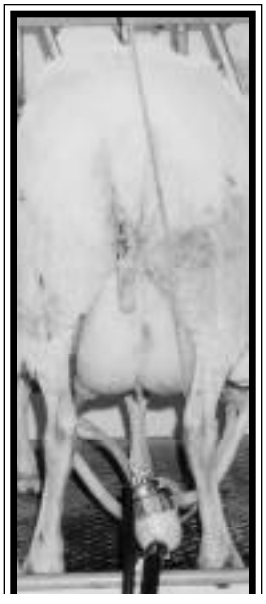
Proceedings of the 6th Great Lakes Dairy Sheep Symposium

November 2-4, 2000

Guelph, Ontario, Canada



PROCEEDINGS OF THE 6TH GREAT LAKES

DAIRY SHEEP SYMPOSIUM

November 2-4, 2000

GUELPH, ONTARIO, CANADA

Organized By:

Ontario Dairy Sheep Association, Shelburne, Ontario, Canada

Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph, Ontario, Canada

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

ORGANIZING COMMITTEE
6TH GREAT LAKES DAIRY SHEEP SYMPOSIUM

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Susan Porter, Madison, Wisconsin

Cover Photographs:

Top: Fraser's Magazine, vol. 2 (November, 1830), pp. 455-57.

Bottom: By Dave Thomas, Madison, Wisconsin, USA.
Left: High-percentage East Friesian ewes on pasture at Mountain Meadow Sheep Dairy, Inc. (Hani and Theres Gasser), Chase, British Columbia, Canada. This flock imported the first East Friesian semen into North America for sheep dairy purposes.

Middle and Right:
East Friesian ewes at Harper Adams University College, Newport, Shropshire, U.K. This flock was the source of embryos imported by WoolDrift Farm (Axel Meister and Chris Buschbeck), Markdale, Ontario, Canada - some of the first purebred East Friesian genetics in North America.

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, and 2000 Proceedings of the 4th, 5th, and 6th, 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

6TH GREAT LAKES DAIRY SHEEP SYMPOSIUM

GUELPH, ONTARIO, CANADA

Thursday, Friday, and Saturday
November 2, 3, and 4, 2000

Thursday, November 4

8:00 **Registration** – Days Inn-Guelph

9:00 Buses leave Days Inn-Guelph

9:30 **Tour Alexander Farm** goat dairy and rotary parlour, Norval, Ontario

11:30 Buses leave Alexander Farm, **Lunch**

14:00 **Tour McMaster Farm** (Northlea Dairy, Canadian Sheep and Milk Producers, Inc.) and sheep milk processing facilities, Indian River, Ontario

16:00 Buses leave McMaster Farm

19:00 Buses return to Days Inn-Guelph

Friday, November 3

8:30 **Registration** – Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA) Building, Ontario Government Complex, 1 Stone Road, Guelph

9:10 **Welcome –** Axel Meister, WoolDrift Farm, Markdale, Ontario

9:30 **Wisconsin Research Update** – Yves M. Berger and David L. Thomas, University of Wisconsin-Madison

10:15 **Break**

10:30 **Udder Morphology and Machine Milking Ability in Dairy Sheep** – Gerardo Caja, Universitat Autònoma de Barcelona, Bellaterra, Spain

11:30 **Dairy Sheep Nutrition** – John Cant, University of Guelph

12:15 **Lunch**

13:30 **Influence of Somatic Cell Count on Ewe's Milk Composition, Cheese Yield, and Cheese Quality** – Antonio Pirisi, Istituto Zootecnico e Caseario per la Sardegna, Olmedo, Italy

14:30 **Ontario Sheep Milk Quality Study** – Bill Lachowsky, University of Guelph

15:15 **Break**

15:30 **Mastitis of Sheep – Overview of Recent Literature** – Paula I. Menzies, University of Guelph

16:15 **Reproductive Technologies** – Brian Buckrell, University of Guelph and Small Ruminant Genetics, Georgetown, Ontario

17:00 **Adjourn** for the day

19:00 **Social and Dinner** – Eramosa Restaurant

Saturday, November 4

8:30 **Registration** – Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA) Building, Ontario Government Complex, 1 Stone Road, Guelph

9:00 **Physiologic Factors that Modify the Efficiency of Machine Milking in Dairy Ewes** – Brett C. McKusick, University of Wisconsin-Madison

9:45 **Factors Affecting Milk Traits and Udder Health in East Friesian Milk Sheep** – Christian Scharch, Institute of Animal Breeding and Husbandry with Veterinary Clinic, Halle, Germany

10:15 **Break**

10:30 **Design and Implementation of a Genetic Improvement Program for Comisana Dairy Sheep in Sicily** - F. Pinelli, Istituto Sperimentale Zootecnico per la Sicilia, Palermo, Italy and Pascal A. Oltenacu, Cornell University, Ithaca, New York

11:30 **Development of a Computerized Dairy Record Keeping System** – Chris Buschbeck, WoolDrift Farm, Markdale, Ontario and Small Ruminant Genetics, Georgetown, Ontario

12:00 **Lunch**

13:00 **An Update on Coopérative Laitière Ovine du Québec** – Daniel Vasseur, Coopérative Laitière Ovine du Québec, Bécancour, Québec, Canada.

13:30 **Sheep Cheese-Making and Marketing** – Hani Gasser, Mountain Meadow Sheep Dairy, Inc., Chase, British Columbia

14:00 **Producer Panel and Question Period**

15:00 **Symposium Adjourns**

SPEAKERS

Yves M. Berger, Researcher and Superintendent, Spooner Agricultural Research Station, University of Wisconsin-Madison, Spooner, Wisconsin, USA.

Dr. Brian Buckrell, DVM, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada and Reproduction Specialist, Small Ruminant Genetics, Georgetown, Ontario, Canada.

Dr. Chris Buschbeck, DVM, Dairy Sheep Producer, WoolDrift Farm, Markdale, Ontario, Canada and Reproduction Specialist, Small Ruminant Genetics, Georgetown, Ontario, Canada.

Dr. Gerardo Caja, Professor in Animal Production, Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, Bellaterra, Spain.

Dr. John Cant, Animal Scientist, Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada.

Hani Gasser, Dairy Sheep Producer and Sheep Milk Processor, Mountain Meadow Sheep Dairy, Inc., Chase, British Columbia, Canada.

Bill Lachowsky, Dairy Specialist, Dairy Regulatory Unit, Lab Services Division, University of Guelph, Guelph, Ontario, Canada.

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Axel Meister, Dairy Sheep Producer, WoolDrift Farm, Markdale, Ontario, Canada.

Dr. Paula I. Menzies, DVM, MPVM, Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada.

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Dr. Antonio Pirisi, Dairy Foods Specialist, Istituto Zootecnico e Caseario per la Sardegna, Olmedo, Italy

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Dr. David L. Thomas, Professor of Sheep Genetics and Management, Department of Animal Sciences, University of Wisconsin-Madison, Madison, Wisconsin, USA.

Daniel Vasseur, Manager, Coopérative Laitière Ovine du Québec, and Dairy Sheep Producer, Bécancour, Québec, Canada.

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THE EFFECT OF THREE TIMES A DAY MILKING AT THE BEGINNING OF LACTATION ON THE MILK PRODUCTION OF EAST FRIESIAN CROSSBRED EWES

Linda de Bie[1], Y.M. Berger[2], and D.L. Thomas[3]

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[3]Department of Animal Sciences, University of Wisconsin-Madison, Madison, Wisconsin, USA

Introduction

In a study of different weaning systems in which, during the first 30 days of lactation, ewes were either (1) milked twice daily after weaning at 24 hours post partum (DY1), (2) allowed to raise their lambs naturally and then were machine milked twice daily after weaning at 30 days (DY30), or (3) suckled for part of the day and then separated from their lambs during the night to allow for machine milking once daily the following morning (MIX), McKusick et al. (1999) showed that MIX ewes produced only 40% less commercial milk than DY1 during the first 30 days and produced 7% more milk than DY1 ewes during the peri-weaning period. The same authors explain that the superior production of MIX ewes is due to a more frequent and more complete udder evacuation reducing local concentration of a feedback inhibitor of lactation. Other authors working with dairy cows (Pearson et al. 1979, Waterman et al. 1983, DePeters et al. 1985, Allen et al. 1986, Van der Iest and Hillerton 1989, Erdman and Varner 1995) showed that by increasing the milking frequency, it was possible to increase the total milk production. In a trial conducted by Pearson et al. (1979), 3 groups of cows (twice a day milking, three times a day milking until they dropped below 31 kg, and three times a day milking until they dropped below 21 kg) were compared for total milk and fat production. There was little effect of increased frequency on milk production in early lactation. With time, however, the superiority in yield increased such that cows milked three times a day produced 20% more milk than cows milked twice a day. The authors of the study showed that the increased yield was primarily due to a prolonged peak yield and a lower subsequent rate of decline. Three times a day milking had a positive carryover, apparently due to higher starting yield at the point the cows were switched to twice a day milking. Moreover, it has been shown that the magnitude of increase due to higher milking frequency is the same in primaparous and multiparous cows (Pearson et al, 1979), that cows responded quickly to a higher milking frequency (Erdman and Varner, 1995), and that the milk produced was of an acceptable composition (Van der Iest and Hillerton, 1989).

The effect of milking frequency on milk quality has been documented by several authors. Klei et al. (1977) and Campos et al. (1994) found a significant increase in fat and protein yield of cows milked three times a day, while Pearson et al. (1979), Allen et al. (1986), Van der Iest and Hillerton (1989) and Sapu et al. (1997) found lower fat and protein percentage (.2 to .3% lower) in cows milked three times a day. In terms of somatic cell count, an indicator of udder health, there was no difference in cows milked 2 or 3 times a day (Klei et al., 1977; Waterman et al., 1983; Van der Iest and Hillerton, 1989). McKusick et al. (1999), however, in their study of weaning systems for dairy ewes, found that the somatic cell count in MIX ewes was lower than

in DY30 and DY1 ewes, implying that perhaps more frequent and (or) more complete udder evacuations are more desirable with respect to udder health.

The present study aims at describing the influence of 3 times a day milking during the first 30 days of lactation on the total milk production and milk quality of East Friesian crosssbred ewes. Since the price of sheep milk in the U.S. ($ 1.32/liter) is 4 to 5 times the price of cow milk, the extra expenses incurred by an additional milking might be justified if the magnitude of increase in milk yield is similar to the one found in cows.

Materials and Methods

Multiparous East Friesian crossbred ewes (125) were used. At the time of parturition 53 ewes were randomly assigned to three times a day milking (3TM) and 72 ewes to twice a day milking (2TM). The lambs were removed from the ewes between 6 and 24 hours after parturition and the ewes were put in their respective milking group. The colostrum was discarded for the first 3 days. All lambs were raised on milk replacer.

Ewes were milked in 2 x 12 high line “Casse” system (Alfa Laval Agri™). Machine milking parameters were set to provide180 pulsations/min., in a 50:50 ratio, with a vacuum of 37 kPa. Milking of the 3TM group occurred at 6 a.m., noon, and 6 p.m. while milking of the 2TM group occurred at 6:30 a.m. and 5:30 p.m. Milk production at the evening, morning and noon milkings was measured once a week for the first 30 days with Waikato milk meter jars. Milk samples were taken for each ewe on test days at the morning milking. The samples were analyzed by a State of Wisconsin certified laboratory for percentage of milk fat, percentage of milk protein, and Fossomatic somatic cell count. After 30 days, all ewes were put on a twice a day milking frequency and the next test day occurred 14 days later.

All ewes received alfalfa-grass hay ad libitum (CP 19%). 3TM ewes received 454g of concentrate (whole corn and pelleted soybean meal, CP 16%) in the parlor at the morning milking and 227g of the same concentrate at the noon milking and at the evening milking. 2TM ewes received 454g of the same concentrate at each milking. Although the distribution of the concentrate during the day was not the same for each group, the amount of nutrients given was the same for each group.

Least squares means analysis of variance was performed using the GLM procedure of SAS (SAS, 1999). The main effects in the model included: milking frequency (3TM or 2TM), the percentage of East Friesian breeding (25%, 37.5%, and 50%), and the percentage of East Friesian-milking frequency interaction. The daily milk production, as well as the 30 day milk production, were adjusted for ewe age using the correction factors given by Thomas (1996). The dependent variables analyzed were: average daily milk production, percentage of milk fat, percentage of milk protein, log-transformed somatic cell count every 7 days for the first 30 days, total milk production for the first 30 days and during the whole lactation, peak yield, rate of decline in milk production, and lactation length. A simple economic analysis of 3TM vs. 2TM systems was performed using the cost of extra labor to milk a 3rd time during the day, the additional cost of milking equipment and supplies, and the increased milk income of a 3TM vs. a 2TM system.

Results and discussion

In order to verify that both groups of ewes were effectively at the same level of production at the start of the trial, a simple analysis of variance was performed on the 1999 adjusted milk production of the ewes using the percentage of East Friesian and the assigned group in 2000 (3TM or 2TM) as main effects. The 1999 milk production was adjusted for the age of ewe using the correction factors given by Thomas (1996). No difference was found in the 1999 milk production of the 2 groups (285 and 282 liters, respectively).

Effect on milk production

The daily milk production at each weekly testing, the total milk production for the first 30 days of milking, and the daily milk production 2 weeks after the ewes were all at the milking frequency of twice daily are shown in Table 1. The difference in the daily yield of ewes milked 3 times a day or 2 times a day is small but always significant during the length of the trial. Ewes milked 3 times a day produced 12.6 liters more milk (15%) during the first 30 days than the ewes milked twice a day. However, the daily milk production of 3TM ewes dropped to the level of 2TM ewes as soon as they were switched to a twice a day milking frequency. The hypothesis that ewes milked 3 times a day, and reaching a higher production peak, would stay at a higher level of production for the rest of the lactation does not appear to be valid in this trial, contrary to what Pearson et al (1973) found in dairy cows.

More importantly, the response of ewes to milking frequency is not constant between the different percentages of East Friesian breeding. The 25% East Friesian crossbred ewes do not show any response at all to a third milking while the 50% East Friesian ewes show a significant response (12.8% more milk in 30 days), and the 37.5% East Friesian have a greater response yet (36% more milk in 30 days). A possible explanation is that the 25% EF ewes have reached their maximum genetic potential production and increasing demand through a third milking does not result in an increasing supply. On the other hand, 37.5 % EF and 50% EF ewes have a genetic potential to produce more milk but are limited by their udder storage capacity. By emptying the udder more often, they produce more milk.

Effect on fat percentage

The least square means and the standards errors of the means for the percentage of fat at each testing day are shown in Table 2. The evolution of the fat during the first 7 weeks of lactation is represented in Figure 2. The evolution of the amount of fat in the milk for both 2TM and 3TM groups is typical, decreasing slowly for the first 3 weeks with the lowest point corresponding to the peak of lactation and then increasing slowly. The differences at each weekly testing between 2TM and 3TM are always significant. The 3TM group, producing more milk, has the lowest percentage of fat. The negative correlation between milk yield and fat percentage is well illustrated in this trial and corresponds to the findings of Pearson et al (1979), Allen et al (1986), Van der Iest and Hillerton (1989), and Sapu et al (1997) in dairy cows. As soon as the 3TM group is switched to a twice a day milking frequency, the percentage of fat in this group is at the same level as in the 2TM group. The response of the different breeding groups follows the findings on milk yield. Twenty five percent East Friesian ewes have non-significant differences at each weekly testing while 37.5% and 50% ewes milked three times a day show a lower fat percentage than 2TM ewes. Again, the fat percentage of all ewes becomes the same as soon as they are all on a twice a day milking frequency.

Effect on the percentage of protein

Results are presented in Table 3 and Figure 3. The percentage of protein differs significantly only at the 3rd and 4th week. The differences are small and only the 37.5% East Friesian ewes milked 3 times a day show a significantly lower protein percentage. As soon as both groups are put under the same milking frequency, the differences disappear. The much higher daily milk production of 37.5% East Friesian ewes seems to affect the fat percentage and the protein percentage.

Effect on the somatic cell count

The milking frequency does not have an effect on the somatic cell count which is at a very low level in both groups during the first month of lactation. Klei et al (1977), Waterman et al (1983), and Van der Iest and Hillerton (1989), also, did not find an effect of milking frequency on the somatic cell count of dairy cows. When the 3TM ewes are switched to twice a day milking, only the 50% East Friesian ewes have a slight, but significant, increase in their somatic cell count.

Economics of a third milking

With the milking equipment used in this system, it took 25 minutes with 2 people to milk the 53 ewes at the noon milking for a total labor cost of 12 cents per ewe per day. Washing and sanitizing the system cost approximately $5 per day. Therefore, the total cost of milking one ewe a third time during the day cost 22 cents. Over a 30 day period, the total cost per ewe was $6.60. With the milk being sold at $1.32 per liter, a ewe milked 3 times a day must produce at least 5 liters more over 30 days than a ewe milked twice a day in order to justify the extra cost. In this trial over a 30 day period, 3TM ewes produced 7.6 liters above the threshold or an extra $10. The 25% East Friesian ewes returned $-5.5, the 37.5% East Friesian ewes returned $26.9 more and the 50% East Friesian ewes returned $8.4. It is worthwhile noting, however, that the value of the milk ($1.32/l) does not take into consideration the fat or protein content. If the milk is paid for according to the component (fat and protein), milk from 37.5% East Friesian ewes and from 50% East Friesian ewes will be worth less, therefore reducing the supplemental return obtained by milking these ewes 3 times a day.

Conclusion

The hypothesis that ewes milked 3 times a day during the first month of lactation would stay at a higher level of production during the remainder of lactation has not been proven in this trial. In general, more milk was obtained by milking a third time but the response was variable according to the genotype of the ewes. The variable response was probably due to the genetic potential of the ewes to produce milk and to the storage capacity of their udders. More research needs to be done to determine the exact reason why some ewes respond better than others to a higher milking frequency.

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Table 1. Least square means and standard error of the means of daily milk production at each testing and of total milk production for the first 30 days.

Group	%EF	N	Week1	Week2	Week3	Week4	**Total30day**	Week7
2TM		72	2.6 ±.10 a	2.9 ±.10 a	2.8 ±.11 a	2.7 ±.10 a	**82.6 ±2.8 a**	2.1 ±.09 a
3TM		53	3.1 ±.11 b	3.3 ±.12 b	3.2 ±.11 b	3.0 ±.12 b	**95.2 ±2.3 b**	2.1 ±.09 a
2TM	25%	20	2.7 ±.15 a	3.1 ±.19 a	3.0 ±.19 a	2.9 ±.16 a	**88.3 ±5.0 a**	2.3 ±.15 a
3TM	25%	16	2.8 ±.17 a	3.0 ±.18 a	3.0 ±.17 a	2.9 ±.21 a	**89.1 ±5.1a**	2.0 ±.15 a
2TM	37.5%	12	2.1 ±.20 a	2.4 ±.14 a	2.5 ±.18 a	2.3 ±.17 a	**70.4 ±4.9 a**	1.7 ±.16 a
3TM	37.5%	9	3.2 ±.21 b	3.3 ±.26 b	3.2 ±.23 b	3.0 ±.22 b	**95.8 ±6.6 b**	2.0 ±.16 a
2TM	50%	40	2.9 ±.14 a	3.0 ±.13 a	3.1 ±.15 a	2.8 ±.14 a	**89.3 ±4.0 a**	2.3 ±.12 a
3TM	50%	28	3.4 ±.17 b	3.4 ±.19 b	3.3 ±.17 b	3.3 ±.17 b	**100.7 ±5.1 b**	2.3 ±.12 b

a,b For each group within a column, means with a different letter differ significantly ($P < .05$).

Figure 1. Evolution of daily milk yield during the first month of lactation.

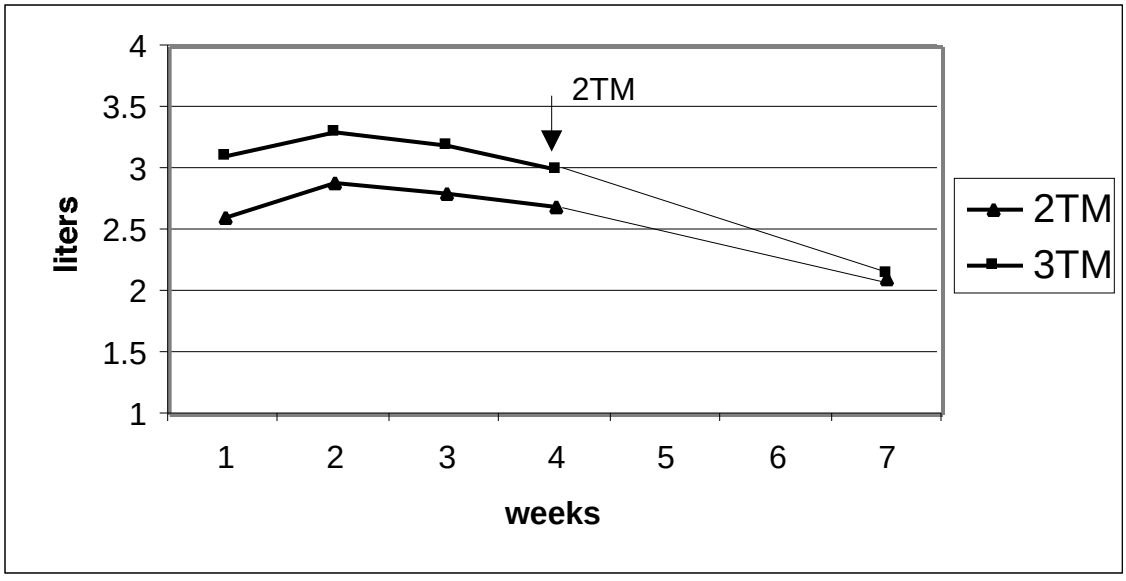


Table 2. Means and standard errors of the percentage of fat at each testing day.

Group	%EF	N	Week1	Week2	Week3	Week4	Week7
2TM		72	5.5±.10 a	4.9 ±.10 a	4.9 ±.09 a	5.0 ±.09 a	5.7 ±.08 a
3TM		53	5.1 ±.13 b	4.6 ±.11 b	4.5 ±.09 b	4.5 ±.09 b	5.7 ±.08 a
2TM	25%	20	5.7 ±.23 a	4.9 ±.18 a	4.9 ±.21 a	5.0 ±.18 a	5.7 ±.16 a
3TM	25%	16	5.1 ±.25 b	4.4 ±.21 a	4.6 ±.16 a	4.7 ±.20 a	5.9 ±.15 a
2TM	37.5%	12	5.4 ±.31 a	5.3 ±.24 a	5.2 ±.21 a	5.7 ±.22 a	5.7 ±.26 a
3TM	37.5%	9	5.9 ±.45 a	4.7 ±.25 b	4.6 ±.16 b	4.6 ±.18 b	5.8 ±.22 a
2TM	50%	40	5.3 ±.14 a	4.8 ±.13 a	4.8 ±.11 a	4.7 ±.10 a	5.6 ±.10 a
3TM	50%	28	4.8 ±.11 b	4.6 ±.15 a	4.4 ±.12 b	4.3 ±.10 b	5.6 ±.15 b

a,b For each group within a column, means with a different letter differ significantly ($P < .05$).

