1.56 vs. 1.44 kg/d) and milk flow rate (244 vs. 208 ml/min) and produced more milk fat (92.2 vs. 81.1 g/d) and milk protein (83.7 vs. 77.5 g/d) compared to CLN ewes, respectively. These trends were maintained during the post-treatment period, despite luteolysis in CLY ewes. Thus, milk production was increased in East Friesian ewes due to the presence of CL, consistent with other reports of a putative role of luteal oxytocin (OT) in milk transfer between milkings and/or a direct effect of OT on secretory epithelium.

Introduction

In species with large cisternal storage capacity, such as the dairy ewe, milk transfer from the alveoli to the cistern between milkings may improve milk yield by reducing the concentration of negative feedback inhibitors of lactation in the area of the alveoli (Wilde et al., 1987), and may improve efficiency of milk removal due to increased udder filling (Bruckmaier, 2001) or by allowing for increased cisternal intramammary pressure, thereby increasing milk flow rate (McKusick and Marnet, 2001, unpublished data). Compared to most other dairy sheep breeds, the East Friesian has relatively larger cisterns (Bruckmaier et al., 1997; McKusick et al., 1999b) and this may provide increased milk storage between milkings.

Although the mechanism by which milk is transferred between milkings from the alveoli to the cistern is not completely clear, it has been hypothesized that oxytocin (OT) secreted from the corpus luteum (CL) might be responsible for myoepithelial contraction and could play a significant role in dairy ewes. Marnet et al. (1998) showed that baseline plasma OT concentrations were higher for lactating ewes during their normal estrous season (fall) compared to ewes lactating during anestrus (spring). Labussière et al. (1993, 1996) demonstrated a significant positive correlation between the number of CL present and the volume of milk obtained at milking in superovulated Lacaune dairy ewes. The East Friesian is highly prolific (McKusick et al., 1999a), and the increased number of CL combined with the large cisternal volume may allow this breed to markedly benefit from an effect of CL on milk production.

The objective of the present experiment was to study the effect of a relatively normal number of CL for the East Friesian breed on milk production and composition during mid-lactation. The experiment was designed to remove the potential stimulatory effect of estradiol (E2) on milk production by maintaining high serum progesterone (P4) concentrations during the treatment period with the aid of intravaginal P4.

Materials and methods

Twenty-four second parity East Friesian crossbred dairy ewes in mid-lactation (77 ± 6 d, mean ± SD) of similar body weight and daily milk production (81 ± 8 kg and 1.9 ± 0.6 kg/d, respectively, mean ± SD) were studied during the summer of 1999. Ewes were selected from the University of Wisconsin-Madison's main dairy ewe flock of 350 ewes at the Spooner Agricultural Research Station based on their lambing date and daily milk production. Ewes were housed in four separate pens in an indoor laboratory facility on the University of Wisconsin-Madison campus, fed a 16% crude protein grain concentrate and alfalfa haylage, and maintained under constant anestrous light conditions (16:8 hr of light to dark).

A schematic diagram of the experimental design is shown in Figure 1. Immediately prior to the experiment, ewes were artificially synchronized for estrus and induced to ovulate by treatment for 14 d with a controlled intravaginal drug-releasing device containing 330 mg of P4 (CIDR, InterAg, New Zealand) from d –17 to –3, relative to expected ovulation (d 0). Twelve hours prior to CIDR removal, 600 IU of pregnant mare serum gonadotropin (PMSG, Sioux Biochemical, Inc., Sioux Center, IA), and 250 mg of PGF2a (cloprostenol sodium, Estrumate, Bayer Corp., USA) were administered.

The experiment was divided into three time periods: d 0 to 5 (pre-treatment), d 6 to 18 (treatment), and d 19 to 25 (post-treatment). Laparoscopy was performed on d 4 for the purpose of counting CL and to affirm that ovulation had occurred. On d 5, ewes were ranked according to number of CL and alternately assigned to one of two treatments: injections at 0630 and 1630 of either saline (CLY, n = 12) or 250 mg of $PGF_{2\alpha}$ (CLN, n = 12) to allow persistence or regression, respectively, of CL during the treatment period. In addition to the treatments, all ewes in both treatment groups received two CIDRs for the duration of the treatment period in order to maintain circulating P4 at normal, or above, luteal phase concentrations. On d 11, laparoscopy was performed to confirm luteal persistence in CLY ewes and luteolysis in CLN ewes. On d 18, CIDRs were removed and all ewes received an injection of 250 mg of $PGF_{2\alpha}$.

Machine milking took place at 0630 and 1630 in groups of 6 ewes on a portable milking platform with cascading head stanchions. The milking machine (Coburn Co., Inc., Whitewater, WI and Interpuls Inc., Albinea, Italy) was set to provide 180 pulsations per minute in a 50:50 ratio with a vacuum level of 37 kPa. Individual ewe milk production and milking time were recorded at every milking (d 1 to 25) and milk samples were collected periodically at the morning milking (d 4, 5, 6, 7, 8, 9, 13, 14, 15, 18, 25). Average milk flow rate was calculated by dividing the amount of milk obtained by the machine milking time (not including machine stripping milk yield or time). Milk composition analyses for percentages of fat and protein were performed by a State of Wisconsin certified laboratory. Test-day milk fat and protein yield were calculated by multiplying morning milk production by percentage of milk fat or protein. Individual jugular blood samples for P4 and/or E2 immunoassay were collected at 0830 (d –2, 0, 2, 4, 6, 10, 14, 18, 21, 25) into vacutainer tubes, refrigerated at 4° C for 24 h, and then centrifuged for 15 min at 3000 x g. The serum was harvested and frozen at –20° C. Serum P4 concentration was determined by enzyme immunoassay in duplicate after double extraction in petroleum ether according to Rasmussen et al. (1996). Intra- and inter-assay coefficients of variation were 9.9 and 11.6%, respectively. Serum samples for E2 concentration were pooled for each ewe within a period (estrus: d –2; pre-treatment: d 0 to 5, treatment: d 6 to 18; and post-treatment: d 19 to 25). Serum E2 concentration was determined by radioimmunoassay according to Kulick et al. (1999) with an intra-assay coefficient of variation of 16.0%.

Analyses of variance were conducted with the general linear models procedure of SAS (1999) for a split plot on time experimental design. Traits analyzed were milk yield, milk flow rate, milk fat and protein content, and serum P4 and E2 concentration. The following independent variables and their interactions were included in the model for each trait, except E2 concentration: main plot effects- treatment (CLY or CLN), pen (A, B, C, or D), treatment x pen, and ewe within treatment x pen; sub-plot effects- period (pre-treatment, treatment, and post-treatment), treatment x period, pen x period, day (0 to 25) within period, treatment x day within period, and pen x day within period. Because of unexpected pre-treatment differences noted a posteriori among treatment groups in percentages of milk fat and protein, the d-4 test-day value was used as a continuous covariable for analyses of milk composition during the treatment and post-treatment periods. Differences among treatment x period combinations and treatment x day within period combinations were tested for significance against residual error. Because serum E2 concentration was obtained from samples pooled within a ewe and period, day within period and all interactions with day within period were dropped from the model used to analyze E2 concentration.

Results

Ovulation and the presence or absence of CL for CLY and CLN ewes was affirmed by laparoscopy on d 4 (3.4 ± 1.6 vs. 3.3 ± 1.3 CL per ewe, mean ± SD, respectively), and on d 11 during the treatment period (2.4 ± 1.1 vs. 0 CL per ewe, mean ± SD, respectively).

Data are summarized in Table 1 for the treatment x experimental period combinations; the evolution of treatment differences over time is displayed in Figures 2 to 5. Following treatment on d 5 with $PGF_{2\alpha}$ (CLN only) and CIDRs (both groups), average daily milk yield of CLY ewes increased ($P < 0.05$) from their pre-treatment production level (from 1.42 to 1.56 kg/d) and was greater ($P < 0.05$) than the milk yield of CLN ewes (1.44 kg/d) during the treatment period (Table 1). Higher milk yield in CLY ewes first reached significance on d 9 (4 d after treatment, Figure 2A) and averaged 10% greater than CLN milk yield throughout the treatment period (d 6 to18, Table 1). Peak milk yield occurred on d 10 (1.71 kg/d) for CLY ewes, but as early as d 6 (1.57 kg/d, 1 d after $PGF_{2\alpha}$ treatment) for CLN ewes (Figure 2A). After CIDR removal and $PGF_{2\alpha}$ treatment on d 18 (post-treatment period), milk yield for CLY ewes returned to levels lower than pre-treatment period production (1.35 kg/d), but averaged 8% greater ($P < 0.05$) than for CLN ewes (1.25 kg/d, Table 1). Average daily milk flow rate was 17 and 25% greater (P <

0.05) during the treatment and post-treatment periods, respectively, for CLY ewes compared to CLN ewes (Table 1) and peaked on d 9 for CLY ewes (Figure 2B).

Average milk fat and milk protein percentage for CLY ewes was lowest ($P < 0.05$) during the treatment period compared to the pre-treatment period (Table 1). Average milk fat yield for CLY ewes was similar during the entire experiment (87.4 g/d), however average milk protein yield was lower ($P < 0.05$) during the post-treatment period (70.8 g/d) compared to the pre-treatment and treatment periods (81.7 g/d, Table 1). During the treatment period, daily milk fat and protein yield for CLY ewes tended ($P < 0.10$) to increase from d 5 to13, decrease ($P < 0.05$) from d 13 to d 18, and remain stable during the post-treatment period (Figure 3). Milk fat yield for CLN ewes tended ($P < 0.10$) to increase from d 5 to 7, and then decreased until d 18; milk protein yield for CLN ewes followed the same pattern, but peaked between d 6 to 8, and decreased until the end of the experiment (Figure 3).