Figure 2. Evolution of the % of fat during the first month of lactation

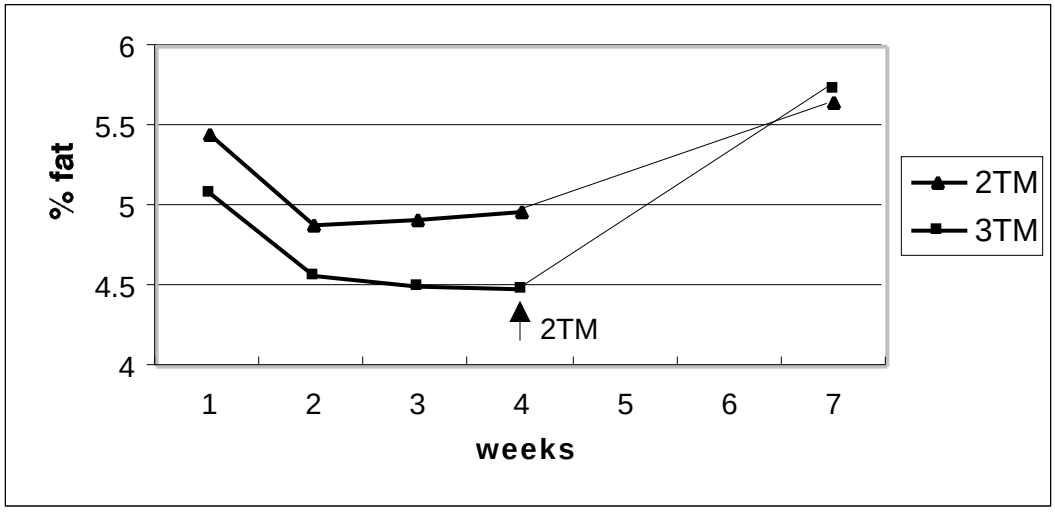


Table 3. Means and standard errors of the percentage of protein at each testing day.

Group	%EF	N	Week1	Week2	Week3	Week4	Week7
2TM		72	5.6±.04 a	5.1 ±.05 a	4.9 ±.04 a	4.8 ±.04 a	4.9 ±.04 a
3TM		53	5.5±.06 a	5.0 ±.04 a	4.7 ±.04 b	4.7 ±.04 b	4.9 ±.05 a
2TM	25%	20	5.5 ±.09 a	5.0 ±.11 a	4.8 ±.06 a	4.7 ±.06 a	5.0 ±.07 a
3TM	25%	16	5.4 ±.09 a	4.9 ±.08 a	4.7 ±.07 a	4.7 ±.07 a	5.1 ±.09 a
2TM	37.5%	12	5.8 ±.11 a	5.3 ±.09 a	5.1 ±.10 a	5.0 ±.11 a	5.1 ±.09 a
3TM	37.5%	9	5.7 ±.23 a	5.1 ±.13 a	4.8 ±.15 b	4.7 ±.13 b	5.0 ±.14 a
2TM	50%	40	5.5 ±.06 a	4.9 ±.06 a	4.7 ±.05 a	4.7 ±.05 a	4.7 ±.05 a
3TM	50%	28	5.4 ±.07 a	4.9 ±.06 a	4.7 ±.06 a	4.6 ±.07 a	4.8 ±.07 a

a,b For each group within a column, means with a different letter differ significantly ($P < .05$).

Figure 3. Evolution of the % of protein during the first month of lactation

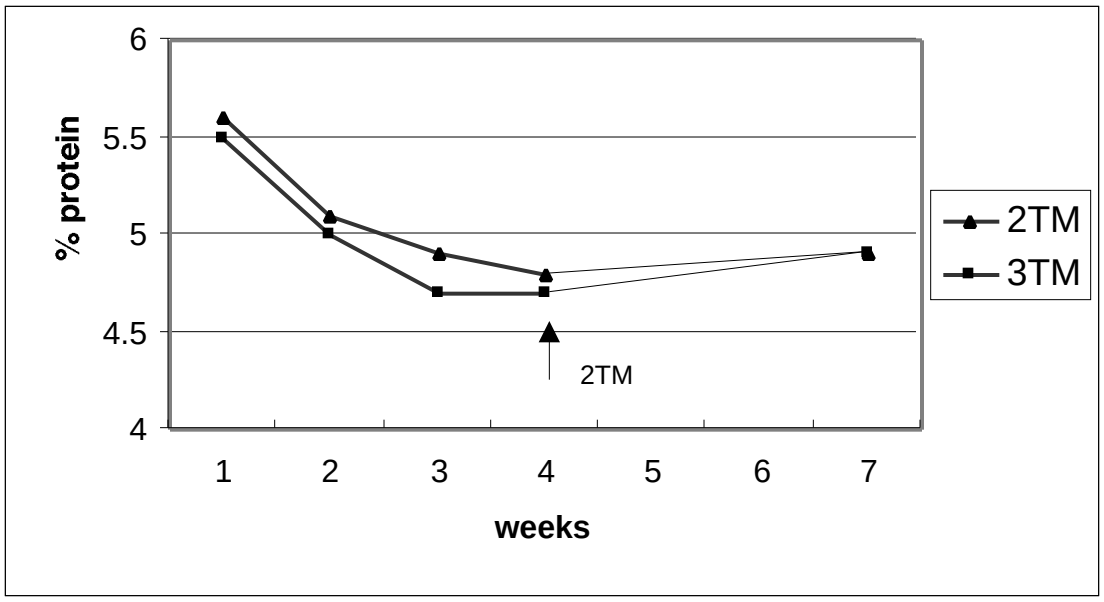
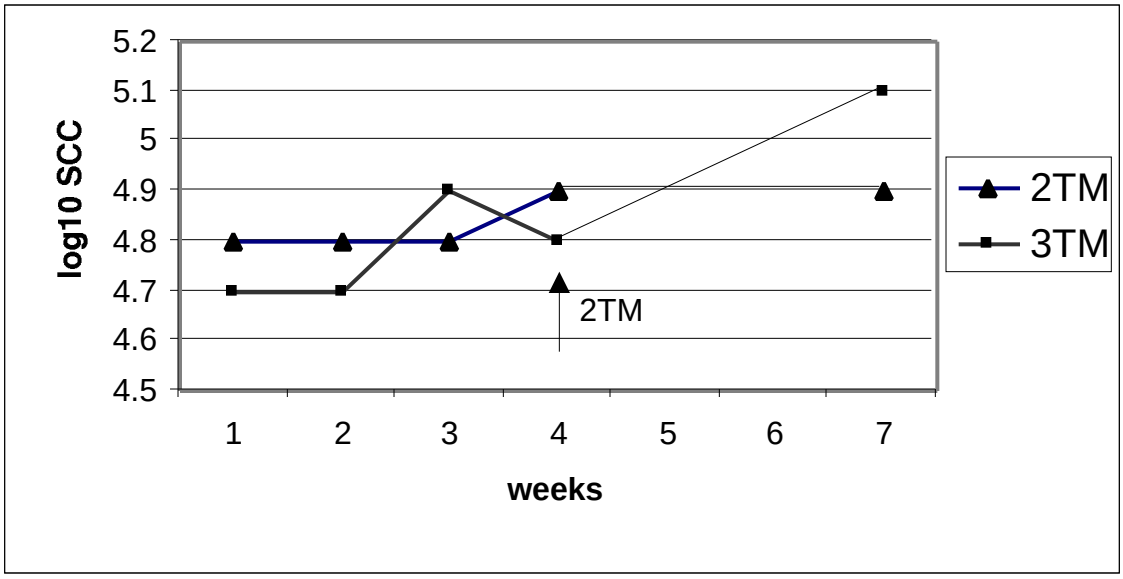


Table 4. Means and standard errors of the somatic cell count (log10) at each testing day.

Group	%EF	N	Week1	Week2	Week3	Week4	Week7
2TM		72	4.8 ±.08 a	4.8 ±.06 a	4.8 ±.06 a	4.9 ±.06 a	4.9 ±.04 a
3TM		53	4.7 ±.08 a	4.7 ±.09 a	4.9 ±.08 a	4.8 ±.07 a	5.1 ±.08 b
2TM	25%	20	4.8 ±.20 a	4.8 ±.11 a	4.8 ±.16 a	5.0 ±.10 a	4.9 ±.08 a
3TM	25%	16	4.7 ±.18 a	4.6 ±.20 a	4.9 ±.15 a	4.7 ±.14 a	5.0 ±.14 a
2TM	37.5%	12	4.9 ±.17 a	4.8 ±.23 a	4.8 ±.13 a	4.8 ±.25 a	5.0 ±.11 a
3TM	37.5%	9	4.8 ±.18 a	4.9 ±.20 a	4.9 ±.14 a	5.0 ±.19 a	5.0 ±.14 a
2TM	50%	40	4.7 ±.10 a	4.8 ±.08 a	4.8 ±.07 a	4.8 ±.07 a	4.9 ±.04 a
3TM	50%	28	4.7 ±.11 a	4.7 ±.10 a	4.8 ±.12 a	4.8 ±.10 a	5.1 ±.12 b

a,b For each group within a column, means with a different letter differ significantly ($P < .05$).

Figure 4. Evolution of the somatic cell count during the first month of lactation



COMPARISON OF EAST FRIESIAN-CROSSBRED AND LACAUNE-CROSSBRED EWE LAMBS FOR DAIRY SHEEP PRODUCTION

FIRST-YEAR RESULTS FROM A MULTI-YEAR TRIAL

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Summary

East Friesian-sired F1 ewe lambs (n = 27) and Lacaune-sired F1 ewe lambs (n = 31) born in 1999 were compared for lamb production, lactation performance, and udder morphology traits in a dairy sheep production environment in 2000. The ewe lambs were the progeny of seven East Friesian and five Lacaune sires. A contemporary group of high percentage East Friesian ewe lambs (≥ 3/4 East Friesian, n = 15), sired by two East Friesian sires, also were evaluated. Approximately 2/3 of the F1 ewe lambs were mated to a ram of the same breed as their breed of sire, and the remaining 1/3 were mated to a ram of the opposite breed. All of the high percentage East Friesian ewe lambs were mated to East Friesian rams. The F1 East Friesian and F1 Lacaune ewe lambs were similar for lamb production and udder morphology traits. The F1 East Friesian ewe lambs were superior to the F1 Lacaune ewe lambs by 15% for lactation length, 21% for milk yield, 9% for milk fat yield, and 10% for milk protein yield. However, none of the differences between the two ewe groups in lactation traits were statistically significant. Performance data will need to be collected on more ewes sired by East Friesian or Lacaune rams over additional years to determine if there are real differences between the two breeds for traits of economic importance. The high percentage East Friesian ewe lambs, mated to East Friesian rams, gave birth to more ($P < .05$) lambs, but the lambs had a higher ($P < .05$) mortality than lambs from the F1 East Friesian or F1 Lacaune ewes. This finding supports earlier results from our flock indicating that, at levels of East Friesian breeding greater than 50%, lamb mortality increases as the proportion of East Friesian breeding of the lamb increases.

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.

While our early results at UW-Madison with crossbred sheep of 50% or less East Friesian breeding were very encouraging, previous researchers had reported some problems with East Friesian breeding, especially at levels of over 50%. In an experimental purebred East Friesian flock in Greece, 38.3% of the lambs were stillborn or not viable at birth, 29.6% of lambs born alive died before the age of two months, and 69.2% of lambs that were weaned died before one year of age. Ewes of 75% or greater East Friesian breeding that survived to one year of age had lifespans ranging from 2.0 to 2.7 years. Lamb survival and ewe longevity of East Friesian sheep were significantly lower than for the native Greek dairy breeds of Karamaniko Katsikas and Karagouniko that were their flockmates (Katsaounis and Zygoyiannis, 1986). The major health problem observed in the East Friesian sheep in Greece was pneumonia in lambs and ovine progressive pneumonia (OPP) in ewes. Ricordeau and Flamant (1969) also reported an increased death loss to respiratory disease of East Friesian-cross lambs in France. In different years and with percentages of East Friesian breeding varying from 50% to 87.5%, they reported a 2.2% to 22.2% increased death loss in East Friesian-cross lambs from pasteurellosis and pneumonia compared to Préalpes du Sud lambs. The Préalpes du Sud is a French dairy breed whose type and performance was very similar to that of the Lacaune in the late 1960's (Ricordeau and Flamant, 1969). We also have 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).

Boyazoglu (1991) reviewed the results of experiments that evaluated the East Friesian in countries of the Mediterranean region. In all countries, the pure East Friesian was found to be unacceptable due to high incidence of respiratory disease and poor adaptability to high environmental temperatures, and only in Israel was a cross of the East Friesian with the local Awassi breed found to result in a more productive animal than the local breed (Gootwine and Goot, 1996).

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, milk, and wool production under dairy sheep production conditions in Wisconsin. This paper will present some of the results from the first year of this study.

Materials and Methods

During the autumn of 1998, Dorset-cross, Polypay, and Rambouillet ewes were artificially inseminated or naturally mated to East Friesian or Lacaune rams. Seven purebred East Friesian rams and five purebred Lacaune rams were represented. Additionally, a group of ewes of 50% or greater East Friesian breeding was mated to two purebred East Friesian rams. Lambs from these matings were born from March 10 to May 24, 1999. Ninety ewe lambs were raised to mating age and naturally mated to rams between November 1, 1999 and January 2, 2000. All ewe lambs of 75% or greater East Friesian breeding (n = 23) were mated to East Friesian rams, ewe lambs of 50% East Friesian breeding (n=33) were mated to either East Friesian (n=23) or Lacaune (n=10) rams, and ewe lambs of 50% Lacaune breeding (n=34) were mated to either Lacaune (n=24) or East Friesian (n=10) rams. As a result of these matings, lambs born were of different percentages of dairy and East Friesian and Lacaune breeding – 87.5% or greater East Friesian, 75% East Friesian, 50% East Friesian and 25% Lacaune, 50% Lacaune and 25% East Friesian, and 75% Lacaune.

Two of the 90 ewe lambs present at mating died between the start of the mating season and the start of lambing. Of the 88 ewe lambs mated and alive at lambing, 87 gave birth (98.9% fertility) to 136 lambs (1.56 lambs per ewe lambing). In our management system, ewe lambs are typically placed on our DY30 system. 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 kg (.5 liters). Of the 87 ewes that lambed, 14 were placed on systems other than the DY30 system for use in other experiments. The results reported in this paper are for the 73 ewes and their 113 lambs on the DY30 system.

Models used to analyze the data were:

Lamb growth traits = lamb birth weight as a covariate + lamb sex + sire breed + dam breeding + lamb birth type (multiple or single). Birth weight was deleted from the model when birth weight was analyzed.

Ewe reproductive traits = ewe breeding.

Ewe lactation and udder morphology traits = litter size (single or multiple) + ewe breeding + litter size x ewe breeding interaction.

Lamb mortality rates were analyzed by Chi-square analysis using dam breeding by lamb survival (dead or alive) two-way tables.

Results and Discussion

Lamb production by ewe breeding is presented in Table 1. Reproduction, lamb mortality, and lamb growth were similar for 1/2 East Friesian and 1/2 Lacaune ewes. The highest percentage East Friesian ewes (≥ 3/4 East Friesian) gave birth to .35 more ($P < .05$) lambs per ewe lambing than the other two groups, but weaned no more lambs per ewe lambing because of a significantly greater lamb mortality to weaning at approximately 30 days of age. Lamb mortality to July 1, 2000 was high for all three ewe groups, especially after weaning, but was highest ($P < .05$) for lambs from the high percentage East Friesian ewes. Sixty-three percent of the lambs from the high percentage East Friesian ewes were dead by July 1, 2000. The high mortality rate of lambs of a high percentage of East Friesian breeding in this set of sheep supports similar findings in this flock from previous years (Thomas et al., 1999b, 2000).

Birth weight and growth to 30 days of age were similar for lambs from 1/2 East Friesian and 1/2 Lacaune ewes but lower for lambs from the high percentage East Friesian ewes (Table 1).

Table 2 presents the lactation performance of the three ewe groups. Compared to the two East Friesian groups, the 1/2 Lacaune ewes were lower by approximately 12 days for lactation length, 17 kg for milk yield, and .5 kg for fat and protein yield. However, none of these differences were statistically significant. More data will need to be collected to determine if these breed differences are real.

Table 1. Least squares means (±SE) for lamb production.

	Ewe breeding		
Trait	≥ 3/4 EF	1/2 EF	1/2 Lacaune
No. ewes lambing	15	27	31
Lambs born per ewe lambing, no.	1.87 ± .12[a]	1.52 ± .09[b]	1.52 ± .09[b]
Lambs weaned per ewe lambing, no.	1.27 ± .16	1.33 ± .12	1.42 ± .11
Lamb mortality, birth – 30 d, % (no.)	33.3[a] (9)	7.7[b] (3)	8.7[b] (4)
Lamb mortality, 30 d – July 1, 2000, % (no.)	44.4 (8)	34.3 (12)	21.4 (9)
Lamb mortality, birth – July 1, 2000, % (no.)	63.0[a] (17)	39.5[b] (15)	28.3[b] (13)
Birth weight, kg	4.2 ± .2[b]	4.8 ± .1[a]	4.7 ± .1[a]
30-d weight, kg	13.0 ± .6[b]	14.5 ± .3[a]	14.0 ± .3[ab]
Preweaning average daily gain, g/d	283 ± 18[b]	332 ± 12[a]	317 ± 11[ab]

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

Table 2. Least squares means (±SE) for lactation traits.

Trait	Ewe breeding		
	≥ 3/4 EF	1/2 EF	1/2 Lacaune
No. of ewes milked	15	27	31
Commercial milk yield, kg	106.5 ± 16.3	104.0 ± 8.4	88.3 ± 8.0
Machine milking period, d	105.5 ± 9.2	101.2 ± 4.8	91.7 ± 4.5
Average daily milk yield, kg	.98 ± .11	.97 ± .06	.92 ± .05
Milk fat, %	5.46 ± .44	5.57 ± .22	5.65 ± .22
Milk fat yield, kg	5.59 ± 1.03	5.67 ± .53	5.11 ± .50
Milk protein, %	4.46 ± .31	4.65 ± .16	4.68 ± .15
Milk protein yield, kg	4.58 ± .78	4.66 ± .40	4.17 ± .38
Test-day 1 SCC, log units	4.71 ± .31	4.56 ± .16	4.98 ± .15
Test-day 2 SCC, log units	5.04 ± .21	4.93 ± .11	5.25 ± .12
Test-day 3 SCC, log units	5.00 ± .20	5.01 ± .12	5.22 ± .12

Udder measurements (Table 3) were remarkably similar among the three ewe groups indicating similar udder shapes, udder sizes, and teat placements. The only difference of significance was longer ($P < .10$) teats of 1/2 East Friesian ewes compared to 1/2 Lacaune ewes.

Table 3. Least squares means (±SE) for udder morphology traits.

	Ewe breeding		
Trait	≥ 3/4 EF	1/2 EF	1/2 Lacaune
Teat thickness[1], mm	5.1 ± .2	4.8 ± .1	4.7 ± .1
Udder circumference[2], cm	44.3 ± 1.8	45.9 ± 1.0	46.6 ± .9
Cistern height[3], cm	1.6 ± .4	2.0 ± .2	2.0 ± .2
Teat length[4], cm	2.7 ± .2[cd]	2.9 ± .1[c]	2.5 ± .1[d]
Teat width[5], cm	1.5 ± .2	1.6 ± .1	1.5 ± .1
Teat angle score[6], no.	6.0 ± .6	5.9 ± .3	6.1 ± .3
Udder half demarcation[7], no.	1.4 ± .2	1.7 ± .1	1.6 ± .1
Udder height score[8], no.	4.4 ± .3	4.1 ± .2	4.6 ± .2

[1] Average teat end thickness of both teats measured with a caliper immediately before milking.
[2] The distance around the udder at its widest point measured with a scrotal circumference tape.
[3] The average distance of both udder halves from the bottom of the udder to the point of attachment of the teat.
[4] The average length of the both teats measured from base of attachment to teat apex.
[5] The average width of both teats measured at middle barrel.
[6] Subjective score assigned to teat placement (caudal view): 1 = horizontal, 5 = 45°, and 9 = vertical.
[7] Subjective score assigned to the udder half demarcation at the intramammary groove (caudal view): 1 = no demarcation, 5 = moderate demarcation, 9 = very strong demarcation.
[8] Subjective score assigned to the height of the udder (caudal view): 1 = udder height closest to abdomen, 5 = udder height equivalent to the level of the hocks, 9 = pendulous udder that greatly surpasses the level of the hocks.
[a,b] Within a row, means lacking a common superscript letter are different ($P < .05$).
[c,d] Within a row, means lacking a common superscript letter are different ($P < .10$).

Conclusions

This is a progress report of the first comparison of East Friesian-cross and Lacaune-cross ewes in the U.S. The data are from the first year of a multi-year trial, and the number of animals evaluated to date is small. The 1/2 East Friesian and 1/2 Lacaune ewe lambs were similar for lamb production and udder morphology traits. The 1/2 East Friesian ewe lambs were superior to the 1/2 Lacaune ewe lambs by 15% for lactation length, 21% for milk yield, 9% for milk fat yield, and 10% for milk protein yield. However, none of the differences between the two ewe groups in lactation traits were statistically significant so data will need to be collected on more ewes over additional years to determine if there are real differences between the two breeds for traits of economic importance.

A contemporary group of high percentage East Friesian ewe lambs (≤ 3/4 East Friesian) mated to East Friesian rams produced lambs that had a significantly higher lamb mortality than lambs from the 1/2 East Friesian and 1/2 Lacaune ewes. This finding supports earlier results from our flock indicating that, at levels of East Friesian breeding greater than 50%, lamb mortality increases as the proportion of East Friesian breeding of the lamb increases.

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UDDER MORPHOLOGY AND MACHINE MILKING ABILITY IN DAIRY SHEEP

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Summary

This paper describes the particularities of the anatomy and morphology of the dairy sheep udder and the current implications on machine milkability. The sheep mammary gland is an exocrine epithelial gland mainly constituted of tubulo-alveolar parenchyma with alveoli and well differentiated cisterns. Two anatomical compartments are used for milk storage: alveolar and cisternal, the large-cisterned animals being more efficient milk producers. New methodologies are available for the study of the mammary gland ultrastructure and for the use of non invasive or dynamic measures. A detailed description of alveolar and ductal changes in the ewe udder occurring during lactation is presented. The study of external morphology by using udder typology, objective udder measurements, and linear scores in practice is also discussed. Machine milkability is evaluated by milk fractioning and milk emission curves during milking. Both criteria are discussed and analyzed in sheep breeds of different milk yield. Relationships between morphological and productive traits in dairy sheep are analyzed as a result of anatomical and physiological characteristics. Phenotypic and genetic correlations indicate that selection for milk yield will produce a worse udder morphology, resulting in udders which are inadequate for machine milking. Teat and cistern characteristics appear to be the most limiting factors in machine milkability. Some selection pressure on udder traits in long-term breeding programs needs to be considered, and the use of linear udder traits is recommended in practice to improve udder morphology and milkability.

Introduction

The mammary gland is an exocrine epithelial gland exclusive to the mammalian species, (animals able to produce milk) which is quantitatively and qualitatively adapted to the growth requirements and behavior of each species. It shows histological similarities to other epithelial glands such as the salivary and sweat glands. Milk secretion is described as the activity of a cellular factory (the lactocyte) which transforms itself into the product (the milk). The entire process is controlled by integrated neuro-endocrine and autocrine systems. It mainly develops during pregnancy and early lactation, and regresses very quickly after dry-off.

The anatomy and morphology of the sheep udder has been well known for many years (Turner, 1952; Barone, 1978), and some examples of curious selection on udder morphology have been assayed (i.e. increasing prolificacy and number of teats). Early works on the relationship between udder characteristics and milking performance in dairy ewes were carried out in the 70's and early 80's (Sagi and Morag, 1974; Jatsh and Sagi, 1978; Gootwine et al., 1980; Labussière et al., 1981) as a consequence of the efforts to adapt the ewe to machine milking.

With this aim and as an initiative from Prof. Jacques Labussière an international protocol (M4 FAO project) was agreed for the evaluation of the dairy sheep udder in the Mediterranean breeds (Labussière, 1983, 1988). Based on this standardized protocol, the udder of many dairy sheep breeds was systematically studied in relation to machine milking in the 3rd International Symposium on Machine Milking of Small Ruminants held in Spain (Casu et al., 1983; Fernández et al., 1983a; Gallego et al., 1983a; Hatziminaoglou et al., 1983; Labussière et al., 1983; Pérez et al., 1983; Purroy and Martín, 1983) and following symposiums (Arranz et al., 1989; Kukovics and Nagy, 1989; Rovai et al., 1999) in Europe, and also in America (Fernández et al., 1999; McKusick et al., 1999).

The interest in the dairy sheep udder has increased in the last few years in which anatomy has been explored in depth (Ruberte et al., 1994b; Caja et al., 1999; Carretero et al., 1999), linear evaluation of udder traits has been proposed (de la Fuente et al., 1996; 1999; Carta et al., 1999) and the genetic parameters evaluated (Gootwine et al., 1980; Mavrogenis et al., 1988; Fernández et al., 1995; 1997; Carta et al., 1999). Moreover, given the negative effects observed in udder morphology as a result of the increase in milk yield, main udder traits of breeds of different production levels (Rovai et al., 1999) or of genetically isolated lines of the same breed (Marie et al., 1999) are under comparison. This paper describes the particularities of the dairy sheep udder and summarizes the current implications of udder morphology on machine milkability.

Structure and development of the mammary gland in the dairy ewe

***Origin and development of the mammary gland*:** The mammary gland is formed by two main structures: the parenchyma and the stroma. The partitioning between both structures defines the anatomical and functional characteristics of each mammary gland. The parenchyma is the secretory part of the gland and it is made up of tubulo-alveolar epithelial tissue, coming from the ectoderm layer of the embryo, and it consists of the tubular (ductal) and alveolar systems. The stroma is formed by other complementary tissues of mesodermic origin such as: blood and lymph vessels, and adipose, connective and nervous tissues. Both structures develop very early from the ventral skin of the embryo and half-way through the pregnancy a total of eight pairs of isolated mammary buds are present in all mammalian embryos (Delouis and Richard, 1991).

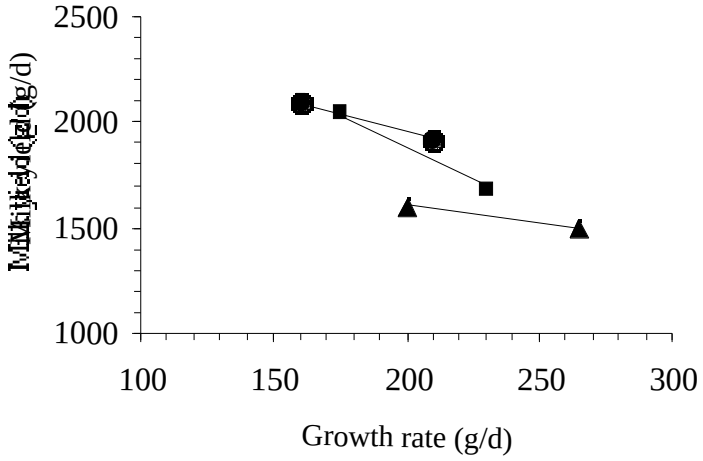
Well developed mammary buds are clearly observed in 2 cm long sheep embryos (near 30 days old) as reported by Turner (1952). An important differentiation in mammogenesis occurs at this stage in the ruminants, in which the mammary parenchyma develops the cisterns. An involution process according to the species then begins, and only the 7th mammary pair located in an inguinal position is maintained in sheep (Delouis and Richard, 1991). Occasionally the 6th pair can also be maintained giving as a result the supernumerary teats. Another particularity of sheep is the presence of skin inguinal bags in the groin behind each teat. They have sebaceous glands and produce a yellow and fatty secretion useful for the care of the udder skin (Ruberte et al., 1994b).

At birth, the sheep udder shows clearly differentiated cisterns (*Sinus lactiferus*)[1] and teats (*Papilla mammae*) and very incipient development of the ductal system, with few primary ducts surrounded by numerous stroma forming cells. After birth the udder grows at the same rate as the body (isometric growth) until puberty, with proliferation and branching of the secondary ductal system.

[1] Names in italics correspond to the Latin denomination of the Nomina Anatomica Veterinaria (1994). World Association of Veterinary Anatomists, 4th edition, Zurich.

Puberty in most species is the quickest period of growth for ducts and stroma of the mammary gland (positive allometric growth), as a result of the action of sexual hormones. Nevertheless, the future milk capacity of the udder can be impaired at this stage by an excessive growth of the stroma (mainly adipose and connective tissues) in comparison to the parenchyma (tubulo-alveolar epithelium). This critical phase occurs earlier in sheep than in cattle, with differences between breeds. Thus, the parenchyma growth ends in sheep before puberty and, as a consequence, mammogenesis in sheep will be affected by nutrition during and after the positive allometric growth phase (Bocquier and Guillouet, 1990). The critical period for mammogenesis is from 2 to 4 months old. Moreover an early onset of puberty will bring forward the decrease in mammary development. According to Johnson and Hart (1985) and McCann et al. (1989), a relative low growth rate (50% of high rate) from weaning (wk 4) to the end of rearing period (wk 20) will increase the parenchyma growth and the milk production in the first lactation in non dairy ewe-lambs (Figure 1). No negative effects were observed at the beginning of puberty. Nevertheless a low growth rate before weaning will also negatively affect mammogenesis (McCann et al., 1989). Unfortunately there is no detailed information available on dairy sheep, but Bocquier and Guillouet (1990) reported that the restriction of concentrate in Lacaune ewe-lambs, after they reach approximately 28 to 30 kg, increases milk yield by 10% in the first lactation.

Figure 1. Effect of growth rate before puberty in ewe-lambs on milk yield at the first lactation (McCann et al., 1989).



During the first and subsequent pregnancies, the parenchyma shows an allometric growth where the placenta plays an important role. A specific ovine chorionic somatotropin hormone (oCS), dependent on prolificacy, can be obtained from the sheep placenta after day 60 of pregnancy (Martal and Chene, 1993). Mammogenesis starts clearly in sheep between day 95 and 100 of pregnancy, with detection of lactose (start of lactogenesis) after day 100 (Martal and Chene, 1993).

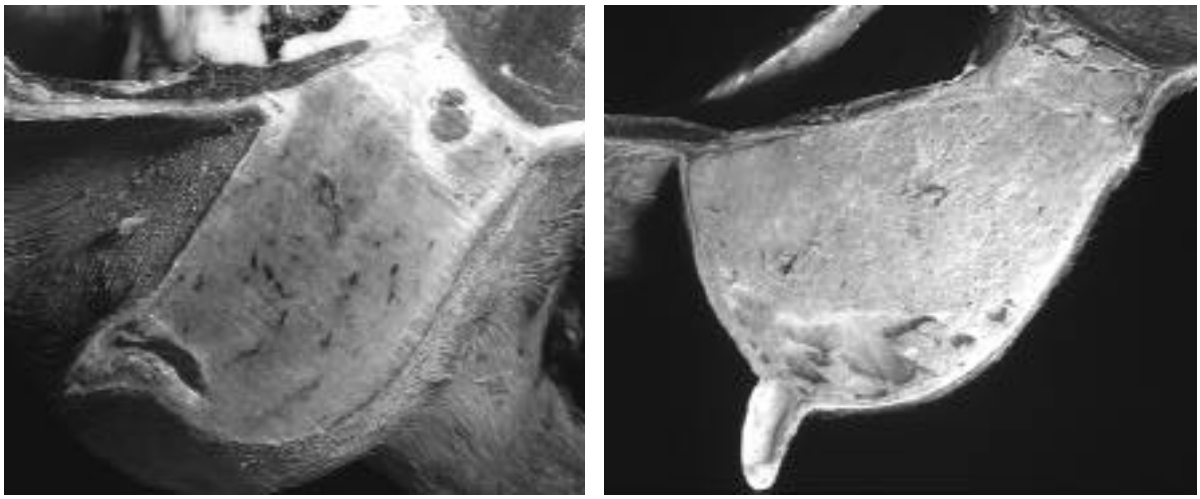
The presence of secretory lobes with alveolus in the extremes of the ducts can be observed in the second half of pregnancy. Delouis and Richard (1991) estimate a change from 10 to 90% in the relative weight of the parenchyma during pregnancy, where the lobulo-alveolar development of epithelial cells takes the place of the adipose tissue. The inverse process occurs during the dry period, with a complete disappearance of the alveoli in the ewe after 3 to 4 weeks, and its replacement by adipocytes (Hurley, 1989). Moreover during the involution process the mammary gland is invaded by macrophages and lymphocytes, the latter being essential for the production of immunoglobulins in the synthesis of colostrum in the next pregnancy.

***Internal structure of the mammary gland*:** The study of the internal structure of the ewe udder was first carried out *in vitro* by anatomical dissection in dead animals (Turner et al., 1952; Barone, 1978; Tenev and Rusev, 1989; Ruberte et al., 1994b). This methodology reveals the presence of two independent mammary glands under a unique skin bag, each of them wrapped by a bag of fibroelastic connective tissue (*Apparatus suspensorius mammarum*) and separated by a clearly defined and intermediate wall of connective tissue (*Ligamentum suspensoris uber*). The strength of this ligament normally produces the presence of an intermmamary groove (*Sulcus intermammarius*) between each gland. This ligament plays an important role in the support of the udder, maintaining the udder tightly attached to the ventral abdominal wall. Each half udder shows internally a typical tubulo-alveolar structure with a big cistern (*Sinus lactiferus*) divided in two parts: glandular cistern (*S. l. pars glandularis)* and teat cistern (*S. l. pars papillaris*). Both cisterns are separated by a muscular sphincter of smooth muscular fibers, traditionally known as the cricoid fold, which plays an important role in milk drainage. It also helps to keep the teat and gland morphology divided during machine milking to avoid the appearance of cluster climbing. The cricoid sphincter is normally missing in goats and it is not very effective in the conic teat udders, which are not favorable for machine milking. Size and form of the gland cistern vary according to the breed and milking ability of the sheep, being greater and plurilocular in high yielding ewes (Figure 2). Another sphincter with smooth muscular fibers is present around the streaks canal (*Ductus papilaris*) in the distal part of the teat, connected to the exterior by a unique orifice (*Ostium papilare*).

The last mammary gland structures in the parenchyma are the secretory lobes, consisting of very branched intralobular ducts and alveoli. The alveolus is the secretory unit of the mammary gland and consists of a bag of a unique layer of specialized cubic epithelial cells (the lactocytes) with an inside cavity (the lumen) in which the milk is stored after secretion.

The mammary gland stores the milk extracellulary and this storage can be explained using a model of two anatomical compartments: ‘Alveolar milk’ (secreted milk stored within the lumen of alveolar tissue) and ‘Cisternal milk’ (milk drained from the alveoli and stored within the large ducts and the gland and teat cisterns). Short-term autocrine inhibition of milk secretion in the mammary gland has been related to cisternal size, the large-cisterned animals being in general more efficient producers of milk and more tolerant to long milking intervals and simplified milking routines (Wilde et al., 1996).

Figure 2. Comparison of cistern size in dairy (right) and non-dairy (left) sheep udders in early lactation.



Partitioning between cisternal and alveolar milk is usually determined by drainage of cisternal milk, by using a teat cannula, and by milking alveolar milk after an oxytocin injection (Ruberte et al., 1994a; Wilde et al., 1996). Nevertheless cisternal milk volume can be increased in some breeds by spontaneous liberation of endogenous oxytocin as a consequence of milking conditioned behavior or as a result of teat manipulation. This effect has been shown in Lacaune but not in Manchega ewes (Table 1) by Rovai et al. (2000), in accordance with the milking ability of each breed, and the use of an oxytocin receptors blocking agent for cisternal and alveolar milk determination is recommended (Knight et al., 1994; Wilde et al., 1996). Values of cisternal milk in sheep vary from 25 to 70% according to the breed (Caja et al., 1999; Rovai et al., 2000) but they are greater than 50% in most dairy sheep breeds. Cisternal : alveolar ratio increases with lactation stage and parity in dairy cows (Wilde et al., 1996), but no references are available on sheep.

Table 1. Cisternal and alveolar distribution in dairy sheep at mid lactation according to the breed and the method used (Rovai et al., 2000).

Item	Manchega		Lacaune		SEM
	Control	Atosiban[1]	Control	Atosiban	
Number of ewes	10		10		-
Milk yield (l/d)	0.935[b]		1.871[a]		0.313
Alveolar milk (ml)	86.2[b]	104.0[a]	88.8[b]	114.9[a]	0.5
Cisternal					
Milk (ml)	121.8[c]	118.3[c]	299.2[a]	239.2[b]	1.2
Area (cm^2)	12.38[b]	13.06[b]	24.02[a]	23.25[a]	0.98
Cisternal : Alveolar (%)	59 : 41	53 : 47	77 : 23	68 : 32	-

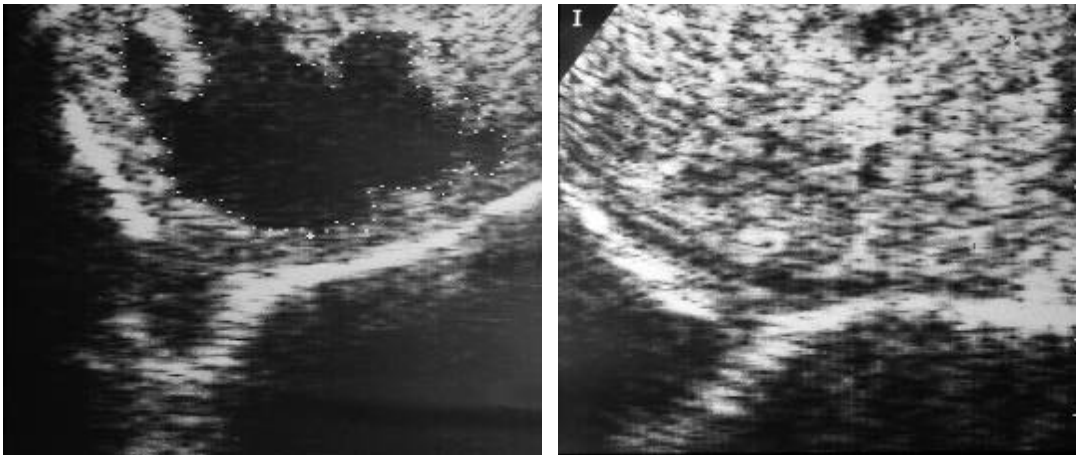
[1] : Oxytocin receptors blocking agent injected in jugular

[a, b, c]: Different letters in the same line indicate significant differences at $P<0.05$

The results in Table 1 also indicate that cistern size plays an important role in the milk yield of the ewe. Thus, despite the differences in milk production (100%) at the same stage of lactation (90 d), alveolar milk was very similar in the two breeds, the difference being only 10% greater in Lacaune. On the contrary, the difference in true cisternal milk was 102% according to the difference observed in yield. This seems to indicate that cisternal size is a direct limiting factor for milk secretion in dairy sheep and its importance is greater than the amount of secretory tissue in the current situation (Rovai et al., 2000). A ratio of approximately 7.5 between daily milk yield and cisternal milk was obtained in both breeds.

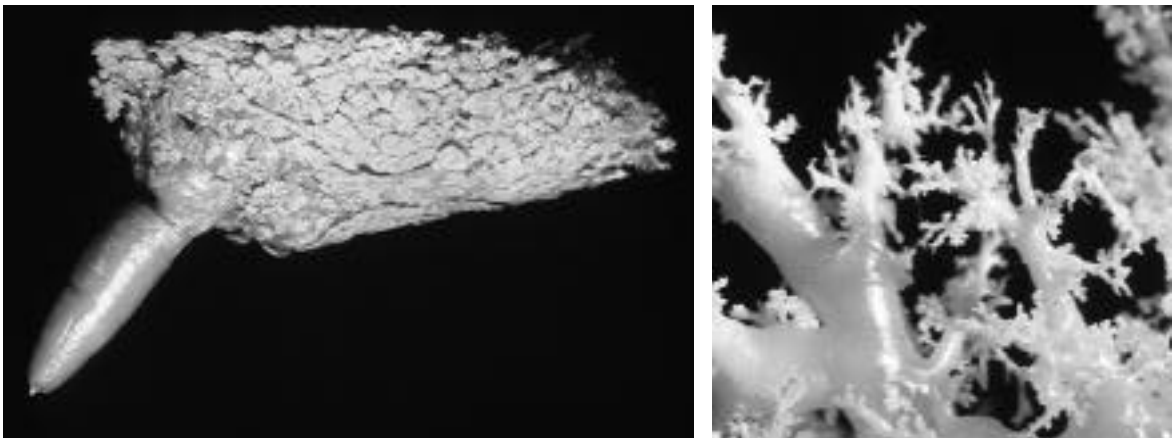
In vitro anatomical studies are in some cases limited because the organ loses the tonus and becomes flaccid, which is important in the case of the udder. An *in vivo* image of the mammary gland structures can be obtained by the non invasive technique of ultrasound scans. A specific method for sheep mammography was proposed by Ruberte et al. (1994a) and its validity in cisternal measurements tested by Caja et al. (1999). The method has been used to make evident the milk ejection reflex in sheep (Caja and Such, 1999), to measure the cistern size and to compare the internal morphology of the udder in different breeds of dairy sheep (Rovai et al., 2000). Using this method it can be demonstrated that the gland cistern is flat when empty after milking as a consequence of the pressure of the mammary suspensor system (Figure 3). The method can also be used to estimate the distribution and movements of milk between the udder compartments and for non invasive dynamic studies on cisternal milk .

Figure 3. Scans of dairy sheep udders showing the gland and teat cisterns full of milk before milking (left) and empty after milking (right).



A different approach in the study of the cisterns and the lobulo-alveolar system in the mammary gland can be obtained by using the corrosion plastic cast method, normally used for the anatomical study of soft tissues (Ditrich and Splechtna, 1989; Ruberte et al., 1994b; Carretero et al., 1999). This method consists of obtaining a cast of the canalicular system of the mammary gland in euthanasied animals, after drainage of the milk from the udder. An epoxy resin is immediately injected through the teat sphincter to obtain the complete repletion of all the tubulo-alveolar system (cisterns, ducts and alveoli). Udders are removed after hardening of the epoxy resin and the organic tissue corroded using a KOH solution. The resulting casts (Figure 4) are used for macroscopic and microscopic studies, where anatomical details can be studied in depth.

Figure 4. Cast of a dairy sheep udder obtained by the epoxy injection and corrosion method (left) and detail of the ductal system with ducts and alveoli (right).



The study of the ultrastructure of the mammary gland is normally done by using the scanning electron microscopy method used by Williams and Daniel (1983), Caruolo (1980) and Carretero et al. (1999), which showed clear images of mammary alveoli in sheep (Figure 4). The method uses the corrosion casts previously described, after conditioning for scanning electron microscopy. Different degrees of development of the canalicular system are identified in the parenchyma of sheep mammary glands during lactation.

Tubulogenic structures found by Carretero et al. (1999) in dairy sheep varied in frequency and type according to stage of lactation but in all cases the sheep casts had the typical appearance of a bunch of grapes as described in the bibliography (Figure 5.1). All the alveoli seen in this work showed a unique and independent lobular duct without fusion between adjacent alveoli. The development of the mammary gland ducts showed a similar morphology to that previously reported in the development of the vascular system (mesodermic origin) in embryos of different species (Ditrich and Splechtna, 1989; Carretero et al., 1995). Structures indicating an extensive proliferation of the canalicular system were found by Carretero et al. (1999) in Manchega and Lacaune dairy ewes between week 1 (suckling) and 5 (start of milking) of lactation at the same time that a large number of alveolar sprouts were observed (Figure 5.2).

Both dairy breeds showed the same mammary structures and followed the same pattern of development during lactation despite the differences in reported milk yield. The development of the mammary canalicular system after parturition has already been described in primiparous sheep (Brooker, 1984) and goat (Knight and Wilde, 1993), but Carretero et al. (1999) used ewes that were in the third lactation. The finding of cellular proliferation at the time of maximum milk production, is also in accordance with the observations of Knight and Wilde (1993). Franke and Keenan (1979) demonstrated that both situations can be found even in a lactocyte.

The identification of concave valve-like structures as previously described by Caruolo (1980) was also common to all stages studied by Carretero et al. (1999). Nevertheless, these valve-like structures do not appear in our studies at the level of the opening of alveolus into the lobular duct, but at the point where a lobular duct drains into a larger duct (Figure 5.3).

Figure 5. Scanning electron microscopy images from epoxy casts obtained in ewes mammary glands at different stages of lactation: 1) Lobular duct (L) and alveoli (✻) on wk 13 (bar = 40 μm); 2) Alveoli (⇨) on wk 1 (bar = 0.2 mm); 3) Valve-like structure (⇨) in a duct (bar = 30 μm); 4) Intussusceptive growth (↘) in a lobular duct (L) on wk 1 (bar = 28 μm); 5) Alveolar sprouts (➞) on wk 5 (bar = 60 μm); 6) Alveolus grooves (➞) on wk 13 (bar = 30 μm); 7) Collapsed alveolus on week 13 (bar = 20 μm).