Serum P4 concentration was similar for CLY and CLN ewes from d 0 to 4 (2.2 ng/ml), corresponding to CL development (Table 1 and Figure 4). Concentration of P4 for CLY ewes peaked between d 6 and 10 (Figure 4) and was consistently greater ($P < 0.0001$) than for CLN ewes until the end of the treatment period (5.3 vs. 2.9 ng/ml, respectively, Table 1); P4 concentration for CLN ewes did not change over time during the treatment period (Figure 4). Concentration of P4 for CLY and CLN ewes was similar during the post-treatment period (0.8 ng/ml, Table 1) and did not differ from P4 measured on d 0 (Figure 4). Serum concentration of E2 was greatest ($P < 0.05$) during estrus, decreased by d 4, and was not different from 0 during the treatment and post-treatment periods (Figure 5). There were no differences in E2 concentration between CLY and CLN ewes during any period (Figure 5).

Discussion

This study provides the most direct evidence, to date, that the presence of CL increases milk production in dairy ewes. Two previous studies using superovulated Lacaune ewes (Labussière et al., 1993, 1996) implicated the CL in milk production and provided the rationale for the present research. Labussière et al. (1993) superovulated Lacaune ewes with various hormonal treatments and analyzed milk yield of ewes that had 0, 1, 2, 3 to 6, or > 6 CL after the hormonal treatments. There was a positive relationship between number of CL and milk yield with ewes in the group with > 6 CL having significantly greater milk yield than ewes with 0 CL. In the second study (Labussière et al., 1996), Lacaune ewes were either untreated, treated with a progestin sponge, or treated with a progestin sponge and superovulated with FSH and LH. Superovulated ewes had greater milk yield (+ 11.3%) and fat yield (+ 11.1%) than untreated or progestin-treated ewes, again implicating the presence of CL in milk production of dairy ewes. These previous studies found significant effects on milk production in the presence of a supraphysiological number of CL and the experimental designs could not preclude the possibility that numbers of preovulatory follicles and circulating estradiol concentrations were the cause of the increase in milk yield. In the present study, ewes were studied during the non-breeding season so that circulating estradiol and progesterone were related to exogenous hormonal treatments. All ewes received the same hormonal treatments except for a $PGF_{2\alpha}$ injection on d 5 to eliminate the CL in CLN ewes. In addition, number of CL (2.4 CL) in this study was similar to the number that would be expected in normally ovulating East Friesian crossbred ewes during the breeding season (average lambing rate of 220%, McKusick et al., 1999a). Within 5 d after regression of the CL there were significant differences in milk yield between ewes that had or did not have CL. Thus, the experimental design of the present study allowed us to produce strong evidence in support of the hypothesis that the presence of a normal number of CL increases milk production; however, the mechanism(s) responsible for this increase are not conclusively demonstrated.

It seems logical that the hormonal milieu produced by the CL is responsible for the increase in milk production and we postulate that an expected increase in circulating OT may be the key hormonal change that produces the observed increase in milk production. The corpus luteum has been found to contain high amounts of both mRNA and protein for OT (Jones and Flint, 1988) and circulating OT concentrations are much greater in ewes with CL than in ewes without CL (Labussière et al., 1993; Marnet et al., 1998; Schams et al., 1982). Although OT was not measured in the current study, other researchers have consistently found significantly elevated basal OT concentrations in ewes with CL as compared to ewes without CL. For example, circulating OT was extremely low during the 2 d prior to estrus (near lower limit of assay of 3 pg/ml), but increased to high concentrations (30-60 pg/ml) between d 5 and 10 after estrus (Schams et al., 1982). Similarly, superovulated ewes with > 6 CL had basal circulating OT concentrations of > 100 pg/ml as compared to 25 to 50 pg/ml in ewes with 1 CL (d 4 to 12 of the estrous cycle) and these concentrations were greater than the < 10 pg/ml concentration found in ewes with no CL (Labussière et al., 1993). Numerous studies have shown that exogenous OT treatment increases milk production in ruminants (Heap et al., 1986; Knight, 1994) and this occurs whether OT is administered before or after milking (Ballou et al., 1993). Daily treatment of Mehraban ewes (Zamiri et al., 2001) with 2 IU of OT from d 15 of lactation dramatically increased total milk yield (+ 55.5%) due to greater average daily milk yield as well as longer lactation length (175 vs. 143 d). Thus, a likely physiological model to explain our results is that the presence of CL increases circulating OT and this hormone increases milk production through possibly multiple physiological mechanisms.

Oxytocin is critical for milk transfer from the alveoli to the cistern. Mice with knockout of the OT gene do not have milk ejection during suckling and pups die soon after birth unless exogenous OT is provided, whereas other aspects of reproduction and parturition appear normal in these mice (Young et al., 1996). Very low concentrations of OT are necessary to elicit milk ejection in ruminants (Gorewit et al., 1983). During machine milking of dairy ewes, plasma OT concentrations peak between 70 and 200 pg/ml and this OT is associated with ejection of milk from the alveoli to the cistern (Bruckmaier et al., 1997; Marnet et al., 1998). There is little scientific literature on the role of OT during the intermilking interval in ruminants. In the goat (Peaker and Blatchford, 1988) and ewe (McKusick et al., 2001, unpublished data), milk begins to accumulate in the cistern immediately following milking and continues to fill the cistern in a linear fashion until 16 to 24 hr, after which milk production begins to reach a plateau. Compared with the cow, the ewe and goat have relatively larger cisternal storage capacity resulting in substantial extra-alveolar storage of milk (Bruckmaier et al., 1997; Knight et al., 1994). Movement of milk from the alveoli to the cistern would result in less alveolar pressure (Labussière, 1988), lower concentrations of local feedback inhibitors of lactation (Wilde et al., 1987), and less alveolar milk fat (Levy, 1964; Williamson et al., 1995), all conditions that could increase milk secretion. In addition, there may be direct effects of OT on milk synthesis by mammary epithelial cells (Ballou et al., 1960; Benson et al., 1960; Ollivier-Bousquet and Courrier, 1976); although, it is difficult to rule out that stimulatory effects are the result of more efficient removal of residual alveolar milk by OT and therefore decreased feedback inhibition of lactation in the area of the alveoli (Carulo, 1971; Heap et al., 1986; Knight, 1994; Peaker and Blatchford, 1988). Our results support a stimulatory effect of OT on milk secretion because CLY ewes continued to maintain superior milk production, milk flow rate, and milk fat and protein yield compared to CLN ewes during the post-treatment period. Differentiation of the cellular mechanism(s) involved in the increase in milk production during the treatment and post-treatment periods will obviously require further research.

Our experimental design did not allow us to eliminate the possibility that the increase in circulating P4 was the cause of the increase in milk production. Continuous provision of exogenous P4 from the 2 CIDRs produced circulating P4 concentrations equivalent to or higher than what is normally reported in the ewe during the luteal phase (2.5 to 3 ng/ml, Murdoch and Van Kirk, 1998) even after induced (d 5 in CLN ewes) or spontaneous (before d 18 in CLY ewes) luteolysis. However, circulating P4 was greater in CLY than CLN ewes between d 6 and 14 of the treatment period. Our primary concern was to maintain similar circulating E2 concentrations in the 2 groups because E2 has been found to be directly mitogenic in mammary tissue and could have been responsible for the previously observed increases in milk production in superovulated ewes (Labussière et al., 1993, 1996). There was no difference in circulating E2 concentrations between the two treatment groups at any of the times that were evaluated in our experiment. Although the effects of P4 cannot be ruled out, exogenous P4 administration was found to have no effect on lactation performance in the ewe (Smith and Inskeep, 1970) or rat (Herrenkohl, 1972).

A number of characteristics of the East Friesian breed may make it more compatible with improved milk production by the presence of CL. The East Friesian breed has a large cisternal storage capacity as compared to other dairy sheep breeds (Bruckmaier et al., 1997; McKusick et al., 1999b) and this may facilitate the storage of milk in the cistern away from the alveoli during the intermilking interval. Additionally, the large cistern may improve milk flow rate during machine milking (McKusick and Marnet, 2001, unpublished data). Moreover, the East Friesian is a prolific breed and therefore substantial numbers of CL would be expected during the normal breeding season. Baseline and peak serum OT concentrations are increased in breeds with high fecundity (Schams et al., 1982). Therefore, the positive effect of the presence of CL on milk production in East Friesian sheep may be an advantage for dairy sheep producers who organize their lactation season to be coincident with the natural estrous season. The improvements in milk production produced by CL in East Friesian ewes may also be produced in other dairy sheep, goats, or cattle; although, this will need to be specifically tested in these animals. Unfortunately the stimulatory effects of the CL may not be maintained throughout pregnancy because luteal OT decreases to minimal concentrations by d 18 of pregnancy in the ewe (Marnet and Combaud, 1995). Thus, practical implementation of improvements in milk yield by CL will require substantial subsequent research.

Conclusions

We conclude that the presence of corpora lutea during lactation can increase milk production in dairy ewes. Although the exact physiological mechanism remains unclear, the results of the present experiment indicate that this effect is not due to estradiol. Instead, we provide evidence that a hormonal milieu created in the presence of corpora lutea, quite possibly as a result of ovarian oxytocin secretion, allows for better transfer of milk from the alveoli to the cistern between milkings. Finally, this would appear to be an advantage for maintenance of lactation in animals with larger cisternal storage capacity such as the East Friesian breed of sheep.

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Table 1. Least squares means ± SEM for lactation traits and serum progesterone for the treatment x period combinations.

Trait	Treatment[2]	Experimental period[1]		
		pre-treatment	treatment	post-treatment
Milk yield, kg/d				
	CLY	1.42 ± 0.03[b]	1.56 ± 0.01[a]	1.35 ± 0.02[c]
	CLN	1.47 ± 0.03[b]	1.44 ± 0.01[b]	1.25 ± 0.02[d]
Milk flow rate, ml/min				
	CLY	206 ± 11[b]	244 ± 6[a]	212 ± 9[b]
	CLN	219 ± 11[b]	208 ± 6[b]	169 ± 9[c]
Milk fat, %				
	CLY	6.46 ± 0.12[a]	6.14 ± 0.06[b]	6.68 ± 0.16[a]
	CLN	5.75 ± 0.12[c]	5.73 ± 0.06[c]	6.33 ± 0.16[ab]
Milk fat, g/d				
	CLY	87.0 ± 2.6[ab]	92.2 ± 1.3[a]	82.9 ± 3.7[ab]
	CLN	81.3 ± 2.6[b]	81.1 ± 1.3[b]	70.2 ± 3.7[c]
Milk protein, %				
	CLY	5.69 ± 0.06[a]	5.44 ± 0.03[b]	5.60 ± 0.08[ab]
	CLN	5.53 ± 0.06[ab]	5.53 ± 0.03[ab]	5.63 ± 0.08[ab]
Milk protein, g/d				
	CLY	79.6 ± 1.7[ab]	83.7 ± 0.8[a]	70.8 ± 2.4[c]
	CLN	77.7 ± 1.7[bc]	77.5 ± 0.8[bc]	60.9 ± 2.4[d]
Serum progesterone, ng/ml				
	CLY	2.3 ± 0.2[c]	5.3 ± 0.2[a]	0.7 ± 0.2[d]
	CLN	2.0 ± 0.2[c]	2.9 ± 0.2[b]	0.8 ± 0.2[d]

[a,b,c,d]Within a trait, means with different superscripts differ ($P < 0.05$).
[1]Pre-treatment: d 0 to 5; treatment: d 6 to 18; and post-treatment: d 19 to 25.
[2]Treatment during d 6 to 18: CLY = ewes with corpora lutea; CLN = ewes without corpora lutea.

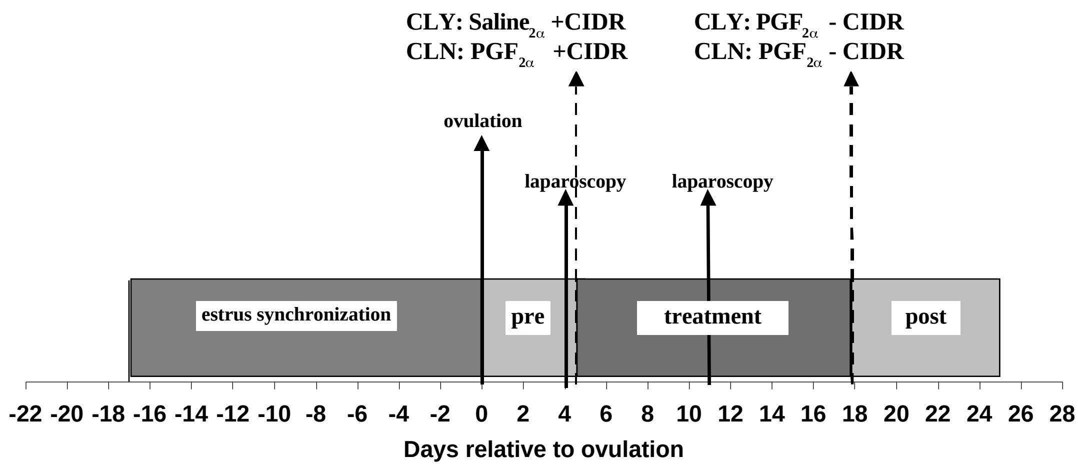
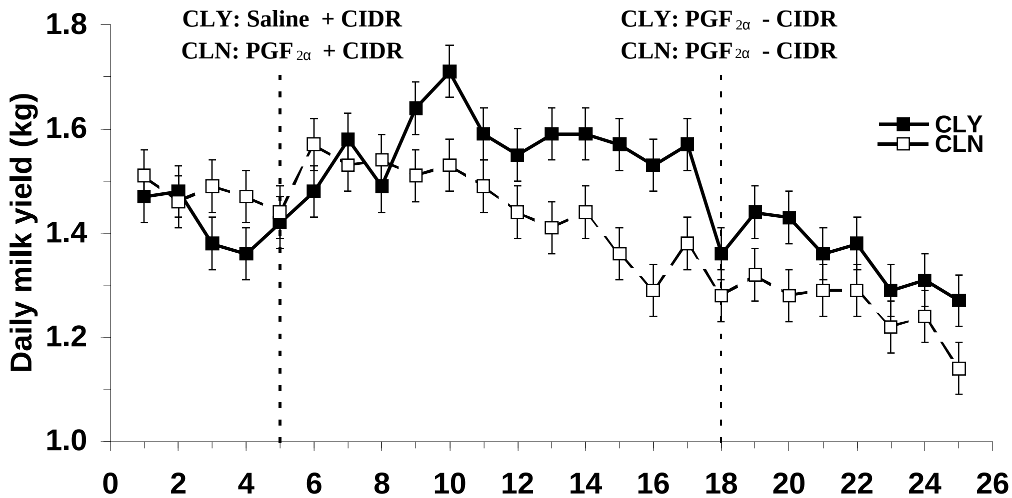


Figure 1. Schematic diagram of the experimental design. Estrus synchronization and induction of ovulation were achieved with intravaginal progesterone (CIDR), $PGF_{2\alpha}$, and gonadotropins. Ewes were studied during three experimental periods: d 0 to 5 (pre-treatment), d 6 to 18 (treatment), and d 19 to 25 (post-treatment). Laparoscopy was performed on d 4 and 11 to affirm presence or absence of corpora lutea (CL). Treatments were applied on d 5 and consisted of: injection of saline (CLY) or $PGF_{2\alpha}$ (CLN) to achieve persistence or regression of CL, respectively. All ewes received two CIDRs from d 5 to 18. Administration of $PGF_{2\alpha}$ was performed on d 18 to ensure luteolysis in all ewes during the post-treatment period.

A



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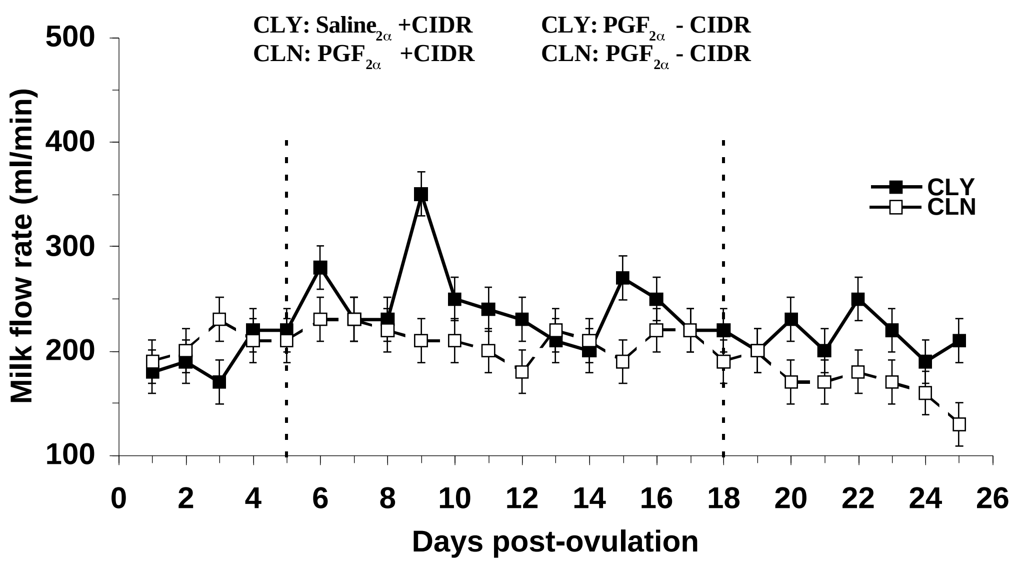
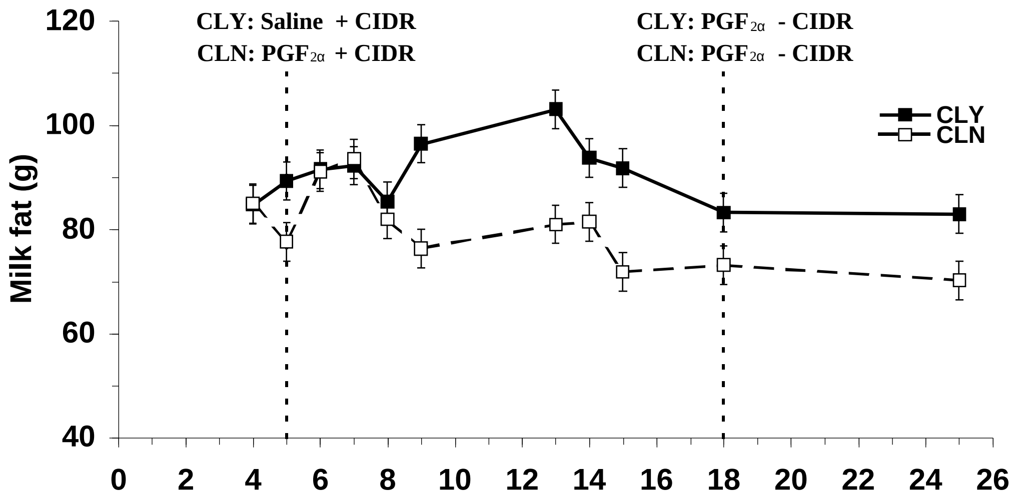