This may indicate the existence of a kind of cellular reinforcement to prevent milk leakage when the alveoli and ducts are full of milk.

At week 1 of lactation Carretero et al. (1999) reported the occurrence of 'intussusceptive growth' at the level of the lobular ducts in sheep during the suckling period. This new type of growth leads to an increase in the number of tubules from preexisting ones (Figure 5.4). Intussusceptive growth has only been reported in some areas of the vascular system (i.e. lung vessels and widely during embryo development) and it is characterized by the formation of pillars of endothelial tissue in the lumen of the duct (Burri and Tarek, 1990; Patan et al., 1992). The pillars appear as transversal holes in the plastic casts. This convergence in the model of development of two different cellular lines, mammary gland ductal and vascular system cells, is produced despite their different embryonic origin (ectoderm and mesoderm origin, respectively).

At week 5 after parturition, corresponding to the first week of the milking period after weaning, duct development by intussusceptive growth seemed to be complete and only changes in mammary alveoli were observed. In this way, fully developed alveoli together with others in the first phases of development were observed at the same time and in the same lobular duct. Nevertheless, structures like angiogenic buds were frequently identified in the tubules at this time. These buds appeared as semispherical enlargements that grow from the ducts and become almost spherical by the narrowing of their connection with the duct. Then, the bud surface loses its smoothness and develops small sockets giving a golf ball like image identified as alveoli. Moreover frequently developing alveoli with sprouting shape were observed on the surface of lobular ducts at this lactation stage (Figure 5.5) as previously described in the mammary gland of ewes by Alvarez-Morujo and Alvarez-Morujo (1982). Alveolar sprouts described by Carretero et al. (1999) are not comparable to the sprouts found in the extremes of lobular ducts producing the longitudinal growth of lobular ducts during puberty by Williams and Daniel (1983).

In mid lactation (week 13) the mammogenic structures were not observed by Carretero et al. (1999) in the canalicular system of the mammary gland and the most relevant observation was the alveoli morphology. They were unilocular, spherical and with their external surface smoothed or grooved (Figure 5.6). The images are in accordance with those obtained by Caruolo (1980) and suggest that grooves may be a consequence of capillary vessels surrounding the alveolus. We also observed, in a few cases, some flattened alveoli (Figure 5.7) that may be considered as collapsed (empty) alveoli, but no fused alveoli were found.

External morphology of the mammary gland

***Udder typology*:** The first practical utilization of udder morphology on dairy sheep was made by using tables of udder typology in Awassi and Assaf (Sagi and Morag, 1974; Jatsch and Sagi, 1978), Sarda (Casu et al., 1983) and Manchega ewes (Gallego et al., 1983a, 1985), all of them based on four main udder types. A comparative table of these typologies can be observed in Gallego et al. (1985). These typologies were later adapted to the Latxa breed (Arranz et al., 1989) and Hungarian Merino and Pleven (Kukovics and Nagy, 1989). The typology used in Sarda was evaluated in field conditions (Casu et al., 1989) and extended to seven udder types mainly based on teat position and cistern size (Carta et al., 1999) with the aim of improving the small discriminating capacity of the previous typologies. Nevertheless, the evaluation of sheep udders by morphological types is easy, quick and repeatable with trained operators (Carta et al.,

1999; De la Fuente et al., 1999). Typology is recommended as a useful tool for the screening of animals, i.e. in the standardization of machine milking groups or in the choice of ewes at the constitution or acquisition of a flock, and for culling of breeding animals (Gallego et al., 1985; Carta et al., 1999).

A well shaped and healthy udder of dairy sheep for machine milking should have:

- Great volume, with globose shape and clearly defined teats
- Soft and elastic tissues, with palpable gland cisterns inside
- Moderate height, not surpassing the hock
- Marked intermammary ligament
- Teats of medium size (length and width), implanted near to vertical.

***Udder measurements*:** The use of objective measurements for the characterization of the dairy sheep udder and for the study of the relations with milk yield or other productive traits has been undertaken by different authors since the development of machine milking. The continuous nature of the measurements increases the discriminating capacity of each variable and the significance of correlation with the productive traits. The methodology generally used corresponds to the standardized protocol of Labussière (1983) with small variations incorporated in some cases (Gallego et al., 1983a; Fernández et al., 1983, 1995). The repeatability of udder measurements made according to this methodology is low for udder dimensions (r= 0.17 to 0.18), medium for teat dimensions and teat position (r= 0.45 to 0.52), and high for teat angle (r= 0.65) and cistern height (r= 0.77), as calculated by Fernández et al. (1995) in the Churra dairy breed.

Table 2 summarizes the comparison of main objective udder measurements carried out by Rovai et al. (1999) in Manchega and Lacaune dairy sheep throughout lactation, with the aim of identifying the most significant udder traits in extreme yield conditions. The stage of lactation produced significant effects on all udder traits in accordance with Gallego et al. (1983a) and Fernández et al. (1983, 1995). Nevertheless, despite the differences in milk yield, breed effects on udder length and distance between teats were non significant, and only showed a tendency in teat angle. Similar results were observed in regard to parity, where differences in teat angle and udder length were non significant. On the contrary, differences in teat dimensions (width and length) and udder height (depth and cistern height) were significant for breed and parity. These results agree with those obtained previously in different breeds (Labussière, 1988; Fernández et al., 1983, 1995) although teat angle was affected by stage of lactation in other references (Casu et al., 1983; Gallego et al., 1983a; Labussière et al., 1983; Fernández et al., 1989a, 1995). Other authors indicate that udder length was not affected by the variation factors analyzed.

In regard to the correlation coefficients between udder traits, three natural groups can be distinguished as indicated by Fernández et al. (1995): 1) udder size (height and width), which are high and positive; 2) teat size (width and length), which are medium and positive; and 3) cistern morphology (height) and teat placement (position and angle) which are medium and positive but show low and negative correlation with teat and udder sizes. As udder width increases, cistern height and teat angle and position decrease; and, as udder height increases, cistern height and teat angle and position also increase.

When morphological traits are related to milk yield the greatest effects are observed for udder width and height and commonly tendencies are only observed for the remaining traits (Gallego et al., 1983a; Labussière et al., 1983; Fernández et al., 1989a, 1995; McKusick et al., 1999). Big volume and cisterned udders produce more milk. Main effects of teat traits are related to milk fat (McKusick et al., 1999) and milk emission during milking (Fernández et al., 1989a; Marie et al., 1999).

Table 2. Mean values of udder traits and effects of breed, parity and stage of lactation in Manchega and Lacaune dairy sheep (Rovai et al., 1999)

Item	Breed		Effect ($P <$)		
	Manchega	Lacaune	Breed	Parity	Stage
Number of ewes	63	24	-	-	-
Milk yield (wk 4 to 20) :					
Total, l/ewe	84.6[a]	153.2[b]	0.001	0.073	-
Daily, l/d	0.82[a]	1.36[b]	0.001	0.017	0.001
Teat:					
Length, mm	33.6[a]	29.1[b]	0.003	0.025	0.001
Width, mm	15.1[a]	13.2[b]	0.002	0.010	0.001
Angle, º	42.5	44.1	0.065	0.487	0.052
Udder:					
Depth, cm	17.2[a]	17.8[b]	0.001	0.001	0.001
Length, cm	11.4	11.3	0.510	0.639	0.001
Teat distance, cm	12.6	12.0	0.619	0.001	0.001
Cistern height, mm	15.5[a]	20.0[b]	0.001	0.002	0.001

[a, b] : Values with different letters in the same line differ ($P < 0.05$)

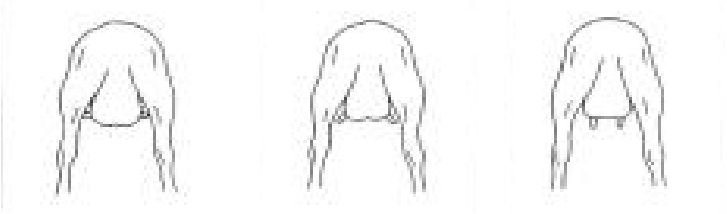
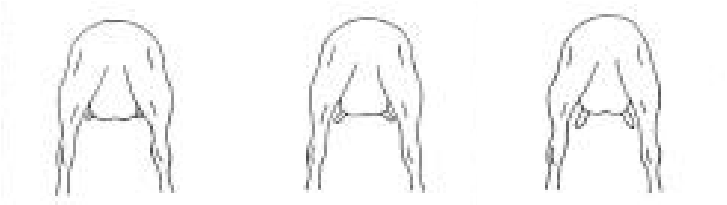
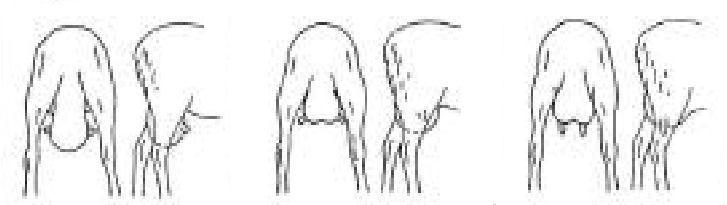
As a conclusion, the most significant and repeatable udder traits agreed by different authors for a wide sample of sheep dairy breeds are:

- Teat dimensions (length) and position (angle)
- Udder height (also called depth) and width
- Cisterns height

***Linear scores*:** The main drawback of the udder typologies is their use for the estimation of the genetic value of breeding animals and when genetic and environment effects need to be broken down for selection. This problem has been solved in dairy sheep, as in dairy cows and goats, by using a breakdown system in which independent udder traits are evaluated according to a linear scale of 9 points (De la Fuente et al., 1996).

The four udder traits considered by De la Fuente et al. (1996; 1999) to be significant for machine milking are: udder depth or height (from the perineal insertion to the bottom of the udder cistern), udder attachment (insertion perimeter to the abdominal wall), teat angle (teat insertion angle with the vertical), and teat length (from the gland insertion to the tip).The system also includes an expanded typology to evaluate the whole udder shape, in accordance with the previously described optimal criteria and udder types, but uses the same linear scale of 9 points. Each udder trait is evaluated independently by using extreme biological standards (Table 3).

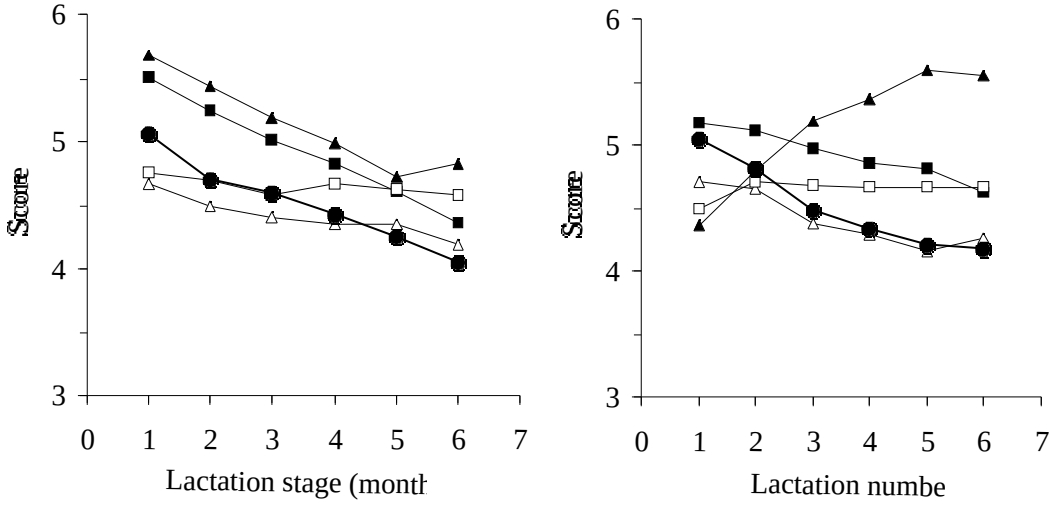
Table 3. Linear scores for the evaluation of main udder morphological traits in dairy sheep (De la Fuente et al., 1996).

	Score (1 to 9)		
	1 (Low)	5 (Average)	9 (High)
Udder height			
Teat angle			
Teat length			
Udder shape			

The desirable value is in some cases the highest score (i.e. teat angle: vertical teats that scored 9 will reduce cluster drops and will make easier the milk drainage) or the average score in others (i.e. teat length: medium size teats scored 5 and agree with a uniform cluster length). In udder height, given its positive relationship with milk production an average score will also be preferable.

This linear methodology has been used in Spain for the evaluation of different flocks (27 flocks and 10,040 ewes) of Churra, Manchega and Latxa dairy ewes (De la Fuente et al., 1999), and it is also being partially used in the Lacaune breed for the evaluation of morphological traits in relation to machine milking ability (Marie et al., 1999). Results for Spanish breeds are shown in Figure 7 according to lactation stage and parity effects. In regard to lactation stage, all linear scores decreased as lactation progressed, udder height and udder attachment being the traits which showed the greatest decrease during lactation, while teat size was only slightly modified. This evolution agrees with the loss of udder volume and milk yield but indicates a deterioration of udder morphology for machine milking as indicated by udder shape. Only udder height was improved. Regarding lactation number, udder height increased dramatically in the first lactations, while other traits decreased and teat size was steadily constant. As a consequence, udder shape deteriorated and its score decreased rapidly from first to third lactation and stabilized thereafter.

Figure 7. Evolution of linear scores of main udder traits in Spanish dairy sheep: ▲, udder height; ■, udder attachment; ∆, teat angle; □, teat length; and, ●, udder shape (elaborated from De la Fuente et al., 1999).



The values of linear scores calculated by Fernández et al. (1997) in the Churra dairy breed (Table 4) were sufficiently repeatable (r= 0.48 to 0.64) and showed intermediate heritability values (h^2=0.16 to 0.24) as reported in cattle. Coefficients of variation ranged between 18 and 37%. The authors indicate that a single scoring per lactation would be sufficient in practice.

Table 4. Genetic parameters of linear udder traits in dairy sheep (Fernández et al., 1997).

Trait	Heritability	Repeatability	Correlation with milk yield	
	(h^2)	(r)	Phenotypic (r_p)	Genetic (r_g)
Udder height	0.16	0.51	0.40	0.82
Udder attachment	0.17	0.48	−0.01	−0.02
Teat placement	0.24	0.64	−0.04	−0.34
Teat size	0.18	0.54	0.03	−0.16
Udder shape	0.24	0.62	0.03	−0.26

Udder shape, equivalent to a typology of expanded categories (nine), was highly repeatable and heritable, indicating its utility as a single trait for dairy sheep selection. Nevertheless udder shape showed high and positive genetic correlation with udder attachment (r= 0.55) and teat placement (r= 0.96), as a result of the main role of these traits in the definition of udder shape. Consequently, the use of the first four linear udder traits will be sufficient to improve programs of udder morphology. Phenotypic and genetic correlations showed that selection for milk yield will produce a worse udder morphology, mainly in udder height and teat placement, giving as a result baggy udders which are inadequate for machine milking.

Repeatabilities of udder linear scores obtained in Lacaune dairy breed (Marie et al., 1999) were also high (r= 0.59 to 0.71) and show moderate phenotypic correlation with milk yield in primiparous and multiparous ewes. Heritabilities of udder traits reported in Assaf (h^2= 0.23 to 0.42; Gootwine et al., 1980), Chios (h^2= 0.50 to 0.83; Mavrogenis et al., 1988), and Sarda with the seven expanded typologies (h^2= 0.55; Carta et al., 1999), gave higher values but, as indicated by the last authors, probably they were overestimated. Nevertheless, taking into account the conclusions of Fernández et al. (1997), the genetic variability and heritability of the studied udder traits indicate that the efficiency of the breeding programs could be improved and some selection pressure on udder traits in long-term breeding programs needs to considered.

Machine milking ability

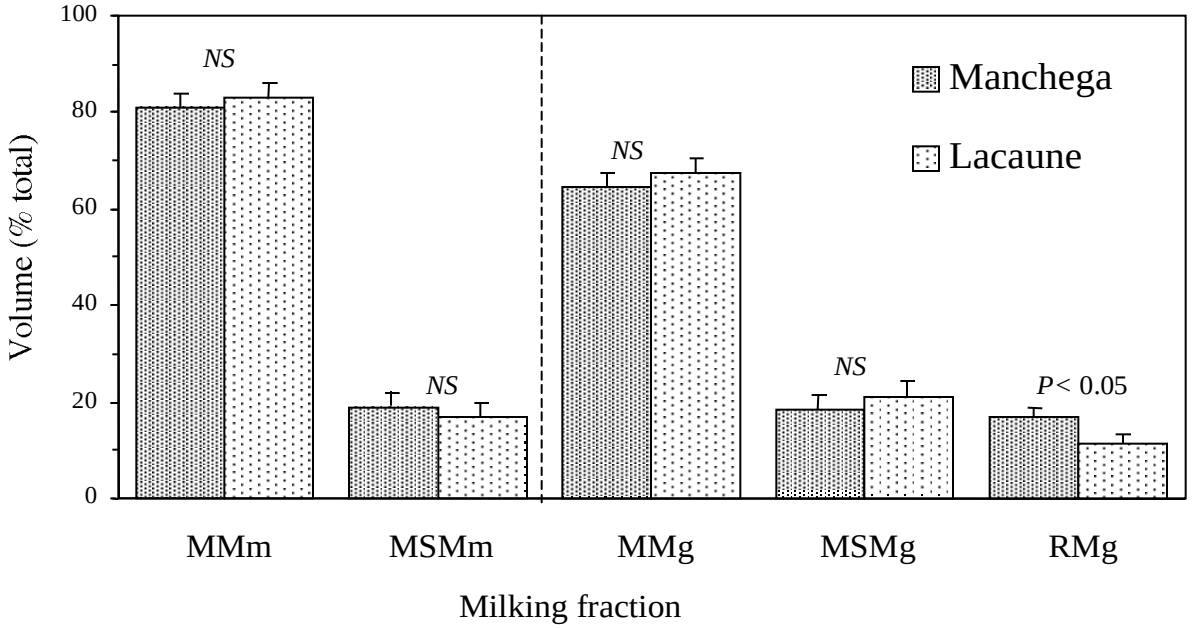
Machine milkability is normally estimated by fractional milking (i.e. machine milking, machine stripping, and extraction of residual milk after an oxytocin injection) or by analysis of milk emission curves obtained during machine milking without massage or extra stimulation of the mammary gland. The methodology proposed in the M4 FAO Project (Labussière, 1983) is normally used as the standardized method for both criteria.

***Milk fractioning*:** Milk fractions were mainly used as an important indicator for the evaluation of the milkability in dairy sheep when the routines included hand stripping as in the M4 FAO project (Labussière, 1983). Reported values of milk fractioning varied according to breed (Labussière, 1988; Such et al., 1999a), milking routine (Molina et al., 1989) and machine milking parameters (Fernández et al., 1999). Values of fractioning ranged normally from 60 to 75 : 10 to 20 : 10 to 15, for machine milking : machine stripping : residual milk, respectively.

The comparison of milking ability of two groups of ewes characterized by different milk yield (Manchega, 0.6 l/d; Lacaune, 1.3 l/d), was carried out by Such et al. (1999a) in late lactation (week 16) and under the same milking conditions. Values of fractional milking (machine milk : machine stripping milk : residual milk) were 65:19:16 and 68:21:11, for Manchega and Lacaune ewes, respectively. No significant differences were observed according to breed in percentages of milk fractions, except in the case of residual milk (Figure 8). Both breeds gave on average 86% milk during machine milking, but Manchega breed retained more milk in the ductal system of the udder. This result was obtained despite the differences reported in milk yield and in absolute values of each fraction, as well as in cistern size (Table 1) and udder morphology (Table 2), of each breed as discussed previously. Differences in udder size and morphology explain the increase in machine stripping milk according to milk yield, and were also reported by effect of lactation stage (Gallego et al., 1983b; Labussière, 1988).

As a conclusion, the obtained results show the unsuitability of the milk fractions as a main indicator for the evaluation of milkability in ewes, fractioning probably being a better indicator for the study of machine or milking routine effects, which were the same in this case. Moreover, Caja et al. (1999a) in goat and Fernández et al. (1999a) in sheep, reported significant differences in the machine stripping fraction according to milking routine or machine milking parameters, respectively.

Figure 8. Milk fractioning obtained during machine milking of dairy sheep according to the breed at the same stage of lactation (Such et al., 1999a): MM, machine milk; MSM, machine stripping milk; RM, residual milk; m, milked; g, present in the gland.



***Milk emission*:** Milk emission is one of the most interesting criteria for studying milkability in the machine milking of dairy sheep and its main traits are considered to be relevant for the design of milking machines and to adopt the optimal milking routine in each breed. As milk yield strongly influences intramammary pressure, a strong effect of milk production on all milk flow parameters is also expected, as indicated by Marnet et al. (1999) and observed clearly in dairy goats (Bruckmaier et al., 1994; Caja et al., 1999a). Moreover, milk emission will be different for a.m. and p.m. milkings, and its curves should be analyzed separately. Morning milking will increase milk flow and milking time, but emission of alveolar milk will be observed easily and separately in the afternoon.

Milk emission curves are obtained by manual (Labussière, 1983; Fernández et al., 1989b; Peris et al., 1996) or automatic methods (Labussière and Martinet, 1964; Mayer et al., 1989b; Bruckmaier et al., 1992; Marie et al., 1999). The flow from the right and left mammary glands can be recorded separately (Labussière and Martinet, 1964; Labussière, 1983) or as a whole (Fernández et al., 1989b; Peris et al., 1996; Bruckmaier et al., 1992; 1996; Marie et al., 1999; Marnet et al., 1999), but results and conclusions of flow may be different in consequence (Rovai, 2000).

A good milk emission curve should mean a quick and complete milking, with a high milk flow rate and an effective ejection of alveolar milk under the action of the oxytocin. The milk emission pattern is related to the structure of the udder (cistern size), to the teat traits (size and position) and to the neuro-hormonal behavior of the ewe (Labussière et al., 1969; Bruckmaier et al., 1994, 1997; Marnet et al., 1998, 1999). Globose and big cisterned udders with medium size, vertical and sensitive teats, that are able to open the sphincter rapidly and widely at low vacuums, are preferable.