Figure 2. Daily milk yield and average milk flow rate (panels A and B, respectively) for the two treatment groups (CLY = ewes with corpora lutea, n = 12; CLN = ewes with no corpora lutea, n = 12) during the three experimental periods: d 0 to 5 (pre-treatment), d 6 to 18 (treatment), and d 19 to 25 (post-treatment). Both groups received intravaginal progesterone (CIDR) from d 5 to

A



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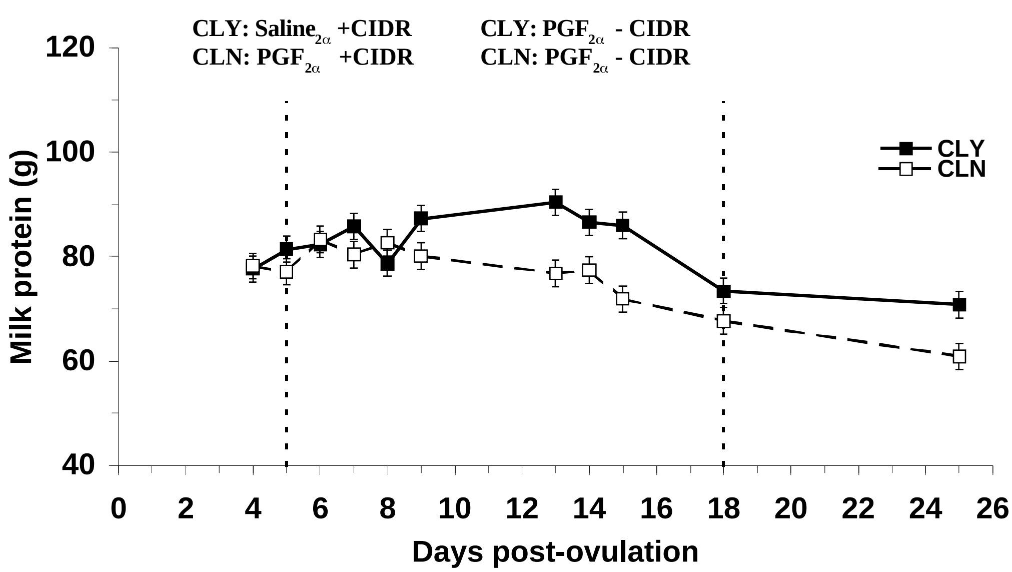

Figure 3. Daily milk fat and protein yield (panels A and B, respectively) for the two treatment groups (CLY = ewes with corpora lutea, n = 12; CLN = ewes with no corpora lutea, n = 12) during the three experimental periods: d 0 to 5 (pre-treatment), d 6 to 18 (treatment), and d 19 to 25 (post-treatment). Both groups received intravaginal progesterone (CIDR) from d 5 to 18.

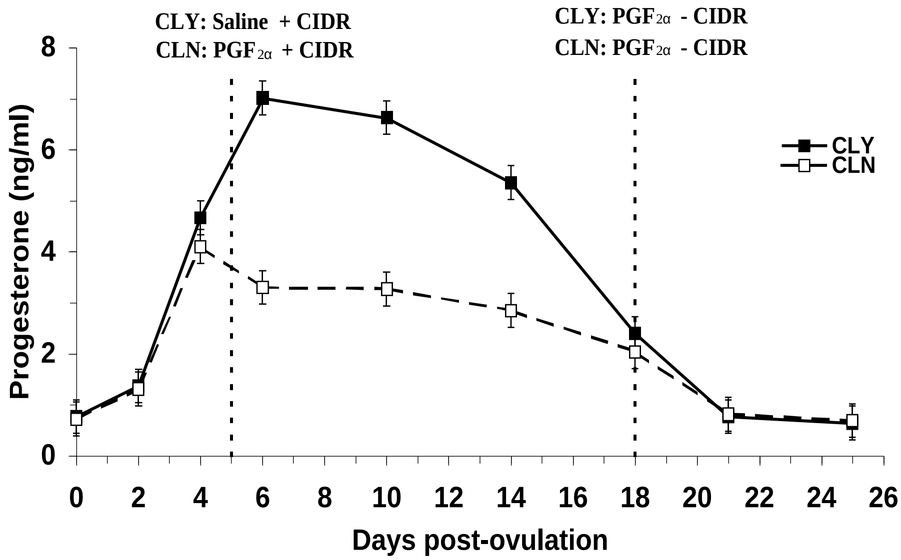

Figure 4. Serum progesterone concentrations for the two treatment groups (CLY = ewes with corpora lutea, n = 12; CLN = ewes with no corpora lutea, n = 12) during the three experimental periods: d 0 to 5 (pre-treatment), d 6 to 18 (treatment), and d 19 to 25 (post-treatment). Both groups received intravaginal progesterone (CIDR) from d 5 to 18.

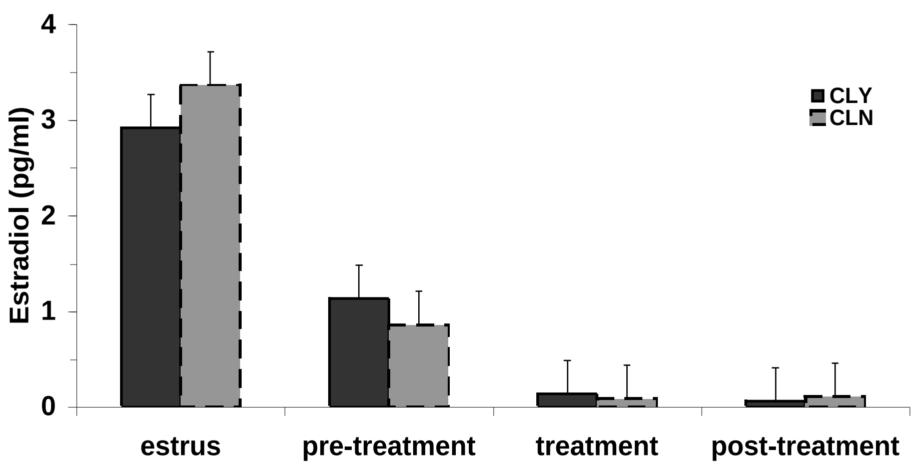

Figure 5. Serum estradiol concentrations for the two treatment groups (CLY = ewes with corpora lutea, n = 12; CLN = ewes with no corpora lutea, n = 12) during estrus (d –2) and the three experimental periods: d 0 to 5 (pre-treatment), d 6 to 18 (treatment), and d 19 to 25 (post-treatment

MILK STORAGE WITHIN THE UDDER OF EAST FRIESIAN DAIRY EWES OVER A 24 HOUR PERIOD

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Abstract

Accumulation and storage of milk within the cistern between milkings is advantageous for dairy ruminants because feedback inhibition of lactation and over-distention of the alveoli, factors that potentially limit milk secretion, can be reduced. While the distribution of milk and udder filling rates in dairy cows and goats have been evaluated, there exist no reliable reports in dairy ewes. Additionally, improved techniques for the study of milk distribution within the udder with the aid of an oxytocin receptor antagonist have been recently developed. Cisternal and alveolar milk fractions were measured in multiparous East Friesian-crossbred dairy ewes (n = 32) at 4, 8, 12, 16, 20, and 24 h in a 6 x 6 Latin square design by administration of Atosiban, an oxytocin receptor antagonist, for the recuperation of cisternal milk, followed by injection of oxytocin to remove the alveolar fraction. Less than half (38 to 47%) of the total milk yield is stored within the cistern for the first 12h of udder filling, compared to up to 57% after 24 h. Because subsequent milk yield was significantly reduced following the 16, 20, and 24-h treatments, it is recommended that the milking interval in East Friesian dairy ewes should not exceed 16 h. Although the cistern of dairy ewes is capable of storing large quantities of milk, cisternal milk is significantly inferior in fat content compared to alveolar milk (4.49 vs. 7.92%, respectively) which highlights the importance for proper milk ejection during machine milking of dairy ewes for recuperation of a milk that is rich in total solids. Milk protein percentage was not different between cisternal and alveolar fractions for the majority of milking interval treatments, indicating that casein micelles pass more freely from the alveoli to the cistern between milkings compared to fat globules. Somatic cell count (SCC) decreased with increasing level of milking frequency treatment; alveolar SCC was significantly higher than cisternal SCC at the 16, 20, and 24-hr treatments. At the 24-h treatment, significant increases in cisternal milk yield, fat and protein content, and SCC were observed which implies that some milk transfer to the cistern had occurred even prior to milking, possibly due to contraction of the overly distended alveoli and small intramammary ducts. We conclude that dairy ewes are capable of supporting longer milking intervals (up to 16 h) and that the main difference between milk fractions is the poor fat content within cisternal milk.

Introduction

Milk within the udder of dairy ruminants can be divided into two fractions: the cisternal fraction which has already been transferred from the alveoli to the cistern during the intermilking interval, and is therefore immediately obtainable without milk ejection; and the alveolar fraction which can only be removed from the udder if milk ejection occurs during machine milking. Large differences between dairy species exist with respect to the proportion of total milk that can be stored within the cistern. For example, the dairy ewe and goat can store up to 75% of the total milk volume within the cistern (Marnet and McKusick, 2001), whereas the cisternal fraction in dairy cattle accounts for approximately only 20% (Bruckmaier, 2001). Physiologically, there are advantages to increased milk storage within the cistern because a protein that serves as a feed-back inhibitor of lactation (Wilde et al., 1995) can be diverted away from mammary secretory epithelium. This protein reduces milk synthesis when present in alveolar milk, but is inactive once it has been transferred to the cistern (Henderson and Peaker, 1987; Knight et al., 1994a). Additionally, increased cisternal storage reduces alveolar pressure and potentially avoids deleterious effects on milk synthesis and milk quality from crushing of the epithelium (Labussière, 1993; Peaker, 1980) and/or impairment to the tight junctions between epithelial cells (Stelwagen et al., 1997).

Indeed there are several reports that demonstrate the differences in distribution and accumulation of cisternal and alveolar milk fractions in dairy cattle and goats. Knight et al. (1994a) constructed mathematical models for the transfer of milk from the alveoli to the cistern in dairy cattle over a 20-h period and found that secreted milk does not readily appear in the cistern until 4 to 6 h following udder emptying. Theses findings differ from reports in dairy goats in which alveolar and cisternal milk accumulation is linear for the first 6 h (Peaker and Blatchford, 1988). The cistern is a crucial anatomical consideration for milk secretion, because cows with a greater degree of cisternal filling after 24 h have significantly lower production loss after once-daily milking (Davis et al., 1998; Knight and Dewhurst, 1994). Freedom of transfer of milk from the alveoli to the cistern between milkings is an important factor in determining appropriate milking frequencies for dairy cows (Davis et al., 1998), and is consistent with observations of Peaker and Blatchford (1988), who conclude that goats which store more milk in the alveoli between milkings have lower milk secretion rates.

Despite the above interest in delineating cisternal and alveolar milk storage within ruminant udders, there are no reliable reports on the way milk is distributed in East Friesian ewes, currently the predominant North American dairy breed. Furthermore, techniques for determining alveolar and cisternal milk fractions have been improved, and now include the use of oxytocin receptor antagonists (Knight et al., 1994b; Wellnitz et al., 1999). The objectives of the present experiment were to measure cisternal and alveolar fractional milk yield and composition at 4, 8, 12, 16, 20, and 24 h with the aid of a specific oxytocin receptor antagonist, to be able to understand how milk accumulates within the udder of East Friesian dairy ewes over a 24-h period.

Materials and methods

Thirty-two fourth parity East Friesian crossbred dairy ewes in their third month of lactation with similar daily milk production (2.5 ± 0.7 kg/ewe, mean ± SD) were studied during the spring of 2001. Ewes had been selected from the University of Wisconsin-Madison's main dairy ewe flock of 350 ewes at the Spooner Agricultural Research Station and synchronized for lambing. Ewes were housed in six pens in an indoor laboratory facility on the University of Wisconsin-Madison campus and fed a 16% crude protein grain concentrate and alfalfa haylage. Machine milking was performed on a portable milking platform with cascading head stanchions. The milking machine (Coburn Co., Inc., Whitewater, WI and Interpuls Inc., Albinea, Italy) was set to provide 165 pulsations per minute in a 50:50 ratio with a vacuum level of 37 kPa.

Ewes were randomly assigned to one of six pens (A to F), balanced with respect to milk production, for use in a 6 χ 6 Latin square design. At the morning milking (0630) immediately prior to treatment administration (0 h), 2 IU of oxytocin was injected intravenously to empty the udder as completely as possible. One of six milking interval treatments (4, 8, 12, 16, 20, or 24 h) was then randomly applied to each pen for the first milking of six 3-d periods (1 to 6). Thus, a pen of ewes was milked at 1030, 1430, 1830, 2230, 0230, or 0630 for the six treatments, respectively. Following treatment administration, the next machine milking occurred at normal milking times (0630 or 1830) and continued twice daily at these times for the remainder of milkings in each 3-d period. At the termination of one 3-d period, oxytocin was administered at the 0630 milking (0 h), and the next series of treatments were applied; the experiment continued until all pens had received all the treatments (18 d).

Cisternal and alveolar milk fractions were determined only at the treatment-milking with the aid of an oxytocin receptor antagonist (Atosiban, Ferring Research Institute Inc., San Diego, CA). Atosiban (1.0 mg/ewe) was administered intravenously to each ewe within a pen immediately prior to entering the parlor. As a result of oxytocin receptor antagonism, milk ejection during machine milking could not occur, and only the cisternal milk fraction was obtained. Cisternal milk volume was recorded and sampled for each ewe. Ewes were then injected intravenously with 2 IU of oxytocin to re-establish milk ejection and allow the alveolar milk fraction to be measured and sampled. Individual ewe cisternal and alveolar milk samples were analyzed for percentages of fat and protein, and for Fossomatic somatic cell count (SCC) by a State of Wisconsin certified laboratory. Somatic cell count was transformed to logarithms of base ten. Milk fat and protein yield was calculated with the following formula, which includes the specific gravity for sheep milk expressed in g/ml (1.036, Jandal, 1996):

Fat or protein yield = milk volume x 1.036 x(fat or protein percentage/100).

Total milk yield, and milk fat and protein yield at a treatment were calculated by adding cisternal and alveolar milk together; total percentages of milk fat and protein at a treatment were calculated by dividing total milk fat or protein yield by total milk yield; and total SCC at a treatment was calculated by averaging the cisternal and alveolar SCC. Milk yield was also measured 12 h prior to time 0, and at all subsequent twice-daily milkings following treatment within each 3-d period. Total 3-d milk yield was calculated by adding together all milk yields obtained during the 3-d period.

Analyses of variance were conducted with the general linear models procedure of SAS (1999) for a 6 x 6 Latin square design. Alveolar and cisternal fraction traits analyzed were milk volume, milk fat and protein percentage, milk fat and protein yield, and SCC for following independent variables and their interactions: fraction (alveolar or cisternal), treatment (4, 8, 12, 16, 20, or 24 h), pen (A to E), ewe within pen, 3-d period (1 to 6), fraction x treatment, fraction x pen, and fraction x 3-d period. For the analyses of total treatment milk yield (alveolar + cisternal milk), 3-d milk yield, total milk fat and protein yield, total milk fat and protein percentage, and total SCC, fraction and its interactions were removed from the model. A separate analysis was performed for milk yield produced prior to and after treatment and included the following independent variables and interactions: time (12-h milk yield prior to treatment or milk yield during the first complete 12-h interval after treatment), treatment, pen, ewe within pen, 3-d period, time x treatment, time x pen, and time x 3-d period.

Results

Treatment milk yield increased (P < 0.01) with increasing level of treatment (Table 1). Cisternal and alveolar fractional yields were different (P < 0.05) at 4, 8, and 24 h, with cisternal milk accounting for approximately 35% of the total milk yield prior to 12 h, and 57% of the total yield at 24 h (Table 1 and Figure 1). Alveolar milk yield increased (P < 0.05) with increasing level of treatment until 20 h (0.26 to 0.89 kg, respectively), whereas cisternal milk yield increased (P < 0.05) until 24 h (0.12 to 1.26 kg, respectively) (Figure 1). Milk yield during the first complete 12-h interval following treatment was similar compared to pre-treatment values for the 4, 8, and 12-h treatments, yet reduced by 15% (P < 0.01) for the 16, 20, and 24-h treatments (Table 1). Total milk yield during a 3-d treatment period was lowest (P < 0.01) for the 20- and 24-h treatments (6.87 kg) compared to all other treatments (7.24 kg) (Table 1).

With respect to increasing milking interval treatment, percentage of milk fat (9.20 to 5.72%) decreased (P < 0.01), while percentage of milk protein (4.13 to 4.65%), and milk fat (36.3 to 127.5 g) and protein yield (15.2 to 104.8 g) increased (P < 0.01) (Table 1). Alveolar percentage of milk fat was higher (P < 0.05) than cisternal percentage of milk fat for all treatments except 4 h (Figure 2A). Alveolar percentage of fat tended to increase from the 8-h to the 24-h treatment (7.5 to 8.9%, respectively), whereas cisternal percentage of milk fat decreased from the 4- to 20-h treatment (9.1 to 3.4%, respectively) (Figure 2A). Alveolar milk fat yield increased with increasing level of treatment (25.0 to 85.0 g), and was consistently higher (P < 0.05) than cisternal milk fat yield for all treatments (Figure 2B). Cisternal milk fat yield increased (P < 0.05) during the 4, 8, and 12-h treatments (11.4 to 29.0 g), was constant during the 16- and 20-h treatments (31.5 g), and then increased (P < 0.05) again for the 24-h treatment (42.5 g) (Figure 2B). Milk protein percentage did not differ between cisternal and alveolar milk fractions for all treatments except 24 h (P < 0.05) (Figure 3A). Alveolar milk protein yield increased (P < 0.05) with increasing level of treatment until 20 h (10.9 to 40.5 g, respectively), whereas cisternal milk protein yield increased (P < 0.05) until 24 h (13.3 to 62.6 g, respectively) (Figure 3B).

Somatic cell count decreased (P < 0.05) from the 4-h to the 20-h treatment (5.29 to 4.94 log units, respectively), and then increased slightly at 24 h (5.02 log units) (Table 1). Alveolar and cisternal SCC were not different during the 4, 8, or 12-h treatments (5.16 log units), however during the 16, 20, and 24-h treatment cisternal SCC (4.85 log units) was lower (P < 0.05) than alveolar SCC (5.08 log units) (Figure 4).