An early typology of milk emission curves was proposed by Labussière and Martinet (1964), and widely adopted for the study of sheep dairy breeds (Labussière, 1983, 1988). The milk emission typology considers curves of different shape: '1 peak' (single), '2 peaks' (bimodal) and others, the last corresponding to animals with irregular or multiple milk emission curves (≥ 3 peaks). In some cases an ewe changes the milk emission typology on consecutive days, and more than two recordings are recommended in practice. The first peak occurs very early after cluster attachment and it is identified as cisternal milk, which is drained after the opening of the teat sphincter. The second peak corresponds to alveolar milk and occurs as a consequence of liberation of alveolar milk during the appearance of the milk ejection reflex by effect of released oxytocin (Labussière and Martinet, 1964; Labussière et al., 1969; Fernández et al., 1989b; Marnet et al., 1998). Milking-related release of oxytocin has been measured in dairy sheep by Mayer et al. (1989a) and Marnet et al. (1998). The machine milk fraction is normally greater and milk flow maintained high during a longer time in the bimodal ewes, which are considered favorable for machine milking in dairy ewes. Milking of ewes showing a single milk emission curve can be completed by using a milking routine with machine or manual stripping ('repasse') after cessation of the machine milk flow, which is unfavorable and increases dramatically the total milking time per ewe. Moreover, simplified milking routines (without hand or machine stripping) are well accepted by bimodal ewes as indicated by Molina et al. (1989) in Manchega dairy sheep.

Distribution of animals in a flock according to number of peaks has also been used as an index of machine milkability in dairy breeds as indicated by Labussière (1988). Sheep breeds with a greater percentage of ewes showing 2 peaks being the most appropriate for machine milking. Nevertheless peak distribution in a flock changes according to the stage of lactation as observed by Rovai (2000) in a flock with breeds of different yield and milkability (Table 5). Number of ewes in the 1 peak typology increased at the end of lactation and on the contrary the ≥ 3 peaks decreased compensating the losses in the 2 peaks group.

Table 5. Distribution (%) of milk emission curves obtained in dairy ewes during machine milking according to breed and stage of lactation (Rovai, 2000).

Stage of lactation (d)	Manchega			Lacaune		
	1 peak	2 peaks	≥ 3 peaks	1 peak	2 peaks	≥ 3 peaks
42[1]	28.6 (62)[2]	56.7 (123)	14.7 (32)	8.0 (16)	57.2 (115)	34.8 (70)
70	29.6 (67)	64.2 (145)	6.19 (14)	9.8 (25)	49.4 (126)	40.8 (104)
98	39.4 (74)	54.8 (103)	5.9 (11)	18.0 (34)	55.6 (105)	26.5 (50)

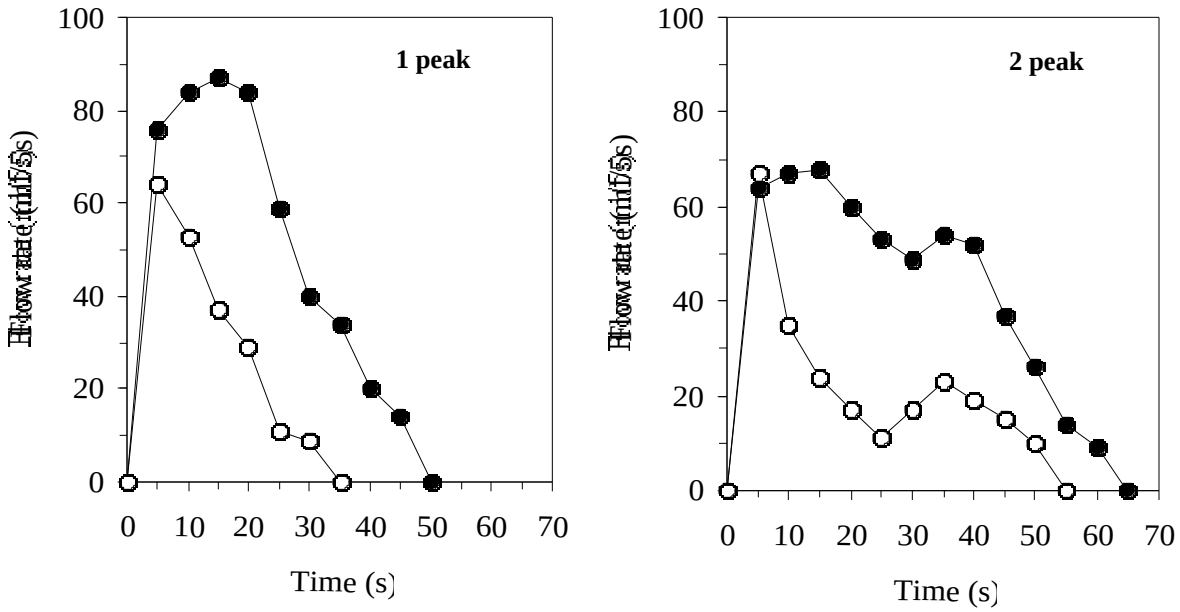
[1]: First week after weaning at day 35.

[2]: Number of emission curves analyzed.

Machine milking parameters can also modify the milk flow characteristics in dairy sheep, mainly the volume of the second peak and the milking time, as reported by Fernández et al. (1999) in Manchega dairy ewes milked at different vacuum levels (36 and 42 kPa) and pulsation rates (120 and 180 P/min) .

Clear differences in milk emission curves during the p.m. milking were observed by Such et al. (1999b) according to breed, when Manchega and Lacaune dairy ewes at the same stage of lactation were compared (Figure 9) indicating the importance of this criterion on the evaluation of milkability. Daily milk yield at comparison and percentage of bimodal ewes during the comparison period were 0.6 l/d and 38%, and 1.3 l/d and 83%, for Manchega and Lacaune ewes respectively.

Figure 9. Milk emission curves resulting from p.m. machine milking of dairy sheep according to breed (□, Manchega; ■, Lacaune) and number of peaks (Such et al., 1999a).



Significant differences in the values of maximum milk flow (76 *vs* 129 ml/5s) and milk peak volume (207 *vs* 586 ml) were observed for the 1 peak Manchega *versus* Lacaune ewes, respectively. The significant values for the 2 peaks ewes were: first peak (72 *vs* 94 ml/s; and, 171 *vs* 344 ml) and second peak (41 *vs* 83 ml/s; and, 78 *vs* 239 ml), for Manchega *vs* Lacaune, respectively. Total emission time until a milk flow <10ml/s were: 1 peak (25 *vs* 39 s) and 2 peaks (48 *vs* 56 s) for Manchega *vs* Lacaune respectively, being the difference significant in all cases. Observed differences in milk flow parameters between breeds were in accordance with their milk yield. Nevertheless, despite the differences of milk emission curves, the total volume of milk obtained in 1 peak *vs* 2 peaks ewes were similar in each breed: Manchega (207 vs 249 ml) and Lacaune (586 vs 583 ml) respectively for 1 *vs* 2 peaks. Moreover maximum milk flow was the same in both breeds for the 2 peaks ewes, despite the differences in yield. As a consequence, it can be suggested that other factors different from milk ejection reflex are mainly conditioning the milk flow during machine milking in dairy ewes.

At present, teat and cistern characteristics seem to be the most important factors in relation to milk flow curves in dairy sheep. Results of Marie et al. (1999) and Marnet et al. (1999) in Lacaune dairy sheep, and Bruckmaier et al. (1994, 1997) studying the effects of milking with or without prestimulation in Saanen dairy goat, and Friesian and Lacaune dairy sheep, are in accordance with these conclusions.

Marnet et al. (1999) indicate that lag time between teat cup attachment and arrival of the first milk jets to the recording jar can be used as an indicator of milkability. Moreover significant correlation of lag time with vacuum needed to open the teat sphincter (r= 0.61), total milking time (r= 0.86), and mean (r= –0.84) and maximum (r= –0.80) milk flow rates, were observed. A low but significant correlation between Somatic Cell Count and maximum milk flow was also obtained (r= 0.39). Moreover, the vacuum value needed to open the teat sphincter seems to remain constant in each animal during lactation and is also positively related with the teat congestion observed after milking. The highest vacuum value needed to open the teat sphincter in this experiment was 36 kPa, suggesting that the use of a low milking vacuum is possible in Lacaune dairy ewes.

According with these results Marie et al. (1999) studied the main udder traits and milk flow characteristics by using an automatic milk recorder in two lines of Lacaune dairy ewes differing 60 l in genetic merit. Milk yield and milking time averaged 0.94 l/d and 2 min 44 s, respectively. Average lag time was 25 s for a minimum volume of milk of 160 ml. Maximum milk flow (0.87 l/min) was observed 27 s later (52 s from cluster attachment) in average. Lag time was negatively correlated with milk yield (r= –0.26) and maximum milk flow (r= –0.49). Measured repeatabilites for milk yield, lag time and maximum milk flow were high in the same lactation (r= 0.46 to 0.59) and between lactations (r= 0.40 to 0.75). Flow parameters varied according to milk yield as previously reported by Bruckmaier et al. (1994) in goats, but the increase in milking time was lower than in milk.

Correlation of udder traits with flow parameters obtained by Marie et al. (1999) were low (–0.3 to 0.3) and tended to increase in multiparous ewes. An increase in teat angle was associated to a greater lag time (r= 0.28) and a lower maximum milk flow (r= –0.26), both unfavorable traits. On the contrary, a very marked intermammary groove was correlated to greater milk yield (r= 0.28) and milk flows (r= 0.33 to 0.34), and lower lag time (r= –0.23). As a final conclusion the authors indicate that a good udder shape tends to improve milkability in dairy sheep and recommended the inclusion of this trait in genetic programs.

Bruckmaier et al. (1997) compared milk flow and udder anatomy, including ultrasound images, in Lacaune and Friesian dairy ewes. Both breeds showed similar milk yield and cisternal areas. Nevertheless, milk flow was lower and stripping milk yield higher in the Friesian ewes as a consequence of udder morphology that showed cisternal bags below the level of the teat channel. The use of a prestimulation routine failed to reduce stripping milk and total milking time but increased milk flow in both breeds. Oxytocin release was different in both breeds and a dramatic increase in blood concentration was observed in Lacaune ewes during teat stimulation and early milking, while only slight release was found in Friesian ewes. During machine milking, significant increase in oxytocin was observed in 88% of Lacaune but only in 58% of Friesian ewes. The authors also indicate the occurrence of single peak typologies in milk emission with or without increasing concentrations of oxytocin in both breeds.

Implications

Relationship between morphological and productive traits are evident in dairy sheep as a consequence of anatomical and physiological characteristics. Breed differences are also detected despite the differences in milk yield. Phenotypic and genetic correlations indicate that selection for milk yield will produce a worse udder morphology, mainly in udder height and teat placement, causing baggy udders which are inadequate for machine milking. Teat and cistern characteristics appear to be the most limiting factors in machine milkability and especially in milk flow. Genetic variability, repeatability and heritability of udder traits indicate that some selection pressure on udder traits needs to be considered. In practice the use of four linear udder traits will be sufficient to improve udder morphology in long-term breeding programs.

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DAIRY SHEEP NUTRITION

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Introduction

In a paper given to the North American Dairy Sheep Symposium, Treacher (1989) concluded that, in the continued absence of costly research into dairy ewe nutrition, dairy sheep farmers should record "feed inputs, the nutritional quality of feeds and the quantities and quality of milk produced". During the summer and fall of 1999, we followed Treacher's (1989) advice on two flocks in the fledgling Ontario dairy sheep industry. Our observations will be used to illustrate some of the points to be made in this paper regarding the calculated approach to formulating rations for the grazing, high-producing milk ewe.

Lactation

If lambs are separated from the ewe wthin 24 h of birth and machine-milking commences twice daily, milk production over the next 100 to 200 d will follow the typical lactation curve observed in other ruminants – a rise in daily production for the first 20 to 40 d and a steady decline thereafter (Figure 1). Typically, however, the difficulties of rearing lambs artificially precludes separation from the dam so lambs are allowed to suckle for the first 30 d or so of lactation. Thus, weaning coincides with peak lactation and daily milk production can be expected to decrease from that time on (Figure 1b). Protein and fat from the East Friesian breed are fairly stable at 5 to 6 % of milk volume until late lactation when daily milk yield falls to 1000 ml/d and less. Lactose percentage changes very little.

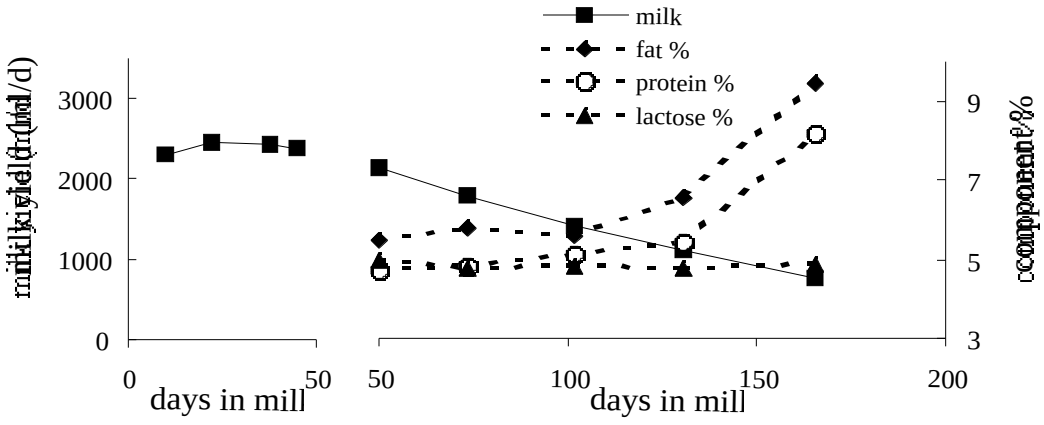

Figure 1. Milk production and composition during lactation in the dairy ewe (a from Bocquier et al., 1999; b from Ontario flock).

There are concerns that leaving the milking up to the lambs during early lactation can limit daily milk yield. Ewes would peak at less than their potential production and, because of the natural decline in milk yield post-peak, total lactational yield could be severely compromised. A partial-milking practice in which ewes were milked once daily at 8 a.m. during the suckling period resulted in an additional 412 ml/d milk for ewes suckling single lambs and

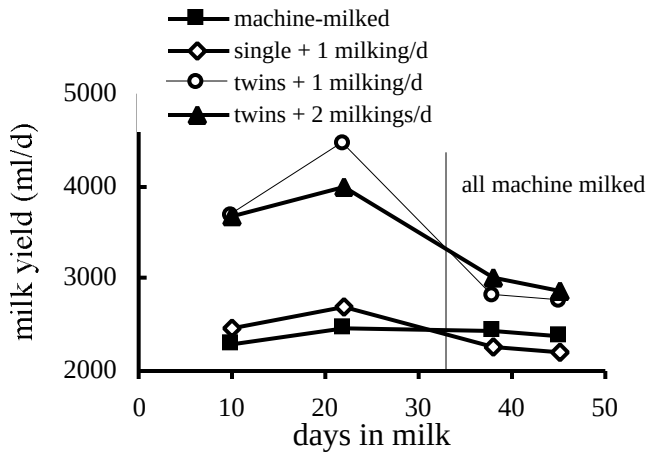

Figure 2. Total daily milk production (suckling + machine-milking) by ewes suckled and/or milked by machine during the first 32 d of lactation (from Bocquier et al., 1999).

177 ml/d for those with twins (Bocquier et al., 1999). Partial milking brought total daily milk yields of ewes with singles up to the level observed in ewes milked solely by machine from the onset of lactation (Figure 2). Ewes with twins, though, were actually stimulated to produce more milk than the completely machine-milked ewes during the first 30 d. At weaning, their milk production dropped off drastically but the advantage of a higher peak carried through to later lactation. The drop in yield at weaning is a common phenomenon (Treacher, 1989;) which indicates that some aspect of suckling is a stronger stimulator of milk production than is obtained with normal milking practices. Possibly the number of milkings per day is a limiting factor. A lamb will suckle 6 to 12 times per day and in the dairy cow, it was shown that 6 milkings per day resulted in 22% more milk produced than on a 3X per day routine (Bar Peled et al., 1998).

Bocquier et al. (1999) tried a second machine-milking during the suckling period at 5 p.m. daily which was preceded by 6 h of separation of ewes from their lambs. These ewes gave 904 ml/d milk for sale during the suckling period. However, total daily milk yield was not increased by the second, more intensive machine milking (Figure 2) and lamb growth rate was reduced from 315 to 271 g/d (Bocquier et al., 1999). One milking per day throughout the suckling period appears to be a successful strategy to avoid underachievement of peak yield and ensure high yields for the remainder of lactation.

Energy and Protein Requirements

There are many factors that determine how much milk a ewe will produce each day. The goal of lactation is to produce as much milk as the suckling lambs demand. Thus, the mammary glands and supporting tissues will attempt to obtain enough nutrients from blood to produce the quantity of milk being removed daily from the udder. If feed intake of the ewe cannot provide all

of these nutrients then fat stores will be mobilized out of adipose tissue. However, with machine-milking, it is possible to exceed upper biological limits of the milk-producing system, whether they be mammary capacity, digestive capacity, adipose responsiveness or some other tissue function. As a consequence, the early-lactation ewe is generally unable to consume enough feed to meet energy demands of high milk production and is losing body weight, mostly from fat stores. Nutrition can be used to manage rate of loss of body condition in early lactation as well as level of milk production, especially at peak. Protein and fat content of milk can also be influenced by nutrition but these issues are beyond the scope of this paper. The reader is referred to Kennelly and Glimm (1998) for a discussion of bovine milk composition. The late, declining part of a lactation curve is due to hormonally directed decreases in mammary capacity so nutrition, unless it is inadequate, has little impact. If inadequate, though, milk production and lactational persistency will suffer. Nutrition should be used in late lactation to manage replenishment of body fat reserves.

Table 1. Metabolizable energy (ME) and crude protein (CP) costs of lactation in the ewe. Each column should be summed to arrive at a total nutrient cost. Body weight (BW) is in kg, gain and loss are in kg/d, milk yield is in ml/d

	ME cost (Mcal/d)	CP cost (g/d)
maintenance	0.101 x $BW^{0.75}$	4.456 x $BW^{0.75}$
activity (if grazing)	0.15 x maintenance	0
lactation	milk yield x (fat % x 9 + protein % x 5 + lactose % x 5)/64,000	milk yield x protein %/56.1
body weight loss	10.5 x BW loss	446 x BW loss (max = 151)
body weight gain	11.0 x BW gain	446 x BW gain

To assist in ration formulation for the lactating ewe during these different stages of lactation, and especially the grazing ewe who will obtain only a portion of her dietary nutrients from supplemented ingredients, we have outlined energy and protein costs for the various processes of milk production (Table 1). These costs should be summed up to determine total dietary energy and protein needs for a given level of production. There is no formally published set of nutrient requirements for the lactating dairy ewe in North America. However, there are similarities with other ruminants that have been studied in more detail which were exploited to arrive at our estimates of energy and protein needs. The sources will be reviewed here.

The sheep NRC (1981) publication suggests that daily metabolizable energy (ME) costs for body weight (BW) maintenance in sheep are 93 kcal/kg $BW^{0.75}$. However, it is known that the lactating animal has a higher maintenance expenditure than her non-lactating counterpart because of larger guts and livers (Fell et al., 1972; Smith and Baldwin, 1974). NRC (1981) has an estimate of 101.4 kcal/$kg^{0.75}$ for lactating goats and Sutton and Alderman (2000) go even higher to 103.7 kcal/$kg^{0.75}$. We selected 101 kcal/$kg^{0.75}$ as representative of the maintenance expenditures in a lactating dairy ewe (Table 1). Activity in the grazing animal will add 15% onto the estimated maintenance cost.

Metabolizable energy costs for lactation in goats are estimated as 1246.12 kcal/kg 4% fat-corrected milk (NRC, 1981) and, for cows, as 1233 kcal/kg (NRC, 1989). A more universal approach is to consider fat and protein percentages individually because of the variation possible in either component. In Table 1, ME values of 9, 5 and 5 kcal/g were applied to milk fat, protein

and lactose contents, respectively, and a 64% efficiency of ME incorporation into milk was assumed. A standard milk lactose percentage of 4.8 can be used if analyzed values are unavailable.

Each kilogram of BW lost in support of lactation is assumed to spare 9.2 to 12.5 Mcal ME for the non-dairy ewe (NRC, 1985). This is a large range but it does not include the 8.2 Mcal ME/kg BW assumed for the dairy cow (NRC, 1989) or the 7.25 Mcal/kg for the dairy goat (NRC, 1981). Sutton and Alderman (2000) report a vlue of 10.5 Mcal ME/kg BW lost which is intermediate to the NRC (1985) sheep values so it was selected by us as most reasonable (Table 1). Gain of a kilogram of BW takes slightly more ME at 11.0 Mcal (Sutton and Alderman, 2000).

Dietary crude protein (CP) requirements were calculated from metabolizable protein (MP) assuming a true digestibility of 85% and biological value of 66% (NRC, 1985). The daily maintenance MP requirement of lactating goats has been set at 2.5 g/kg $BW^{0.75}$ (Sutton and Alderman, 2000) and 2.82 g/$kg^{0.75}$ (NRC, 1981). Because of the tendency to overfeed protein, we selected the former estimate for our calculations (Table 1). Activity, such as walking during grazing, does not use up any additional dietary protein.

Although NRC (1981) calculated the MP requirement for milk production as 51 g/kg 4% fat-corrected milk, other publications use the milk protein yield as the starting point (Table 1), assuming efficiencies of conversion from absorbed protein of 66% (NRC, 1985), 68% (Sutton and lderman, 2000) or 70% (NRC, 1989). Contrary to popular belief, feeding additional protein beyond what is calculated to be needed for nitrogen balance in the ewe does not result in greater yields of protein in milk (Korman and Osikowski, 1999). Milk protein production in the dairy cow is more related to dietary energy supply than dietary protein supply (Hanigan et al., 1998).

Each kilogram of BW gained or lost is expected to contain 256 g MP in cows (NRC, 1989) and 247 g MP in goats (Sutton and Alderman, 2000). We selected 250 g/kg as reasonable (Cowan et al., 1981) and include the restriction that a maximum of 85 g MP/d (Sutton and Alderman, 2000) can be mobilized from body stores in early lactation.

Pasture Supplementation

To evaluate or formulate a feeding programme for ewes, one must have some idea of how much dry matter (DM) is or will be consumed daily. This is very difficult when animals are grazing so extrapolations from stall-feeding observations are a main recourse. Treacher (1989) reported a maximum DM intake of 5.7 % of BW at week 8 of lactation and typical values ranging from 3.6 to 4.2 %. Using daily Cr_2O_3 dosing and fecal collection for 10 d every month, we estimated forage intakes of 2.0 to 4.2 kg DM/d in ewes supplemented with 1.1 kg DM/d concentrate in the milking parlor. These intakes averaged 4.8 % of BW in total.

Prediction of DM intake is often based on BW alone but more precise estimates also consider milk production, fat or energy content of the milk and stage of lactation (Holter et al., 1997). To our knowledge, no such equations exist for the grazing, lactating dairy ewe.