Discussion

During the first 12 h of milk secretion, our experimental East Friesian dairy ewes stored the majority of their total milk volume in the alveolar compartment, which is consistent with reports in dairy cattle (Knight et al., 1994a). However, in contrast, the cisternal compartment began filling as early as 4 h indicating that there was at least passive transfer of milk from the alveoli to the cistern much earlier than one report in dairy cows (Knight et al., 1994a) yet similar to a second report in dairy cows (Stelwagen et al., 1996) and one report in dairy goats (Peaker and Blatchford, 1988). When the milking interval exceeded 12 h, the cisternal compartment became more important in accommodating milk storage, which possibly helped reduce alveolar milk stasis, alveolar pressure, and concentrations of feedback inhibitors of lactation, allowing milk secretion to continue (Labussière, 1993; Wilde et al., 1995). In contrast to one report in dairy goats (Peaker and Blatchford, 1988), which stated that alveolar milk volume remained constant after 6 h, alveolar milk yield in the present experiment continued to increase up to at least 20 h. This discrepancy is probably related to differences in experimental techniques between the use of an oxytocin receptor antagonist and oxytocin in the present experiment versus catheter removal with oxytocin in the former.

Although we assume that the cistern played a crucial role in decreasing the inhibition of milk synthesis when the milking interval exceeded 12 h, we did observe significant decreases in milk yield when the milking interval treatment was equal to or exceeded 16 h during the first complete 12-h interval following treatment and during the entire 3-d treatment period. In fact, following the 24-h treatment, milk yield remained significantly lower than all other treatments for at least the first 3 milkings following treatment (data not shown). Continued use of unilateral once-daily milking compared to thrice-daily milking of dairy goats induced increased levels of apoptosis in the once-daily milked udder half as evidenced by less numbers of secretory cells (Li et al., 1999). It would appear that a routine milking interval for East Friesian dairy ewes should not exceed 16 h to avoid significant losses in overall lactation yield and length; this is slightly shorter than the 18 to 20 h maximum interval recommended for dairy cattle (Davis and Hughson, 1988).

Milk fat is considered to be the most variable component in ruminant milk (Barnicoat et al., 1956) because its synthesis is independent of that of lactose and the major milk proteins (Cowie and Tindal, 1971). This is clearly reflected in the present experiment, as we observed marked differences between milking interval treatments in percentage of milk fat (both in total milk and in the cisternal and alveolar fractions), but not necessarily in milk protein percentage.

We have shown that although the cistern is capable of storing more than 50% of the total milk volume, cisternal milk is relatively poor in fat content. Cisternal milk fat yield tended to plateau during the 16- an 20-h treatments yet at the same time alveolar milk fat yield increased sharply; this indicates to us that transfer of milk fat from the alveoli to the cistern is no longer taking place resulting in a backup of milk fat in the alveolar compartment. Because milk fat globules in the ewe are large (Muir et al., 1993), active expulsion, either by oxytocin-mediated myoepithelial contraction (see review by Bruckmaier and Blum, 1998) or perhaps by less clearly defined spontaneous contraction mechanisms (see review by Lefcourt and Akers, 1983), is required for milk fat removal from the udder. Our results confirm that up to 70% of the total fat yield (e.g. at the 20 h treatment) can be contained within the alveoli, which underlines the importance of milk ejection during milk removal (either during suckling or machine milking) for recuperation of milk that is rich in total solids (Labussière, 1969; McKusick et al., 2001).

Milk protein percentage was generally unchanged in the present experiment with respect to milk fraction. This is consistent with hypotheses based on the evolutionary advantage of a mammal to be able to synthesize and provide milk that is consistent in protein concentration regardless of nutrition and/or other potential environmental stressors (Cowie and Tindal, 1971). Milk protein yield, and its distribution between alveolar and cisternal fractions, were highly correlated with milk yield ($r = 0.98$, data not shown) and is explained by the synergistic synthetic pathway involving lactose synthase in the mammary gland (Cowie and Tindal, 1971). In contrast to our observations on milk fat, milk protein primarily in the form of small casein micelles (Cowie and Tindal, 1971), passes freely from the alveolar compartment into the cistern between milkings, and is therefore less dependent upon milk ejection for its removal from the mammary gland.

Reports in dairy cattle concerning reduced milking frequency demonstrate that SCC increases with decreased milking frequency (Kelly et al., 1998; Hamann and Gyodi, 2000), however, this does not appear to be due to damage of mammary secretory epithelium (Stelwagen and Lacy-Hulbert, 1996). Instead, increased SCC associated with longer milking intervals appear to be due to leaky tight junctions between mammary epithelial cells, however, tight junctions resume their closed state immediately upon milk removal (Stelwagen et al., 1997). Although we observed that SCC decreases with increasing milking interval, our experiment was designed with only one milking interval treatment at the first milking of a 3-d period; this undoubtedly is not comparable to the above reports, which used extended periods of increased milking interval. However, we did observe a tendency for SCC to increase again by the 24-h treatment, which supports the above claims that tight junctions are compromised by long periods between milkings.

One of the novel observations in the present experiment is the fact that there were marked increases in milk yield, milk protein yield, and SCC within the cisternal fraction, but not necessarily in the alveolar fraction, at the 24-h treatment relative to the 20-h treatment. These observations, although less dramatic, were also present for cisternal milk fat yield. Presumably, transfer of milk from the alveoli to the cistern was somehow increased during the last 4 hr of the 24-h milking interval. This might be explained by increased pressure and distention within the alveoli and small intramammary ducts, causing contraction of these structures (Cross, 1954; Grosvenor, 1965), and resulting in expulsion of milk from the upper portions of the udder into the cistern, presumably independent of the oxytocin-mediated milk ejection reflex (Lefcourt and Akers, 1983). Presence of this mechanism might explain some of the individual variation in milk production losses associated with once-daily milking (Davis and Hughson, 1988). In other words, intramammary compliance or elasticity, could play a significant role in determining how often the udder would need to be emptied in order to avoid deleterious effects on milk synthesis due to over accumulation of milk within the alveoli (Peaker and Blatchford, 1988). This remains an important area of investigation in lactation physiology research.

Conclusions

Dairy ewes are capable of storing large amounts of milk within the cistern. However, cisternal milk is significantly inferior in milk fat content compared to alveolar milk, implying that milk ejection during machine milking is obligatory for the removal of milk that is rich in total solids. Milking intervals greater than 16 h will most likely result in significant losses in milk yield and decreased lactation length in dairy ewes. Finally, the fact that milk transfer from the alveoli to the cistern during the last 4 hr of a 24-h milking interval is markedly increased, merits further investigation with respect to determining factors that might improve milkability of dairy ewes.

Acknowledgements

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Table 1. Least squares means and SEM for milk yield and milk composition traits.

Trait		Milking interval treatment (h)[1]					
		4	8	12	16	20	24
Milk yield							
Treatment yield, kg		0.39^{f}	0.81^{e}	1.28^{d}	1.52^{c}	1.86^{b}	2.28^{a}
	SEM	0.04					
Cisternal fraction, %		32.2^{d}	37.8^{c}	46.9^{b}	52.4^{b}	51.0^{b}	57.4^{a}
	SEM	1.8					
12 h before treatment, kg		1.21^{a}	1.24^{a}	1.23^{a}	1.28^{a}	1.25^{a}	1.26^{a}
12 h after treatment, kg		1.19^{a}	1.17^{a}	1.18^{a}	1.10^{b}	1.06^{b}	1.06^{b}
	SEM	0.04					
Total 3-d yield, kg		7.24^{a}	7.23^{a}	7.31^{a}	7.16^{a}	6.89^{b}	6.85^{b}
	SEM	0.08					
Milk composition							
Milk fat, %		9.20^{a}	7.07^{b}	6.26^{c}	5.78^{d}	5.67^{d}	5.72^{d}
	SEM	0.13					
Milk fat, g		36.3^{f}	57.2^{e}	78.5^{d}	86.5^{c}	104.1^{b}	127.5^{a}
	SEM	2.4					
Milk protein, %		4.13^{d}	4.31^{c}	4.51^{b}	4.58^{b}	4.57^{b}	4.65^{a}
	SEM	0.03					
Milk protein, g		15.2^{f}	34.4^{e}	56.8^{d}	68.9^{c}	84.2^{b}	104.8^{a}
	SEM	1.7					
SCC, log units		5.29^{a}	5.11^{b}	5.08^{b}	4.96^{c}	4.94^{c}	5.02^{bc}
	SEM	0.04					

^{a,b,c,d,e,f}Means within a row(s) with different subscripts differ ($P < 0.05$).

[1]The first milking of a 3-d period occurred at 4, 8, 12, 16, 20, or 24 h (n = 32) respective to initial udder emptying with oxytocin at 0 h. Subsequent milkings during the 3-d period occurred at 0630 and 1830.