A 70-kg ewe grazing pasture with a digestibility of 70% will consume approximately 4.5% of her BW in DM daily, which is 3.15 kg/d. To produce 4000 ml/d milk containing 6% fat and 5% protein, according to Table 1, she needs to consume 2.44 Mcal ME/d for maintenance functions, 0.37 for grazing activity and 6.44 for milk production. This is a total of 9.25 Mcal/d. Crude protein requirements are 108 g/d for maintenance plus 356 g/d for lactation, equalling 464 g/d in

total. At 3.15 kg/d DM intake, 2.94 Mcal ME/kg DM and 14.7% CP are required. The pastures we observed on Ontario farms had 2.71 Mcal ME/kg DM and 18.9% CP (Table 2). Thus, ME, and not protein, appeared to be limiting dairy ewe performance. However, chemical analysis of a sample of pasture, no matter how well procured, does not accurately represent the quality of forage actually consumed because of selective grazing by ewes. Table 2 shows the composition of a representative sample of pasture and of the forage that disappeared over 3 days of grazing from that same pasture. The grazed material had a higher protein and fat content and was lower in NDF, ADF and lignin. Selection thus allows for improved animal productivity from pastures but maintaining forage quality over the whole season may prove difficult when plant species are not completely grazed. Even though ewes selected forage of a higher TDN and ME content than was available on average, these pastures alone were unable to provide the ME needed for production of 4000 ml milk/d.

Energy supplementation can be provided by whole grains. Protein supplementation should not be considered given the ease with which high-protein forage species can be cultivated and the selective consumption of high-protein plant parts by sheep. However, rumen-undegradable protein supplementation may be warranted because the proteins in fresh forages are highly degradable in the rumen and, if in excess, may not provide metabolizable protein to the ewe. Feedstuffs high in undegradable protein include fish meal, blood meal, corn gluten meal and roasted soybeans. Treacher (1989) documented 600 to 940 ml/d improvements in milk yield with fish and blood meal supplementation of forage-fed ewes.

Tabel 2. Chemical composition of forage pasture or taken off pasture by grazing.

% of DM	ungrazed pasture	disappeared pasture
crude protein	18.9	23.1
soluble protein	4.78	5.09
ND-insoluble CP	7.40	9.90
AD-insoluble CP	1.79	1.91
NDF	59.9	55.6
ADF	33.3	26.0
lignin	2.87	2.29
fat	2.99	3.26
ash	8.68	8.92
TDN[1]	70.9	73.4
ME	2.71	2.82

[1]calculated from Weiss et al. (1992)

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INFLUENCE OF SOMATIC CELL COUNT ON EWE'S MILK COMPOSITION, CHEESE YIELD AND CHEESE QUALITY

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Abstract

Milk samples with low (<500,000/ml), medium (500,000-1,000,000/ml) and high (1,000,000-2,000,000/ml) Somatic Cell Counts (SCC) were obtained from a flock of 120 Sarda breed ewes. Milk was analysed for chemical composition and rheological properties (Formagraph), and used for a laboratory scale cheesemaking. The milk of the three groups showed differences ($P<0.01$) in pH, lactose, whey protein and total Na content. Soluble casein, casein to protein ratio, soluble Ca and total K content were significantly different at $P<0.05$. Rennet clotting time (R), rate of curd firming (K_{20}) and curd firmness (A_{2R}), in milk with non-standardised pH value, were significantly different ($P<0.01$). Protein recovery rate was higher in cheese from low SCC milk ($P<0.01$), while adjusted cheese yield did not show significant differences. Protein losses in whey were greater ($P<0.05$) when medium or high SCC milk was processed. Neither 1 d-old nor fully ripened cheeses showed significant differences in chemical composition or rheological characteristics.

Introduction

The Somatic Cell Count (SCC) of milk represents a marker of the sanitary state of the udder. In fact, during the course of mastitis the immune defenses of the udder become active, polynucleated leucocytes move from the blood towards the mammary gland in large numbers and the number of somatic cells in the milk increases (Poutrel, 1981). Yet SCC can vary irregularly in sheep milk independently of infective processes, and it can reach very high levels during the colostral period and at the end of lactation (Dulin *et al*., 1983; Fruganti *et al*., 1985; Konig *et al*., 1985). An increase can also be the result of other factors: animal age, milk yield, flock management, season and stress (Duranti *et al*., 1990; Konig *et al*., 1985; Olivetti *et al*., 1989). It is therefore difficult to establish the level of SCC which can be considered to indicate infection in the udder. Konig *et al*. (1985) have established that a SCC value equal to 2,000,000 is to be considered normal, whereas Vecchi & Cavani (1987) consider the normal value to be 500,000. More recently Gonzalo *et al*. (2000) have proposed 3 sanitary categories for ovine flocks relating to the SCC of the tank: good (SCC<500,000), an average of 30% of sheep infected; average (SCC of between 500,000 and 1,000,000), 40% of sheep infected; bad (SCC>1,000,000) with an infection rate of over 45%. It can therefore be very important to know the level of SCC on a farm not only for the sanitary management of the flock, but also for the quality traits of the milk produced. In fact numerous studies, mostly done on cows' milk, have shown that an increase in SCC determines a modification in the chemical composition of milk. Milk yield (Raubertas & Shook, 1982; Ng-Kwai-Hang *et al*., 1984), fat content, total solids, casein and lactose amounts are negatively correlated with SCC, while SCC is positively correlated with TN, NPN, whey proteins and pH (Schukken *et al*., 1992; Politis & Ng-Kwai-

Hang, 1988a). The α-CN and β-CN (Ali *et al*., 1980; Anderson & Andrews, 1977) percentages decrease when SCC increases, but SA and Ig do not (Duranti & Casoli, 1991). Lactodynamographics parameters, R and K_{20}, present significant increments when SCC increases (Duranti & Casoli, 1991; Ali et al., 1980); A_{30} on the other hand shows the opposite trend (Duranti & Casoli, 1991). Saeman *et al*. (1988) and Senyk *et al*. (1985) have demonstrated that an increase in SCC determines higher proteolytic activity in milk; Politis & Ng-Kwai-Hang (1988b) and Barbano *et al*. (1991) have observed that increased SCC causes a decrease in cheese yield, related to fat and protein losses in the whey. Although sheep's milk is nearly all used for cheesemaking, little is yet known of the relationship between somatic cell count (SCC), milk composition and the suitability of milk for cheesemaking, and still less the quality of the finished product. Some authors (Duranti & Casoli, 1991; Pulina *et al*., 1991) have concentrated mainly on the effect of SCC on the nitrogen fractions of milk, lactodynamographic parameters (Duranti & Casoli, 1991; Pirisi *et al*., 1996) and cheese yield (Pirisi *et al*., 1996). The purpose of the present work is to study the impact of 3 different levels of somatic cells on the composition and on the suitability for cheesemaking of sheep's milk and on the quality traits of the cheese obtained.

Materials and Methods

Milk samples. In order to obtain milk with the three different somatic cell levels (SCC<500,000, 500,000<SCC<1,000,000, and 1,000,000<SCC<2,000,000) to be studied, a flock of 120 sheep was milked half-udder by half-udder. Upon milking a sample was taken from the milk of each half-udder in order to determine its SCC (Fossomatic, FossElectric), while the rest was conserved in a plastic bag and stored at 4°C. On the basis of the SCC of each sample, the milk was then blended to give three bulk milk corresponding to the three pre-established SCC thresholds.

Milk analysis. On the three bulk milks the following analytic assessments were carried out in duplicate: pH (potentiometric method, Orion 420A), total solids (FIL-IDF, 1987), lactose (Milkoscan-FossElectric, Denmark), fat (Gerber method), SCC (Fossomatic cell counter-FossElectric, Denmark). The TN, NPN and NCN contents were determined according to Rowland (1938) using a Kjeldahl block digester apparatus (Gerhardt, Bonn, Germany), soluble casein (Sala *et al*., 1993) and urea (differential pH-metry). The same methods were used on whey samples. Total and soluble Ca, total Na and total K were measured by atomic absorption spectrometry (SpectrAA 250 Plus, Varian); total and soluble P were measured according to the FIL-IDF (1990) method and the degree of micellar hydration according to Thompson *et al*., 1969. Rheological parameters were studied by Formagraph (FossElectric, Denmark) under the conditions proposed by Piredda et al. (1993), except for A_{2R} (curd firmness), which was measured as the amplitude obtained at 2 times the flocculation time. The pH of milk samples was previously standardized at 6.5 using a solution of lactic acid (100 g/L).

Cheesemaking and cheese analysis. Thirty laboratory-scale cheesemaking trials were carried out in a pilot plant (Cardenas *et al*. 1991), 10 for each SCC level. Typically, three milks were made into cheese simultaneously using three identical 11-litre cheese vats. The milks were allocated to different vats over the course of a series of experiments in order to eliminate any vat effect. An uncooked cheese type was manufactured for analytical purposes, in loaves weighing about 1 kg each. The milk (11 kg for each cheesemaking) was previously thermized at 65°C, quickly cooled to 38°C, then a freeze-dried mixed starter culture (*Streptococcus thermophilus*

and *Lactobacillus delbrueckii* ssp. *bulgaricus*, Jointec®-CSL, 20136 Milano, Italy) was added to 20 mg/L of milk. Liquid calf rennet (1:10,000 strength) was added to 250 µl/L of milk. After 1.5 times the clotting time, the coagulum was cut into small granules (about 6 mm in size) and then put into moulds. The loaves were sweated at 32°C for 5 h and then salted in saturated brine for 7 h. The cheeses were ripened for two months at 12°C and 85% relative humidity. The following analyses were performed on 1 d and 2 month old cheeses: pH (potentiometric method, Orion 420A), total solids (FIL-IDF, 1982), fat (Soxhlet extraction), nitrogen fractions (TN, SN, SN-TCA and SN-PTA) (Gripon *et al*., 1975). During the first 24 hours the pH value of the cheeses was constantly monitored (Spinnler & Corrieu, 1989) by connecting the pHmeters (mod. 420A - Orion, U.S.A.) to a programmable measuring station (Castor II - Agil, France) in order to record the relative values at regular intervals of 1 minute. The data recorded were used to construct an acidification curve for each cheese and to establish the following parameters: V_m (maximum acidification rate), T_m (time at which V_m was observed), pH_m (pH at which V_m was observed). Various indices were used to establish cheese yield: gross cheese yield after 1 day, adjusted cheese yield at 550 g DM/kg, protein recovery rate (PRR).

Rheology. Rheological analysis by means of a rheometer TA-XT2 (Stable Micro Systems, England, UK) was carried out on the 1 d and 2 month old cheese under the conditions proposed by Pirisi et al., 2000. Engineering stress σ (kPa) and Cauchy strain ε (-) were calculated according to $\sigma = F_t \cdot A_0^{-1}$ and $\varepsilon = (h_0 - h_t)\, h_0^{-1}$ where F_t (N) refers to the force at each time t, A_0 (m^2) to the initial cross-section of the specimen and h_0 and h_t (m) to specimen height at time 0 and t (Peleg, 1987) respectively. The modulus of deformability M_D (kPa), the apparent fracture stress σ_f (kPa), the apparent fracture strain ε_f (-) and the work to fracture W_f (kJ m^3) were calculated from the stress-strain curves.

Statistical analysis. Analysis of variance was carried out using the General Linear Model procedure of the SAS programme (SAS, 1988).

Results and Discussion

The results relating to the physico-chemical characteristics of the milk with the three levels of SCC are reported in Table 1. The results show the SCC to have had a significant effect ($P<0.01$), as regards the two extreme thresholds, on the pH value of the milk, which increased together with the SCC, whilst the results for the milk with an intermediate level of SCC show intermediate values, not significantly different from those found for the other two thresholds. Lactose content also fell significantly ($P<0.01$) hand in hand with the SCC. As regards protein fractions, a significant SCC effect was detected on soluble protein content ($P<0.01$), whose values increase together with the level of somatic cells, and, in this case too, the whey protein content of the milk with the intermediate threshold of SCC is intermediate and not significantly different from that of the milk with extreme SCC thresholds. The greater whey protein content of the milk high in SCC brings about an increase, albeit not significant, in the true protein content and a lower casein:protein ratio ($P<0.05$) in the milk with the highest level of SCC, the casein content in the three milks being practically the same. No significant differences were noted for non-protein nitrogen and urea contents, while an increase in soluble casein content ($P<0.05$) was decteted in milk with high SCC. This could cause a greater losses in the whey and a smaller recovery of protein and total solids in the cheese. In fact there appears to be a negative correlation ($r=-0.451$ $P<0.05$) between soluble casein and the protein recovery rate.

The mineral content of the milk (Table 2), as regards the total fractions of calcium and phosphorus and also soluble phosphorus, displayed no significant differences, while significant differences were found for soluble calcium ($P<0.05$), for sodium ($P<0.01$) and for potassium ($P<0.05$). This can be explained by an alteration in the filtration system of the udder following its being in a state of infection (Jaubert *et al.*, 1996).

As for the micellar characteristics of the milk (Table 3), there appear to be no significant differences between the milks with the three somatic cell thresholds examined, only some tendencies, as in the case of the degree of hydration of the micelle, which, being higher in the milk with a high SCC, gives the micelle itself greater stability, which could in turn affect the clotting time of the milk.

Table 4 shows data relative to the behaviour of the milk with the three levels of SCC as regards rennet coagulation. The results obtained from the milk at native pH show the level of SCC to exercise a strong influence on the parameters taken into consideration. In particular the milk with the highest SCC displayed a significant lengthening ($P<0.01$) in milk clotting time (R), which was around twice as long as that found for the low SCC milk. Increased SCC in milk therefore means difficulties for cheesemaking. Furthermore, for the high SCC milk the curd firming time is significantly higher ($P<0.01$), around twice that found for low SCC milk, highlighting the difficulty high SCC milk has in organising itself into a well-structured curd. The curd firmness, measured as A_{2R}, was significantly different ($P<0.01$) for the low and intermediate SCC threshold milk in comparison with the high threshold milk. The lactodynamographics parameters are notably affected by the pH value of the milk ($r=0.88$ $P<0.001$ for curdling time; $r=0.87$ $P<0.001$ for the K_{20} parameter; $r=-0.51$ $P<0.05$ for the A_{2R} parameter), which, as highlighted, is closely linked to the variation in SCC. In actual fact, if the same clotting parameters are applied to milk with standardized pH value at 6.50, the differences diminish significantly. Clotting time and curd firming time are still higher for the high SCC milk but not significantly so, whilst curd firmness is still significantly lower ($P<0.01$) for the high SCC milk.

Table 5 shows the data relating to the losses of useful cheesemaking (protein+fat) matter in the whey. The results show there to be a greater loss of protein in the whey ($P<0,05$) when high SCC milk is used for manufacture, which is to be compared with the greater richness of this milk in soluble proteins. As for cheese yield (Table 6), the only differences to highlight between the three types of milk regard the protein recovery rate, which is significantly lower ($P<0.01$) for the high and intermediate SCC milk, meaning that the milk with the lower SCC level is the most efficient for cheesemaking. In fact, from this milk, it was possible to recover 4% more protein in the cheese than from with milk with the highest SCC.

Table 7 shows data relative to the progressive acidification of the cheese. The parameters studied: V_m (maximum acidification rate), T_m (time at which V_m was observed), pH_m (pH at which V_m was observed) did not highlight any significant SCC influence on the development of the lactic acid bacteria used as starters or, therefore, on the progress of the acidification process of the cheese.

The cheese composition, with reference to two stages of maturation, 1 d and 2 months (Table 8), shows no great differences. It has, however, been possible to detect a tendency for the cheese made from the high SCC milk to possess a lower total solids content and, therefore, higher humidity, as well as a lower fat content. As for secondary proteolysis, estimated by determining different nitrogen fractions, no appreciable differences were found. Nevertheless, the cheeses displayed, generally, low SN/TN values, and thus little proteolysis, as is typical for cheeses manufactured in trials. Lipolysis, studied by determining the free fatty acids (Tables 9 and 10), also presented no significant differences. The results show that the SCC of milk does not greatly affect the maturation process of cheese. This could be linked to the transformation technology used in the manufacture of the cheese and in particular to the preventative thermization treatment undergone by the milk, which could have reduced the greater enzymatic activity typical of milks with a high SCC. Table 11 shows the rheological parameters relative to the cheeses after 1 d' and 2 months' maturation. As can be seen, the mechanical characteristics of the different cheeses are practically identical. All the cheeses are very elastic, not particularly firm and highly cohesive. Such characteristics are essentially the result of the type of technology adopted and thus of the type of cheese manufactured.

Conclusions

The results obtained so far allow us to highlight a direct link between the somatic cell content and the composition of sheep's milk. In particular, it was possible to note a close relationship between the SCC, the pH value and the whey protein and lactose content of the milk, as well as its content of certain mineral elements. The coagulation properties, too, are dependent on the somatic cell content, an increase in which provokes a considerable slowing-down of coagulation and serious difficulties in the structuring of the curd and consequentially a lengthening of the cheesemaking process. This state of affairs can, however, be improved by standardizing the milk's pH to values of 6.5, as is demonstrated by the results we have obtained. The protein recovery rate was higher for milk with low SCC which had the highest cheesemaking efficiency. The data relative to the composition of the cheeses have not allowed us to highlight any significant differences, only a tendency for milk with a high somatic cell count to produce a cheese containing more water and less fat. Nor was the process of secondary proteolysis or that of lipolysis influenced by the somatic cell content of the milk used. As a result, the rheological characteristics of the cheeses were practically identical. It appears, therefore, in the light of the results obtained, that, the somatic cell content of milk does not significantly affect the qualitative characteristics of the final product.

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Table 1 - Compositions of bulk ovine milk with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
SSC	x 1000/ml	229 ± 55	653 ± 250	1200 ± 214
pH		6.52 ± 0.09^{B}	6.62 ± 0.09^{AB}	6.68 ± 0.10^{A}
Dry matter	g/100g	17.03 ± 0.99	17.15 ± 0.91	16.89 ± 0.90
Lactose	g/100g	4.74 ± 0.20^{A}	4.54 ± 0.23^{B}	4.38 ± 0.17^{B}
Fat	g/100 ml	6.61 ± 0.73	6.34 ± 0.76	6.36 ± 1.00
True protein	g/100g	5.25 ± 0.35	5.45 ± 0.29	5.51 ± 0.28
Casein	g/100g	4.18 ± 0.26	4.26 ± 0.24	4.20 ± 0.30
Soluble casein*	%	6.51 ± 1.10^{a}	6.98 ± 0.63^{ab}	7.77 ± 0.49^{b}
Whey protein	g/100g	1.07 ± 0.16^{B}	1.19 ± 0.12^{AB}	1.30 ± 0.09^{A}
Non-protein N	gN/100g	0.06 ± 0.01	0.05 ± 0.01	0.05 ± 0.01
Casein:protein ratio	%	79.71 ± 2.12^{A}	78.16 ± 1.72^{ab}	76.27 ± 2.10^{b}
Urea	mg/100 ml	54.21 ± 17.58	54.18 ± 17.90	52.86 ± 15.58

% on casein.

^{A}, ^{B}, ^{a}, ^{b} Values in the same line with different superscript letters were significantly different: ^{A}, ^{B} $P<0.01$; ^{a}, ^{b} $P<0.05$.

Table 2 - Mineral composition of bulk ovine milk with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
Total Ca	g/l	2.21 ± 0.32	2.14 ± 0.10	2.26 ± 0.26
Soluble Ca	g/l	0.46 ± 0.12^{a}	0.38 ± 0.08^{a}	0.36 ± 0.09^{b}
Total P	g/l	1.36 ± 0.23	1.27 ± 0.07	1.34 ± 0.16
Soluble P	g/l	0.35 ± 0.15	0.28 ± 0.08	0.34 ± 0.19
Total Na	g/l	0.80 ± 0.11^{B}	0.95 ± 0.18^{AB}	1.11 ± 0.24^{A}
Total K	g/l	1.18 ± 0.13^{a}	1.12 ± 0.07^{ab}	1.08 ± 0.05^{b}

^{A}, ^{B}, ^{a}, ^{b} Values in the same line with different superscript letters were significantly different: ^{A}, ^{B} $P<0.01$; ^{a}, ^{b} $P<0.05$.

Table 3 - Micellar characteristics of bulk ovine milk with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
Micellar hydration	gH_2O/gSS	1.56 ± 0.15	1.63 ± 0.15	1.69 ± 0.15
Colloidal Ca/casein	mg/g	42.78 ± 4.79	41.92 ± 2.97	43.40 ± 7.00
Colloidal P/casein	mg/g	32.85 ± 3.51	30.40 ± 2.58	32.72 ± 2.96

Table 4 - Curdforming properties of bulk ovine milk with different SCC at native and standardized pH (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
R	min	19.82 ± 5.01^{B}	27.21 ± 7.52^{AB}	35.21 ± 11.45^{A}
K_{20}	min	7.89 ± 2.33^{B}	9.96 ± 3.02^{B}	13.93 ± 4.32^{A}
A_{2R}	mm	25.71 ± 1.52^{A}	24.43 ± 2.52^{A}	20.58 ± 3.45^{B}
pH milk standardized at 6.5				
R	min	17.11 ± 3.05	18.75 ± 2.50	20.00 ± 3.03
K_{20}	min	6.61 ± 1.42	7.75 ± 1.27	7.96 ± 1.19
A_{2R}	mm	26.36 ± 2.32^{B}	24.79 ± 3.34^{AB}	21.42 ± 4.29^{A}

$^{A, B,}$ Values in the same line with different superscript letters were significantly different: $^{A, B}$ $P<0.01$.

Table 5 - Useful cheese matter losses in whey of bulk ovine milk with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
Dry matter	kg	0.73 ± 0.02	0.77 ± 0.06	0.76 ± 0.03
Fat	kg	0.12 ± 0.04	0.14 ± 0.05	0.15 ± 0.06
Protein	kg	0.13 ± 0.006^{b}	0.19 ± 0.006^{a}	0.19 ± 0.006^{a}

$^{a, b,}$ Values in the same line with different superscript letters were significantly different: $^{a, b}$ $P<0.05$.

Table 6 - Cheese yield of bulk ovine milk with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
Gross cheese yield	%	17.55 ± 1.36	18.15 ± 0.97	17.89 ± 1.00
Adjusted cheese yield	%	18.21 ± 1.82	18.57 ± 1.25	17.79 ± 1.32
Protein recovery rate	%	79.56 ± 2.28^{A}	77.57 ± 1.39^{B}	75.38 ± 1.32^{C}

A, B, C Values in the same line with different superscript letters were significantly different: A, B, C $P<0.01$.

Table 7 - Characteristics of acidification kinetics in cheese made from ovine milks with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
V_m	mUpH	-10.50 ± 3.57	-11.75 ± 5.92	-14.61 ± 4.73
T_m	min	59.00 ± 2.83	72.50 ± 26.16	54.50 ± 17.68
pH_m	UpH	5.91 ± 0.04	5.73 ± 0.11	5.90 ± 0.01

V_m (maximum acidification rate); T_m (time at which V_m was observed); pH_m (pH at which V_m was observed).

Table 8 - Composition of 1 d and 2 month old cheese made from ovine milks with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
1 d old cheese				
pH		5.71 ± 0.30	5.72 ± 0.28	5.76 ± 0.22
Total solids	g/100g	56.87 ± 1.52	56.06 ± 2.09	54.75 ± 2.53
Fat	g/100 ml	27.24 ± 2.05	27.07 ± 1.75	25.67 ± 1.87
Protein	g/100g	23.82 ± 1.04	23.31 ± 0.68	23.23 ± 0.95
WSN/TN	%	5.97 ± 1.77		7.64 ± 2.60
7.50 ± 0.97				
TCA-SN/WSN	%	40.66 ± 3.35	34.81 ± 10.31	33.18 ± 4.58
PTA-SN/WSN	%	14.31 ± 4.98	12.89 ± 5.33	12.71 ± 4.87
2 month old cheese				
pH		5.64 ± 0.15	5.76 ± 0.08	5.75 ± 0.09
Total solids	g/100g	64.12 ± 3.59	64.24 ± 3.33	63.69 ± 3.68
Fat	g/100 ml	30.59 ± 2.53	30.93 ± 1.63	29.93 ± 1.43
Protein	g/100g	24.56 ± 0.83	24.53 ± 0.99	25.19 ± 1.66
WSN/TN	%	14.71 ± 3.35	14.65 ± 1.75	13.67 ± 0.42
TCA-SN/WSN	%	52.73 ± 7.52	49.28 ± 9.38	49.55 ± 9.71
PTA-SN/WSN	%	22.15 ± 6.80	23.77 ± 5.52	22.32 ± 5.32

WSN/TN: water soluble N/total N; TCA-SN/WSN: trichloroacetic acid (12%) soluble N/ water soluble N; PTA-SN/WSN: phosphotungstic acid (2.5%) soluble N/water soluble N.

Table 9 - Free fatty acid content in 24 h old cheese made from ovine milks with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
C 4	mmol/kg	0.33 ± 0.02	0.37 ± 0.03	0.36 ± 0.04
C 6	mmol/kg	0.13 ± 0.02	0.15 ± 0.03	0.14 ± 0.02
C 8	mmol/kg	0.08 ± 0.02	0.10 ± 0.03	0.09 ± 0.02
C 10	mmol/kg	0.17 ± 0.06	0.20 ± 0.09	0.18 ± 0.06
C 12	mmol/kg	0.09 ± 0.03	0.12 ± 0.06	0.10 ± 0.03
C 14	mmol/kg	0.14 ± 0.05	0.17 ± 0.08	0.15 ± 0.05
C 16	mmol/kg	0.30 ± 0.07	0.35 ± 0.15	0.30 ± 0.10
C 18	mmol/kg	0.10 ± 0.01	0.10 ± 0.03	0.09 ± 0.02
C 18:1 cis	mmol/kg	0.27 ± 0.03	0.33 ± 0.11	0.31 ± 0.09

Table 10 - Free fatty acid content in 2 month old cheese made from ovine milks with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
C 4	mmol/kg	1.25 ± 0.30	1.30 ± 0.34	1.23 ± 0.27
C 6	mmol/kg	0.39 ± 0.13	0.45 ± 0.15	0.35 ± 0.11
C 8	mmol/kg	0.27 ± 0.11	0.33 ± 0.16	0.23 ± 0.10
C 10	mmol/kg	0.51 ± 0.20	0.65 ± 0.35	0.47 ± 0.22
C 12	mmol/kg	0.29 ± 0.12	0.41 ± 0.28	0.28 ± 0.15
C 14	mmol/kg	0.49 ± 0.20	0.69 ± 0.46	0.50 ± 0.25
C 16	mmol/kg	0.99 ± 0.41	1.37 ± 0.83	0.97 ± 0.47
C 18	mmol/kg	0.30 ± 0.14	0.37 ± 0.17	0.27 ± 0.12
C 18:1 cis	mmol/kg	0.91 ± 0.43	1.16 ± 0.52	0.87 ± 0.36

Table 11 - Rheological characteristics of 1 d and 2 month cheese made from ovine milks with different SCC (means±SD)

		SCC< 500	500<SCC<1000	1000<SCC<2000
		x 1000/ml		
1 d old cheese				
E	kPa	180 ± 15	170 ± 34	169 ± 32
ε_f		0.51 ± 0.04	0.55 ± 0.04	0.55 ± 0.03
σ_f	kPa	195 ± 43	220 ± 83	217 ± 77
W_f	kJ/m^3	42.2 ± 10.9	47.3 ± 21.9	46.8 ± 20.2
2 month old cheese				
E	kPa	111 ± 7	107 ± 2	105 ± 1
ε_f		0.52 ± 0.01	0.52 ± 0.01	0.53 ± 0.01
σ_f	kPa	134 ± 8	129 ± 3	128 ± 2
W_f	kJ/m^3	27.3 ± 1.6	26.4 ± 0.7	26.4 ± 0.6

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MASTITIS OF SHEEP - OVERVIEW OF RECENT LITERATURE

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Introduction

Mastitis is by definition, inflammation of the mammary gland. Inflammation is most commonly due to infection with a pathogen (intramammary infection or IMI) but may also be due to injury and less commonly due to allergy and neoplasm. If inflammation is present without a detectable IMI, it may be that the udder was injured, it is recovering from an infection that has self-cured, the infection is not due to a bacteria, or that the sampling and culturing technique was faulty. The literature varies considerable in what is considered to be pathogenic level of inflammation or significant infection with a pathogen. However, if IMI and / or presence of inflammation adversely affects the level of production or the quality of milk products, then it is significant to the sheep industry.

Clinical Picture

Quinlivan in 1968 developed a classification system of ovine clinical mastitis that can still be applied today: The four categories of small ruminant mastitis:

1. A small fibrotic lesion within the mammary tissue. Secretions were within normal range. Thought to be chronic in nature.
2. A more extensive fibrosis of the udder. Milk ranged from normal to purulent to cheesy or no milk due to teat occlusion with fibrous tissue. Again thought to be chronic.
3. Extensive swelling of the udder. Milk was found to be white, watery, serum-like or purulent. Udders could also be abscessed or ruptured due to previous gangrenous mastitis. Likely acute mastitis.
4. Peracute mastitis. Complete udder involvement with severe inflammation. Secretions were serum-like with varying amounts of fibrin and purulent material. Mammary lymph nodes were enlarged and body temperature generally elevated.

Cases of clinical mastitis can occur at any time of lactation or of the dry period. The highest incidence of severe clinical or peracute mastitis seems to be approximately 2 to 4 weeks post-lambing and again just post-weaning. There is little well documented evidence to support this impression, however. Mastitis that develops during the dry period or late lactation is often not noticed until the subsequent lambing as well as, in the case of non-dairy sheep, at shearing time.

Peracute Mastitis

In peracute mastitis, the clinical picture is generally dominated by depression, initial fever which may be followed by hypothermia, dehydration, anorexia and a swollen, discoloured gland.

Occasionally, lameness may be an important presenting sign. The skin of the affected gland may become reddish to purple and cold to the touch. The discolouration often extends beyond the gland to the belly wall and groin area. Secretions are serum-like and reddish and may contain gas. The animal is weak and may become recumbent. Case fatality rates due to the effects of toxaemia are high (30 to 40%) if left untreated. If it survives the initial disease, the gangrenous gland and surrounding tissue are sloughed over a period of weeks and the wound heals by secondary intention. Commonly, *Staphylococcus aureus* is cultured from these cases, as well as occasionally *Pasteurella* spp and coliforms. Clostridial organisms are sometimes demonstrated on gram stain, and may be present perhaps as secondary invaders of anoxic tissues.

Acute and Chronic Clinical Mastitis

Clinical mastitis is characterized by palpable changes in the consistency of the glandular tissue, i.e. hard, fibrotic, abscesses, gland size (either swollen or shrunken) and / or appearance of the milk, which may contain flakes, purulent material and be discoloured. In cases of sheep raised for meat production it may not be possible to tell the duration of the mastitis as the udder may only be examined at lambing or at weaning or if the animal is clinically ill.

Subclinical Mastitis

The definition of subclinical mastitis is an inflammation that is not readily detected clinically but adversely affects production. What constitutes subclinical mastitis in sheep in terms of level of somatic cell counts (SCC), California Mastitis Test (CMT) results and bacteriological culture results are not as clearly defined as for dairy cattle.

PREVALENCE OF MASTITIS

How common mastitis is in sheep is extremely variable. Studies of cull ewes at slaughter in Britain show a very high prevalence ranging from 13 to 50% , indicating that clinical mastitis is likely an important cause of culling of ewes in the UK. In American range flocks, prevalence of clinical mastitis ranges from 1 to 3%, but the prevalence is much higher if the udders are cultured as well (5 to 30%) or a positive SCC reaction is obtained (14 to 20%). Dairy sheep have been reported to have a prevalence of mastitis, as determined by a positive milk culture, of up to 35% of ewes and by positive SCC and milk culture of 4 to 17%.

ETIOLOGIC AGENTS

Staphylococcus aureus: is a very common isolate from cases of clinical sheep mastitis, up to 35% of clinical cases may be due to this bacteria.

***Pasteurella* spp**: *Pasteurella haemolytica* is a very important cause of peracute and clinical mastitis of sheep. Experimental infection of ewes' udders with as few as 10 colony forming units (cfu) of *P haemolytica* isolated from ovine and bovine pneumonic lesions or the nasal cavities of healthy lambs, produces clinical cases that resemble naturally occurring disease. These findings strongly support the theory that the source of udder infection with *P haemolytica* is from the nose and throats of nursing lambs.

Coliforms: Commonly isolated coliforms from sheep include *E. coli*, *Pseudomonas aeruginosa* and *Klebsiella pneumonia* as the most common, with *Salmonella* spp being more rarely isolated. *Pseudomonas aeruginosa* has been implicated in outbreaks of acute mastitis with high levels of mortality in lactating dairy sheep.

Environmental *Streptococcus* spp: In most sheep surveys, environmental streps are also rarely isolated with the exception of one UK survey which found it to be more common than coagulase negative staphylococcus.

Coagulase Negative *Staphylococcus.* (CN-S): There are many different species of CN-S which have variable capacity to cause mastitis in sheep, for example *S. chromogenes, S. hyicus, S. epidermidis, S. simulans*, and *S. warneri*. As a group they are the most common isolates from subclinical mastitis in ewes across all stages of lactation including at dry-off or weaning. Many of species of CN-S have been isolated from sheep and many are likely of very low pathogenicity, however some species have been shown to cause as severe a clinical mastitis as *S aureus.* However, not all C-NS isolates are associated with inflammation. One report found that 87% of 400 clinically normal milking ewes, had C-NS cultured as the primary isolate and also exhibited a low SCC of 200,000 cells/ ml of milk or less.

Contagious Agalactia: If the clinical picture of mastitis in a sheep flock includes arthritis and conjunctivitis with or without pneumonia, contagious agalactia should be considered as a diagnosis. The causative agent of this disease syndrome is *Mycoplasma agalactiae*. This agent is a common pathogen of sheep in the Mediterranean and Alpine areas of Europe, but (fortunately) is classified as an foreign disease agent to North America but it has been isolated from a case of mastitis in a California goat.

Maedi Visna: Maedi-visna virus (MV-v), also known as Ovine Progressive Pneumonia virus (OPP-v) has been implicated in chronic progressive pneumonia and weight loss as well as changes to the ovine mammary gland. Clinically at lambing, the udder is hard and appears to be full of milk but little milk can be expressed from the glands. "Hard bag" and decreased milk is far more prevalent in MV-v serologically positive flocks when compared to MV-v negative (63.1% vs 8.0% in one study). MV-v can be isolated from the mammary tissues and from the milk. Much higher levels of virus are found in colostrum at parturition than in milk suggesting that colostrum is an important method of infection of lambs.

Unfortunately this viral form of mastitis has a detrimental effect on ewe productivity. Some western US sheep producers reported culling as many as 10% of ewes each year due to "hard bag". Another study found that ELISA positive ewes were less productive in terms of lamb growth (8.5 lb per ewe lambing) although it isn't known if this difference is due to mastitis or other effects of the disease. However it has been found that there is a significant negative correlation between lamb weaning weight and the damage in ewes' udders due to MV-v. Lambs nursing the most affected ewes, weighed 5 kg less at weaning than lambs nursing unaffected ewes.

Miscellaneous Infections. *Serratia macrescens* has been associated with contaminated teat cups. Aspergillosis has also occurred involving the mammary gland subsequent to treatment with antibiotics prior to lambing.

DIAGNOSIS

Clinical Examination

As mentioned previously, there have been good attempts to try to categorize mastitis based on clinical examination of the gland and milk. The difficulty in meat or fibre sheep is in early recognition as the udder may only be routinely inspected at lambing, shearing or sometimes at weaning whereas infection in this type of animal may occur at any time but most often 2 to 3 weeks post parturient and after weaning. Some producers also have difficulty identifying mild changes to the udder during lactation and sometimes clinical changes only become evident during the dry period. In meat animals, it is important to identify chronic clinical mastitis prior to breeding so that ewes or does with compromised udders can be culled at that time.

Milk Culture

The protocol for obtaining milk samples is as follows:

- The sample vial should be labelled with date, farm ID, sheep ID and left or right or "C" for composite.
- The udder should be free of mud and manure.
- If the udder is dirty, it should be washed and dried with a clean towel.
- Hands should be washed with an antibacterial soap and dried with a clean towel.
- The fore-milk (milk that is sitting in the teat and cistern) should be stripped, ideally into a strip cup.
- Teat ends should be disinfected with alcohol-soaked cotton swabs until the swabs are clean.
- The far teat should be disinfected first and sampled last to avoid contamination.
- A sterile milk vial should be used.
- Take care not to touch the inside of the lid or vial nor have dirt fall into the vial when sampling.
- The container should be half-filled (minimum) and the cap replaced.
- The sample should be refrigerated and transported to the lab as soon as possible, or frozen if no somatic cell counts are to be done and the sample won't be transported for at least 24 hrs.

A positive culture is a pure culture with a minimum of 5 colony-forming-units (CFU's)

Somatic Cell Counts

Measuring somatic cell levels in the milk is a surrogate measure of mastitis, i.e. inflammation as a response to infection. Many factors other than infection will elevate SCC. What is most important is what levels of SCC are associated with decreased milk production.

Levels Indicating Significant Intramammary Infection (IMI):

In normal ewes' milk, 50 to 70% of the cells are macrophages with PMN's making up another 15-40%, lymphocytes 6-14% and other cells types (epithelial, eosinophils, etc.) making up less than 5%. Unlike goat SCC determination, it doesn't matter which type of counter is used (Coulter, Fossomatic, Direct Microscope), all are highly accurate for determining ovine SCC levels. There are various opinions as to an appropriate SCC cut-point to use for selecting which sheep should be sampled for culture. Suggested threshold values vary from a low of 100,000 SCC to a high of 1,000,000, with the most common level suggested being 1,000,000. However, using the same threshold value as for cattle (250,000) will ensure that almost all truly infected sheep are sampled and thus detected.

Factors other than IMI that affect SCC level:

Stage of Lactation. Sheep SCC levels will rise towards the end of lactation without IMI, but not to the same degree as in goats.

Lactation Number. First lacation Italian dairy sheep have a much lower mean SCC of 57,000 cells/ ml milk suggesting that this group of sheep may have a lower normal value than multiparous dairy ewes. However, lactation number accounts for only 6.6% of the variability in SCC, indicating that lactation number is not very important when interpreting SCC flock levels.

Time of Day. Milk samples taken in the morning milking had 7 to 22% higher SCC level than those taken in the evening.

Freezing and Storage. Freezing does not adversely affect SCC levels to the degree where they can't be interpreted, however it is still recommended to perform SCC determination on fresh milk samples for the most accurate determination. Storage greater than 7 days will cause significant decreases in SCC values (14%).

Indirect Measure of Inflammation

California Mastitis Test (CMT)

The CMT reagent reacts with DNA present in epithelial and inflammatory cells. More DNA = more gelling of the milk. In each well of the paddle, equal amounts of milk and CMT reagent are mixed (5 ml each) and immediately evaluated. Results are generally reports as:

- negative no gelling seen at all
- trace small amounts of gel noticed when the paddle is tipped
- 1+ significant amounts of gel seen when tipped
- 2+ when paddle is swirled, gel tends to clump in the middle
- 3+ mixture completely gelled and clumps in middle when swirled

There is fair to good correlation between CMT and SCC, remembering that CMT is a subjective test. With regards to predicting presence of IMI, CMT is better able to classify udders as not infected as opposed to correctly identifying infected glands. If CMT values of 1 + or higher are used to select animals for culture, then most infected sheep will be sampled.

RISK FACTORS FOR MASTITIS (IMI & ELEVATED SCC)

Teat & Udder Damage. The occurrence of IMI in non-dairy sheep has been hypothesized to be predisposed by the size of the lambs nursing the ewe. Two early investigators of mastitis speculated that because heavy lambs can be rough when nursing, this may lead to bruising and eventually invasion of *Pasteurella* spp organisms. There is little written about the relationship between visible udder or teat lesions and the risk of mastitis but one study did not find any association.

Udder Conformation. Poor udder conformation (supernumery teats, unconventional teats or poorly shaped udders) has a significant but minor effect on the frequency of IMI in sheep. An inconvenient approach for lambs to suckle the udders might explain the inefficient evacuation of milk from the glands and predisposition to IMI.

Number nursing. The number of lambs born has been found to have a positive correlation with incidence of IMI but only accounts for a small proportion of its total variability. This suggests that the damage from frequent and vigorous suckling of lambs may cause udder damage that predisposes ewes to IMI.

Age. Overall there was a significant positive association between the prevalence of IMI and ewe age .

Stage of Lactation. The prevalence of subclinical mastitis increased with later stages of lactation.

Milking Systems and Management. Sheep that are hand-milked tend to have a higher level of subclinical IMI, particularly with *S epidermidis*. High stocking density has an adverse effect on milk production and udder health of sheep. Sheep housed at 2 m^2/animal were healthier than those housed at higher densities.

Level of milk production. A study of dairy sheep at the farm level found that farms with higher milk production had significantly higher prevalence (48%) of subclinical mastitis compared to the lower production farms (22%). It was hypothesized that high producing ewes associated with high milk yield farms were more susceptible to IMI than low producing ewes associated with low milk yield farms.

Genetic resistance. The heritability of resistance to mastitis in sheep, i.e. how many years the ewes produced without coming down with mastitis, was estimated to be only 0.13. This suggests that selection for longevity to not developing mastitis might be valuable to include in some breeding programs, perhaps particularly in high incidence flocks but that genetic progress will likely be slow.

IMPACT OF MASTITIS ON PRODUCTIVITY

Mortality and Culling. Abattoir studies have shown that mastitis or abnormal udders are a common finding in culled ewes, leading to speculation that it is an important reason for culling. In one British study, 46% of all ewes culled from two large lowland flocks, were removed due to udder problems. In a Scottish study, in a three year survey on sheep losses mastitis accounted for 8.4% of all ewe deaths.

Milk Yield & Composition. IMI in ewes has a well-documented effect on milk production with reduced milk production of 20 to 37%. Lactose concentration is also decreased by IMI and elevated SCC, thus adversely affecting cheese production.

Offspring Performance and Mortality. An important cause of perinatal lamb mortality is starvation due to mismothering estimated at 34% in one study, of which an important component is due to mastitis or lack of milk. Infection also reduces average daily gain of up to 20 gm/day and up to 4 kg by weaning. Another study found that for an increase of 10 gm in the average daily gain of lambs, there was a decrease in IMI prevalence by 0.09%.

Treatment and Prevention

Use of Antimicrobial Drugs in Dairy Sheep. Very few drugs are approved for use in lactating dairy sheep in Canada and the USA as indicated by the Bureau of Veterinary Drugs (Canada) (http://hwcweb.hwc.ca/food-aliment/english/veterinary_drugs/index.html) and the Centre for Veterinary Medicine (USA) (http://dil.vetmed.vt.edu/FDA/NADA/NADA.cfm) although there is movement with respect to streamlining the approval process in the USA (http://www.fda.gov/cvm/fda/TOCs/minortoc.html). Veterinarians in North America are allowed to prescribe drugs in an off-label manner but they are then obligated to assure that residues do not enter the food chain. Sparse literature exists on appropriate withdrawal periods for the milk of dairy sheep. One study showed that a commercial lactating cow intramammary infusion product (Synulox LC which contains amoxycillin, clavulanate and prednisolone) required a withdrawal period of 112 hrs after its use in healthy goats, over twice recommended on the label for bovine. Studies using commercial dry cow products have found the occasional goat with antimicrobial residues at the subsequent kidding, even when the dry period was as long as 100 days. This contradicts earlier findings that suggest that the bovine withdrawal period is suitable for most intramammary infusion products. It is strongly recommended to consult FARAD (http://www.farad.org/) and to use antimicrobial detection tests for milk whenever antimicrobial drugs are used to treat dairy sheep, although false positives and negatives are possible when bovine kits are used in these species particularly if the milk is heated or a preservative is added.

Clinical Mastitis. There is very little scientifically supported information on the appropriate treatment of clinical mastitis in lactating sheep. If the sheep is systemically ill (e.g. fever, poor appetite), treatment should be systemic and supportive therapy (fluids, anti-inflammatory agents) as well systemic antibiotics should be used. A veterinarian should be contacted to provide the best care. Sheep with gangrenous mastitis are at grave risk of dying. No recently published information exists on treatment of dairy sheep with intramammary infusion products during lactation. In dairy cows, response to treatment with intramammary infusions during lactation is poor (*S. aureus*) to fair (CN-S and environmental infection).

Dry period therapy. The use of dry cow intramammary therapy in sheep has been well studied. There is evidence of improved cure rates and decreased level of new infections, although these levels vary considerably between studies. One study showed an improvement in milk production in the group that received procaine penicillin at weaning, although a 72 hr fast post-weaning produced a similar improvement. In a study conducted recently in Ontario, the prophylactic injection of tilmicosin one month prior to lambing (at the same time as the routine pre-lambing clostridial vaccination was done) has been shown to be of benefit in terms of a 43% reduction in udder abnormalities at weaning, and increased weaning weights of lambs (0.52 kg heavier than the control group). The decision to use a form of dry period antimicrobial therapy needs to be based on the prevalence of mastitis in the flock as well as ease of treatment (e.g. injection vs intramammary infusion) and withdrawal considerations.