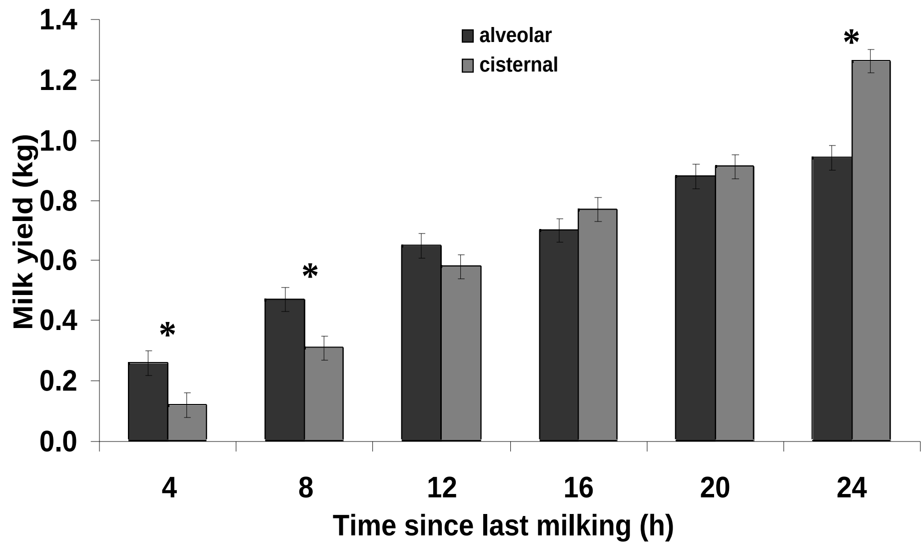
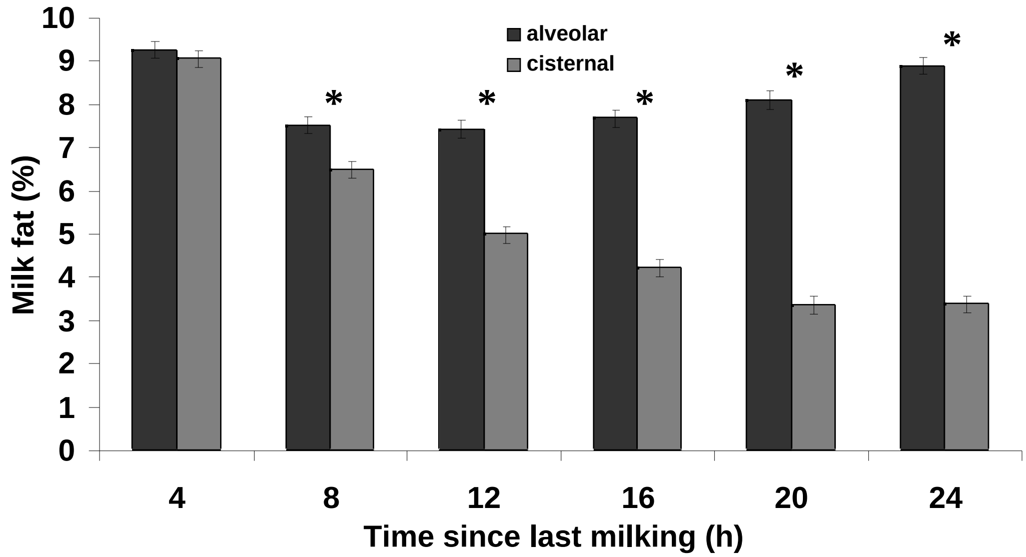


Figure 1. Alveolar and cisternal milk yield obtained 4, 8, 12, 16, 20, and 24 h since the last milking. Values are means of 32 ewes studied in a 6 x 6 Latin square design every 3 d for 18 d. Significant differences between alveolar and cisternal fractions within a time category are indicated by * ($P< 0.05$).

A



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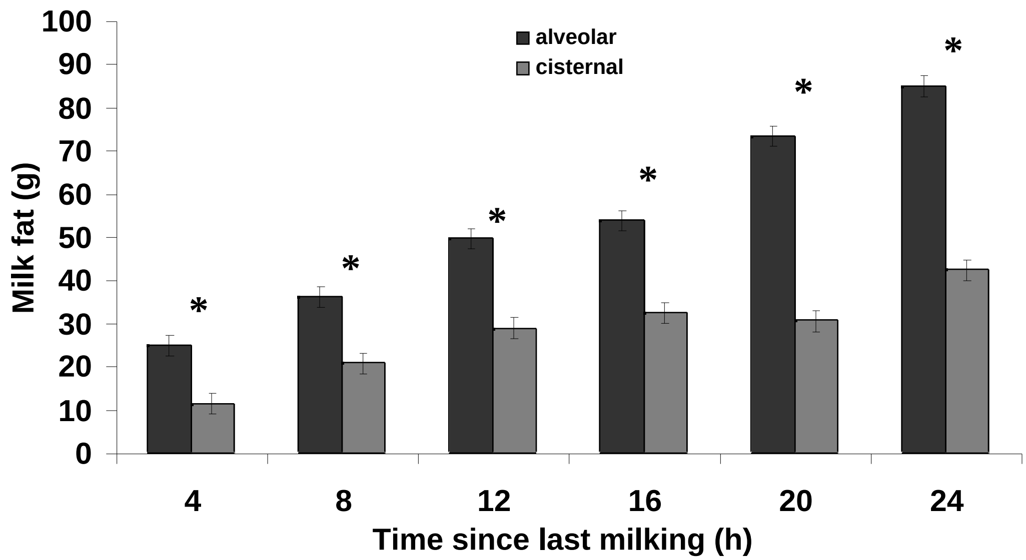
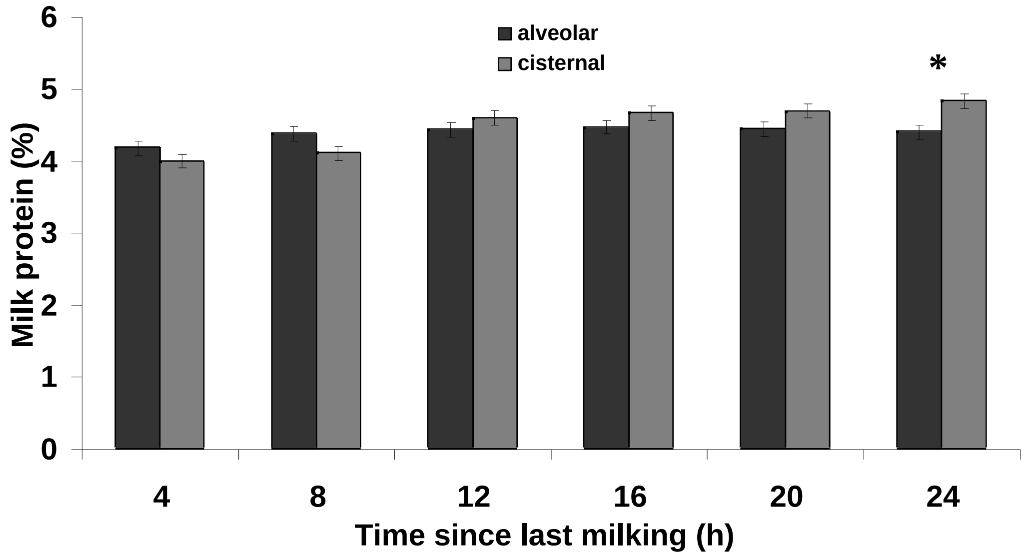


Figure 2. Milk fat percentage and yield (panels A and B, respectively), for alveolar and cisternal milk obtained 4, 8, 12, 16, 20, and 24 h since the last milking. Values are means of 32 ewes studied in a 6 x 6 Latin square design every 3 d for 18 d. Significant differences between alveolar and cisternal fractions within a time category are indicated by * (*P*< 0.05).

A



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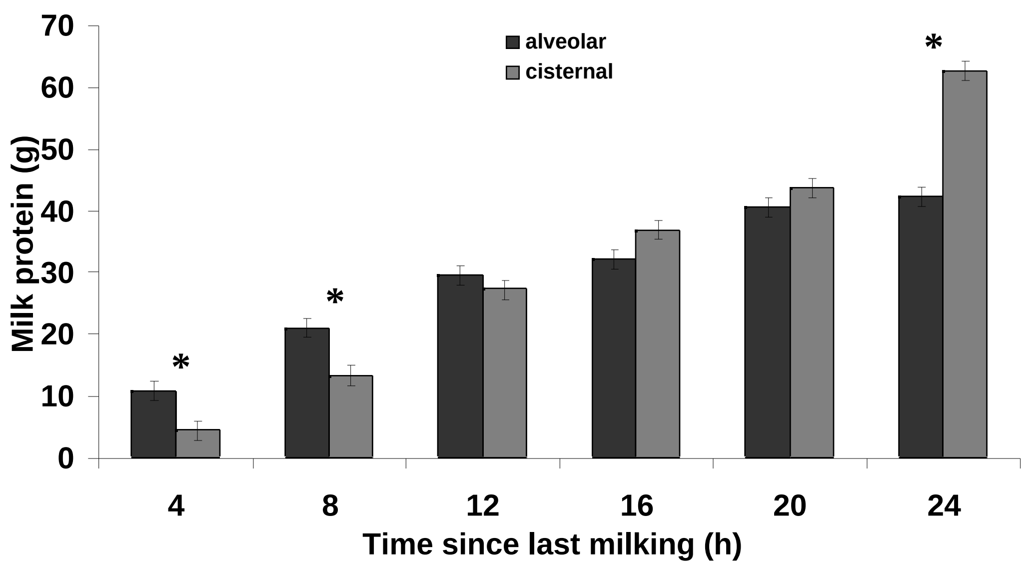

Figure 3. Milk protein percentage and yield (panels A and B, respectively), for alveolar and cisternal milk obtained 4, 8, 12, 16, 20, and 24 h since the last milking. Values are means of 32 ewes studied in a 6 x 6 Latin square design every 3 d for 18 d. Significant differences between alveolar and cisternal fractions within a time category are indicated by * ($P < 0.05$).

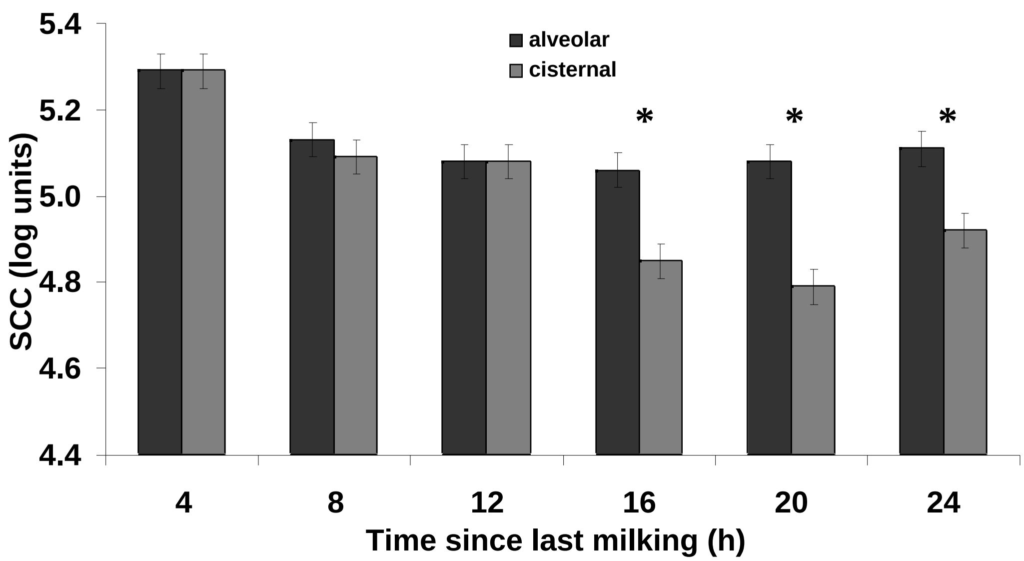

Figure 4. Somatic cell count (SCC) within alveolar and cisternal milk obtained 4, 8, 12, 16, 20, and 24 h since the last milking. Values are means of 32 ewes studied in a 6 x 6 Latin square design every 3 d for 18 d. Significant differences between alveolar and cisternal fractions within a time category are indicated by * ($P < 0.05$).

TAPPE FARM TOUR

Jon & Kris Tappe, Tappe Farms

Durand, Wisconsin

Total farm acreage is 1000 acres of which 360 acres are tillable and the remainder is woodland/swamp pasture. Currently have approximately 300+ ewes and ewe lambs, 8 rams, 3 horses and 30 beef cattle.

The basis for our operation is diversification for cash flow, deriving income from feeder cattle, cash crops, and dairy sheep. This mix of enterprises offers the most efficient use of our farm. Two thirds of our land is Chippewa River bottom land and unsuitable for dairy sheep primarily due to coyotes and wolves. The remaining third has sandy soil and is best suited for hay ground and pasture.

The beef operation is primarily a cow/calf operation with very little overhead. The cattle are pasture raised with free access to liquid protein suplement. During the winter, the cows are fed large round bales and corn silage. The majority of steers and terminal heifers are shipped at around 600 to 800 pounds based upon market conditions. The breeding stock is primarily Simmental and Charlois with one Texas Longhorn.

The cash crops are primarily corn, soybeans and oats; occasionally hay. The number of acres planted of each is determined by projected feed needs for the next year. We then try to plant what we need plus 30 to 50% extra as insurance against a bad year.

The main focus of the farm is the sheep dairy. Our goal is 300-400 ewes in milk. Our first year we had 165. The sheep are milked in a double 12 indexing stanchion system. We currently milk with 6 milking units with plans to expand to 12 milking units this next year. With 6 milking units, one person can milk approx. 60 to 72 ewes per hour. We lamb in February to March and dry up the ewes August and September. The lambs are separated from the ewe at 12 hours and bottle/nipple bar fed colostrum for 3 days and then switched to milk replacer. The lambs are weaned at 25 to 30 days of age and placed on a 18% protein grower ration. At 50 to 70 lbs. the replacement ewe lambs are separated and placed on a finisher ration of 12% protein and hay. The remaining slaughter lambs are placed on the same finisher ration till reaching a market weight of 120 to 140 lbs. Lambs may be sold as feeders, depending upon market conditions.

Our facilities consist of a 60’ x 100’ x 14’ pole shed with a 18’ x 100’ lean-to. This building is for machinery and hay storage. The lean-to is shelter for the beef herd in winter. We have a 32’ x 50’ conventional barn for hay storage and housing the horses, rams, and extra area for weaned lambs. The parlor, milk house, and a 9’ x 16’ walk in freezer are housed in a 42’ x 42’ x 8’ insulated pole building. This building is heated with an outdoor wood furnace utilizing in-floor heating.

A VISIT TO EWEPHORIA FARM

Carolyn Craft

EwePhoria Farm
Fall Creek, Wisconsin

A Little History

For the first 40 years of my life, I was a city girl. Although I did see a bit of farm life through visits to my Grandma's, I only dreamed of farm life rather than experienced it. After a last minute decision to join a friend on a visit to a sheep dairy, I came away deciding to buy some sheep and start my own dairy. Living in the upstairs of an old house isn't exactly conducive to sheep raising, so I started looking for a farm and moved 40 days later in 1994. A week after I moved in, I spent two days with Mary and Rusty Jarvis during lambing time to get a first-hand look at sheep and getting my first of many lessons on sheep raising. Soon after, I put up fences and welcomed my first sheep. As I look back now, it is probably a blessing that it happened in a whirlwind – it kept the panic from setting in.

My Operation

EwePhoria Farm is a 35-acre farm located in Eau Claire County. Since my acreage is small and my knowledge of tractors is even smaller, I set up my pastures for rotational grazing and purchase all of my hay. My foundation flock was a group of 15 Polypay sheep that I purchased from Jarvis' sheep dairying operation. I chose these sheep since they had been selecting for milking qualities for a number of years and their sheep were the highest producing flock in operation at the time. Also, as a newcomer to sheep, I needed the healthiest sheep I could find since I didn't have the expertise to handle sickly sheep. The flock I purchased was healthy and also OPP negative, to me a necessary aspect in a dairy sheep operation.

In 1995, I began to introduce East Friesian genetics into my flock. I brought in three new rams over the next three years, including a 78% black ram and a purebred white ram imported from Canada. I also imported a purebred Est A Laine Merino ram, which is used as a terminal sire, a great wool source, and as ram for my children's 4-H lambs. The flock is closed, with the only entries being the rams from OPP tested flocks. My flock has grown from 15 to 50, although only 30 are milked each season. Milking began on the farm in 1997 and the farm is licensed as a Grade A dairy.

The Dairy Operation

With a full-time + job off the farm, I designed my operation to be small enough to enable me to do both. I built a milk room and milking parlor within an existing pole barn. My parlor is a ramp-type system and has 6 goat-style head gates. The parlor is very small with a ramp that tips up on one end, offering convenient access to the front of the head gates. The small parlor saves steps and can be doubled in size, if milking is ever expanded. The windows on both sides of the parlor offer an easy way to check on what is happening in the barn and great scenery for both the sheep and me. I use Surge-type buckets for milking. Milking is more labor intensive in a small system, with the process of milking and clean-up taking about 1 1/2 hours. With such a small milking group, I'm not quick to kick off uncooperative ewes. So, between the favorites (who get a little special attention every day) and the kickers, a little time gets lost that I try to make up in the cleaning process. An over-the-sink washer unit, which is attached to the vacuum system, eliminates much of the manual cleaning.

Initially, the milk was collected in buckets, cooled in coolers of ice water and frozen in a chest freezer. With changing customer requirements and higher milk volume, the system became outdated and was this year replaced with a small bulk tank and commercial freezer. The bulk tank also made it possible for me to be included in some fresh milk shipments this past summer, which saved on freezer space needs.

For the first two years, I operated under a system of milking once per day. Lambs were left with their moms overnight and separated from them in the morning. Milking was done at 6 PM. Two hours after the last ewe was milked, moms and lambs were reunited. The delay in reuniting allowed ewes to accumulate a milk supply before the lambs nursed, avoiding mastitis problems. It was always an amazing sight to put moms and lambs back together – the noise level would go from a roar to utter silence as they all found each other. This system offered a number of advantages for me. The lambs grew well, the time commitment was less than would have been required for twice/day milking, and I had the option of skipping a day if I had a work commitment or simply needed a day off. The downside was lower butterfat, as ewes held the butterfat for the lambs. My butterfat rose from 4% to over 9% on the first test I took after lambs were taken off for the season.

In my third season, I took the year off to work on the many farm and fencing projects that had accumulated while the dairy operation was getting up and running. This past summer, it was back to business. For the first time, the sheep were milked twice per day. Fortunately, my daughter was willing to step in and help out in a big way this year.

Other Adventures

Over the last seven years, the farm has branched off in a number of unexpected directions that have cemented it as a way of life and helped to support the operation. The first was Denny, the border collie, who has been a lifesaver in time and energy. Sue was later added and the first litter of puppies arrived in 2000. Sue's next batch is due on the same day as the Symposium tour (bad timing!). In 1996, I married a folk singer who vowed never to become a sheep farmer. And I vowed never to become a musician. We have since found the middle ground and have termed EwePhoria Farm as Home of Happy Sheep and Sweet Music. We have combined the music and sheep raising and are now performing music together, taking Denny on the road doing demonstrations, giving spinning demonstrations, and selling sheep related crafts at festivals and other events. Spare time has become something of a luxury, to say the least. Although the farm at its current size doesn't support the family, it does provide supplemental income and a great existence.