Milking Management. The following recommendations are a summary of the current recommendations for the milking of sheep in Europe, USA and Argentina. More official recommendations for small ruminant milking machines will be forthcoming soon from the International Dairy Federation and will be published in Bulletin 354 (http://www.fil-idf.org/Welcome.html).

Vacuum Pump Capacity. Israel recommends 75 l / min per unit whereas Holland recommends values based on ISO Standard 5707 that takes into account effective reserve, air consumption of different components of the milking machine and air demand for cleaning, for example 650 l / min for 6 units; 1500 l/min for 24 units; and 1950 l/min for 30 units.

Pulsation Characteristics. Sheep are milked with a much faster pulsation rate than goats. The recommendations are 120-180 cycles/min and a pulsator ratio of 50%. 180 cycles/min was found to have the lowest SCC level in sheep.

Vacuum Levels. Sheep are milked at lower vacuum level at the claw than is recommended for cattle (32-40 kPa) but there are many differences depending on the milking system used. Recommendations vary from 33-36 kPa for lowline and bucket systems to 44-48 kPa for high line systems. 36 kPa has been recommended for dairy ewes in a system with the line 0.9 m above the platform.

Clusters. Dairy sheep producers tend to use cylindrical or hemispherical claws with a volume of between 60 and 200 cm^3. The claw should also have a shut-off valve.

Other. Automatic cluster removal systems are rarely used for sheep although automatic cleaning systems are popular in large dairies. Some producers use udder holders to straighten teat placement.

Maintenance. Routine maintenance of small ruminant milking machines is at best sporadic. Problems such as liner cracks, vacuum fluctuations due to equipment malfunction, accumulation of dirt and milk stone in the system, can all lead to poor milk quality and increased incidence of IMI.

Units per Person. This varies greatly depending on the design of the parlour. For platform type parlours, 2 to 4 units/person are recommended for single platform and 2 to 7 for double platform. Milk-out time for sheep is very short (1.5 to 3 min) and over-milking is likely a common feature in many automated dairies.

Teat Dips. Very little work has been published on the evaluation of teat dips in small ruminants. More work needs to be published to be able to determine the level of efficacy in preventing new cases of IMI in sheep.

Udder Preparation. Because milk out time is very short in small ruminants, udder preparation needs to be done quickly as well, to prevent the loss of the effect of the udder stimulation on let-down. If udders are washed in preparation for milking, it is very important that they are dried sufficiently to prevent environmental mastitis, in particular *P. aerginosa* mastitis, due to wet udders. One study compared goat herds that washed and dried udders with individual towels to herds that used a common wash towel and air dried the udder, and found that the latter practice was associated with higher rates of IMI. It may be better to only selectively wash dirty udders or reduce the number of units per milker to allow more time to properly dry udders, to help avoid this problem.

Other Treatments

The administration of vitamin E and selenium to dairy ewes during the dry period resulted in a reduction of SCC levels, particularly PMN's but not in the incidence of clinical mastitis or prevalence of IMI.

Zoonotic Considerations of Sheep Milk

The sale of raw milk is illegal in Ontario despite some people's view that it is a health food. It can contain many disease agents that can cause illness in humans. *S. aureus* is a commonly found bacteria in bulk tank milk with an average of 2 to 3 cfu / ml milk and has been isolated from up to 13% of cheese . Verocytotoxin-producing *E coli* H7:0157 has been isolated from raw sheep milk in Italy and is known to survive the processing system for soft Italian cheeses. *Listeria monocytogenes* has been isolated from store-bought semi-soft and soft sheep cheeses and from the milk, mammary lymph node and feces of sheep with subclinical mastitis. *Coxiella burnetii* is a common infection in sheep and outbreaks of human disease, in which people were hospitalized with severe illness, have been linked to the handling and consumption of raw goats' milk . Other pathogenic contaminants of milk include *Yersinia enterocolitica, Salmonella* sp, *Klebsiella* sp, *Streptococcus faecalis* and *E coli*.

Conclusions

In the last two decades, there has been a tremendous increase in knowledge of mastitis in sheep, particularly with respect to the infectious agents responsible for IMI and the interpretation of SCC levels. But if veterinarians are to effectively understand and control mastitis in sheep, the large gaps in our knowledge of the disease must continue to be addressed. With the increasing popularity in North America of dairy sheep milk products, better guidelines are required for the use of not just intramammary antimicrobial agents in the treatment of mastitis, but for all classes of drugs that might be beneficial for maintaining the health of this minor species that produce milk for human consumption.

Reproductive Technologies

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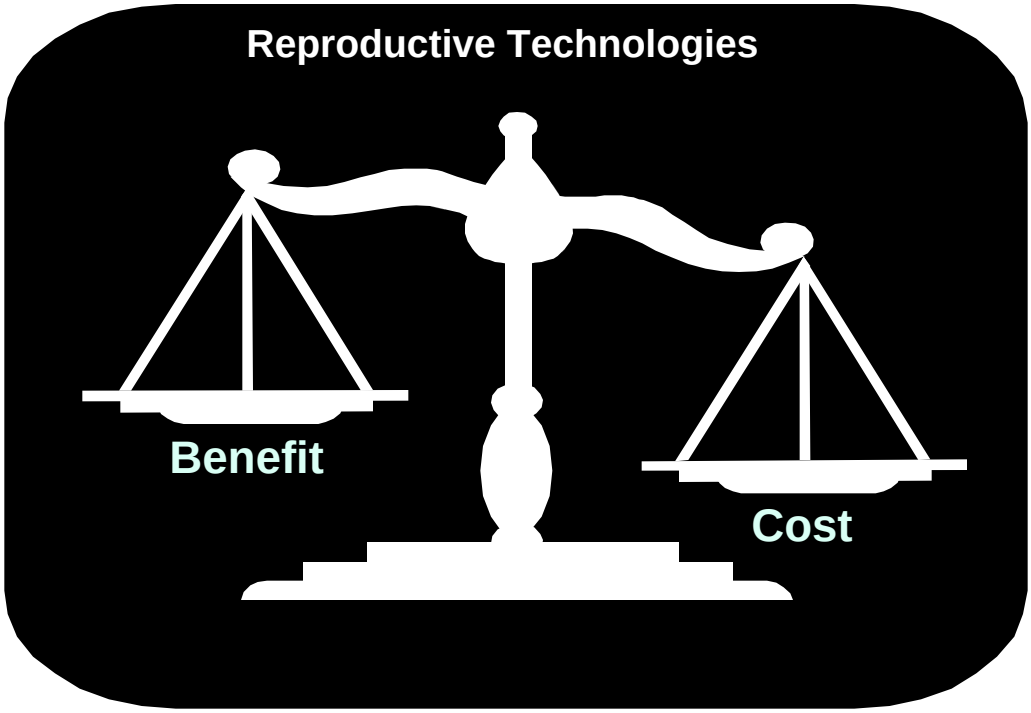
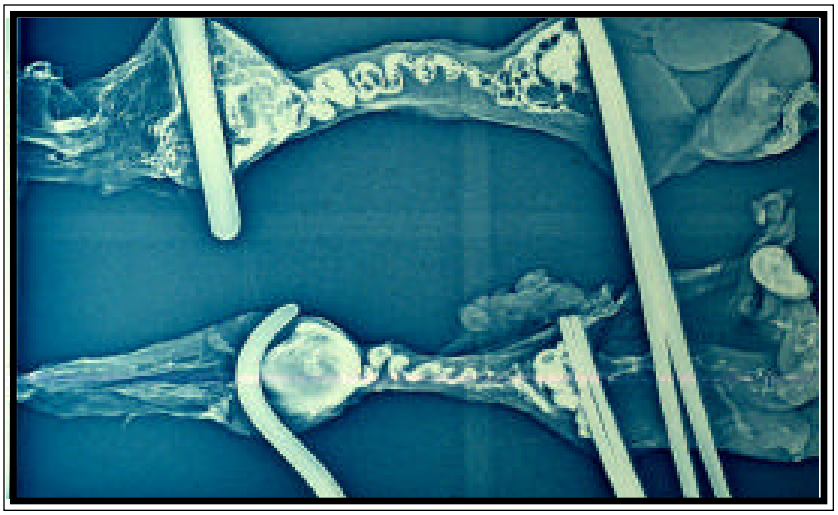


Most limiting factor in application of reproductive technologies to sheep production ?



Complex sheep cervix causes reproductive techniques to be developed that are different from cattle, are more difficult to apply, are less effective and more costly.

Still, in good programs, we achieve the same rates of success for AI and ET in sheep as the North American cattle industry.

But what is required costs relatively more per lamb born (as compared to the cost of technologies used in cattle).

So the reasons for using reproductive technologies, and the likely results, need to be very clear.

Within the sheep industry, no group could benefit more from these techniques than the dairy sector.

Benefits from Semen Programs

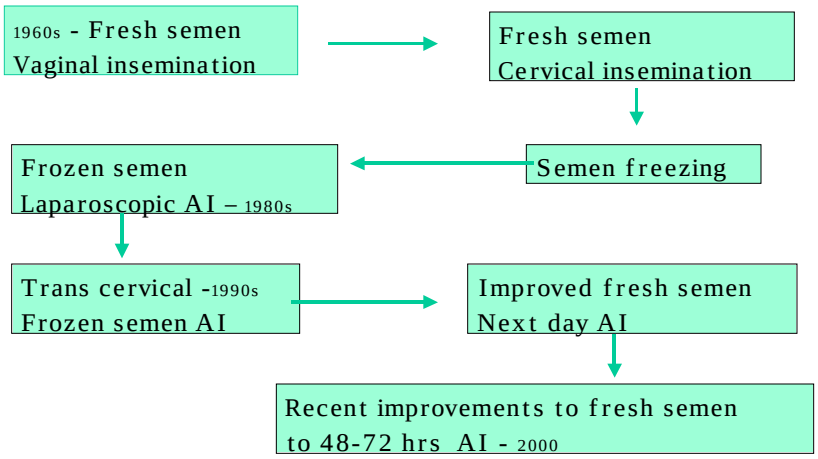
- Makes high value genetics available at low cost
- International movement of genetics
- High health genetics for closed flocks
- Increase return on high value genetics
- Increased breeding from selected rams
- Establishment of genetic improvement schemes (sire referencing)

Artificial Insemination

Fresh semen AI Programs

Frozen semen AI Programs

Evolution of AI for Sheep



Location of Insemination

- **Vagina**
  - easy
  - reduced success
  - only used with fresh semen
- **Cervix**
  - more difficult - sheep
  - success increases as penetration increases
  - use fresh and frozen semen
- **Uterus**
  - very difficult - sheep
  - best results
  - fresh and frozen semen

Fresh Semen Programs

GOOD	BAD
Potential for best results	Same-day AI
Simple insemination techniques	Restricts distances
	Requires high numbers of sperm cells
	Ram performance affects
	Semen quality varies

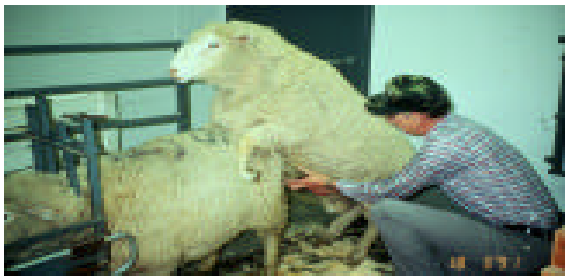
Fresh Semen AI Used Word-wide

Chinese Fine Wool Industry

French Dairy Sheep Industry

Fresh Semen AI

- Rams follow CFIA protocol for testing and quarantine in approved facility
- Semen collected and processed
- Semen cooled and shipped
- Domestic use only



Fresh Semen AI

- Producer deposits semen into vagina – 30%
- On the milking stand - natural heat AI ?
- Sire referencing – power of AI for genetic improvement

Future for Fresh Semen AI ?

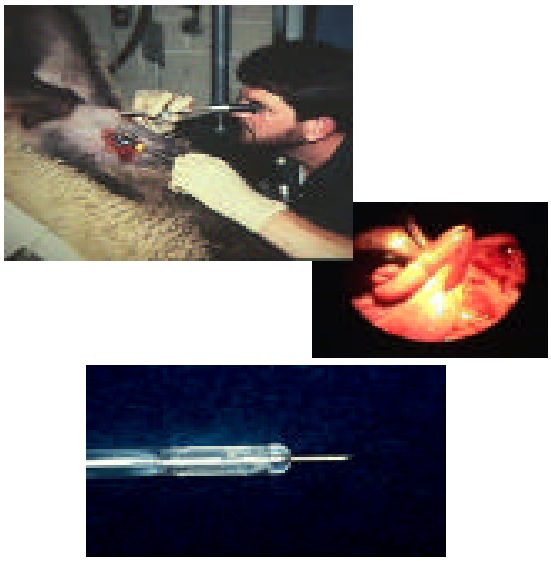
- Improvements in semen extenders to add life to 48 + hours
- Opens opportunities for new programs

Frozen Semen Programs

GOOD	BAD
Semen collected any season	Location of insemination critical
Only high quality semen used	Must be deposited into uterus for best results
Higher health product	Uterine insemination techniques difficult and costly
Shipment – international	
One collection breeds many ewes	

Laparoscopic AI

- best for frozen semen
- low semen dose
- success 60% +
- (range 30-90%)
- expensive
- restricted to DVMs
- surgical risk



Transcervical AI

Guelph System for TAI

Low cost

Training needed

Inconsistent results

Gourley Scope

Expensive

Training Needed

Results?

Sperm Membrane Changes

Time in female tract →		
DECAPACITATED	CAPACITATED	ACROSOME REACTED
NOT FERTILE	FERTILE	NOT FERTILE

←

Adding selected seminal plasma to frozen semen (Maxwell and Evans)

Reverses change and extends life and fertility

Typical Results from AI

	Fresh	Frozen
Vaginal	40-50 %	10-20 %
Cervical	40-65%	25%
Transcervical (those penetrated)	60-80 %	40-70 %
Laparoscopic	70-90%	50-80%

Factors Affecting Success of AI

- Fresh or frozen semen
- Method of freezing
- Individual ram
- Location of insemination
- Semen dose
- Semen handling
- Insemination frequency
- Teaser rams
- Synchronization program vs natural
- Timing of insemination
- Season
- Ewe stress - before and after
- Body condition
- Diet - plant estrogens
- Diet - high protein diets
- Period since last lambing
- Lactation

Effect of Teasers in AI Programs

- Identify responding animals
- Improve timing of first estrus
- Shorten time to ovulation – adjust program
- Improve sperm transport – oxytocin, PG ?
- Replace with GnRH?

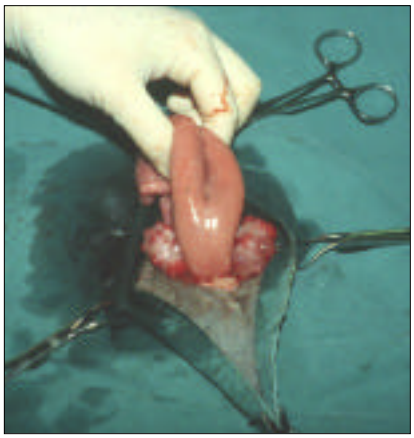
Embryo Programs

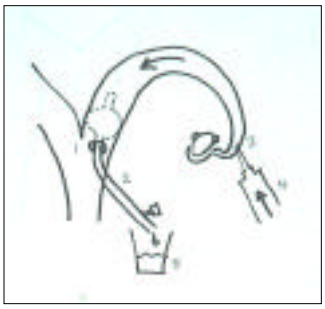
- Highest health standards – clean flocks
- Obtain complete genetics (sire and dam)
- Increase offspring from superior females
- Increase return from superior females
- Sales of genetics

But, ET in sheep

- Requires surgical intervention
- Risk involved – minimal
- Is costly – generally $75- 100 per good quality embryo produced

Surgical Embryo Recovery





Problems with ET

Superovulation
- not all animals respond
- response highly variable

Embryo fertilization
- young donors, young rams
- over-stimulation

Premature failure of CLs

Surgical Risk

Expected Success per ET Donor

Outcome	Average	Range
Ovulations	10	0->50
Embryos	7.5	0-10
Unfertilized	2.5	0-10
Transferable	6	0-10
Lambs fresh	4	0-32
Lambs frozen	3	0-?

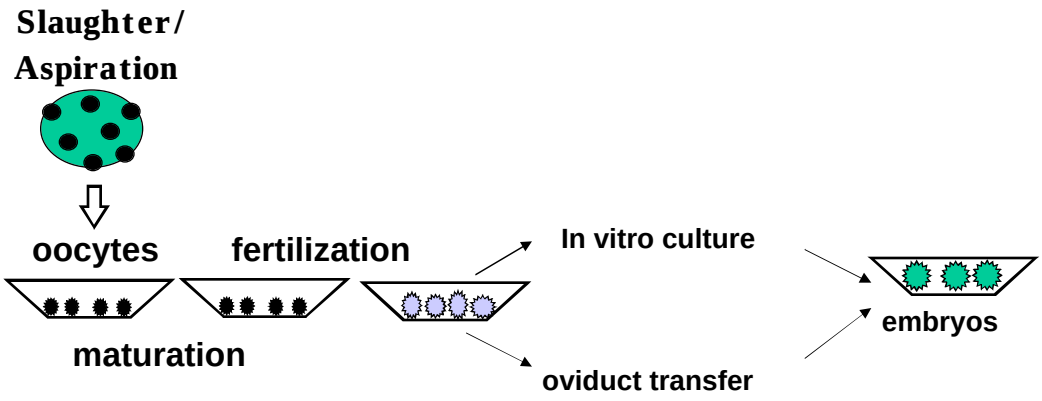
Factors Affecting Success of DONOR

- age
- breed
- season
- diet
- body condition
- health
- superovulation program – stage of follicular wave
- Stress – premature luteal failure
- breeding management

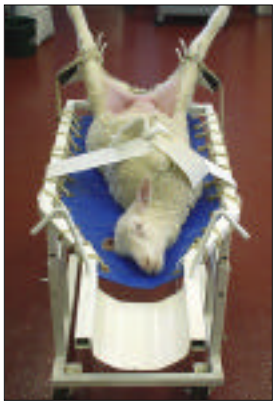
In vitro Embryo Production

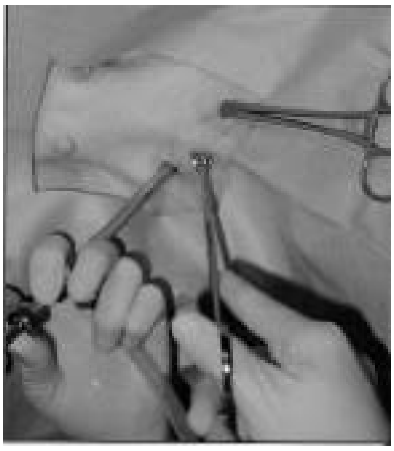
- Mass production of low cost embryos
- Production from mature and juvenile donors
- Production from slaughter animals ovaries
- Production from aged or diseased animals

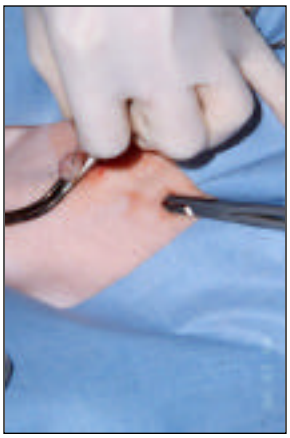
In vitro embryo production

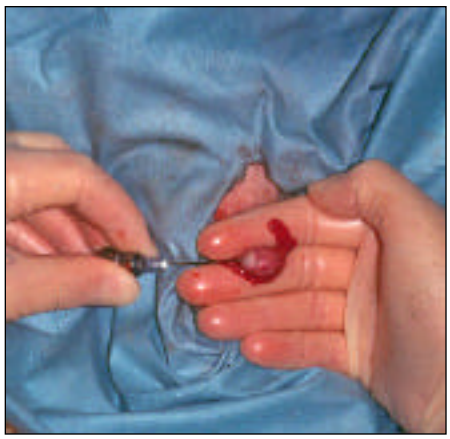


Mature or Juvenile Ewe
Ovarian Aspiration



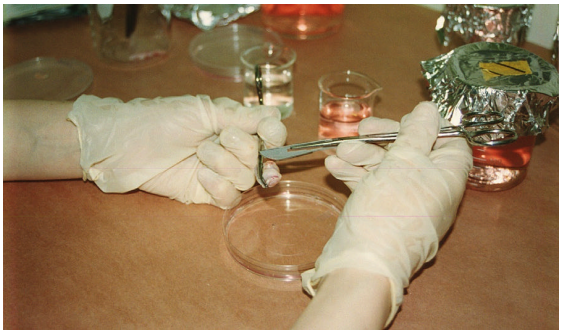




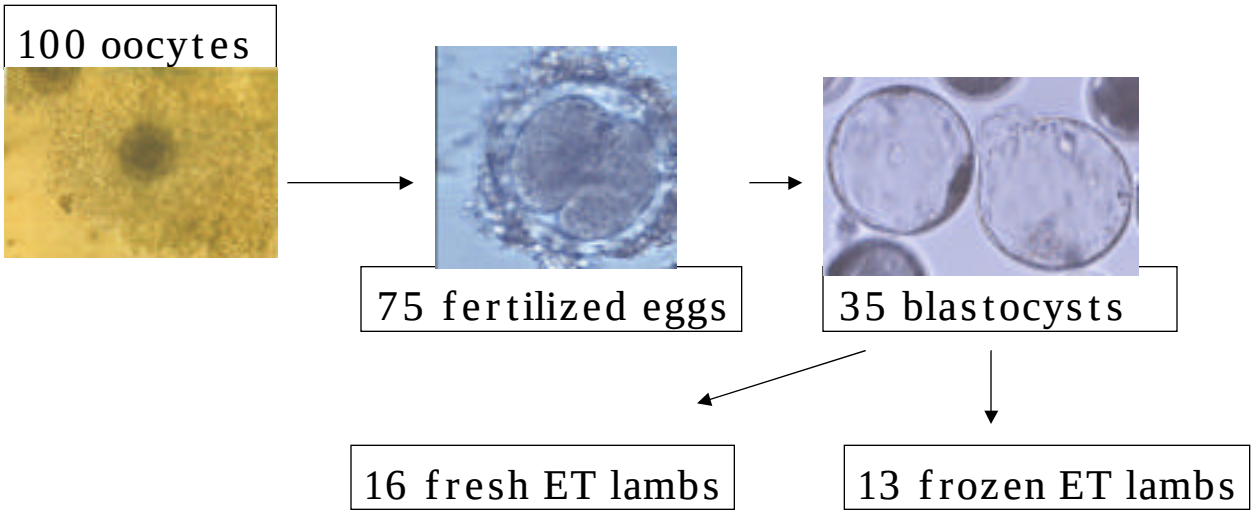


Slaughter Oocyte recovery

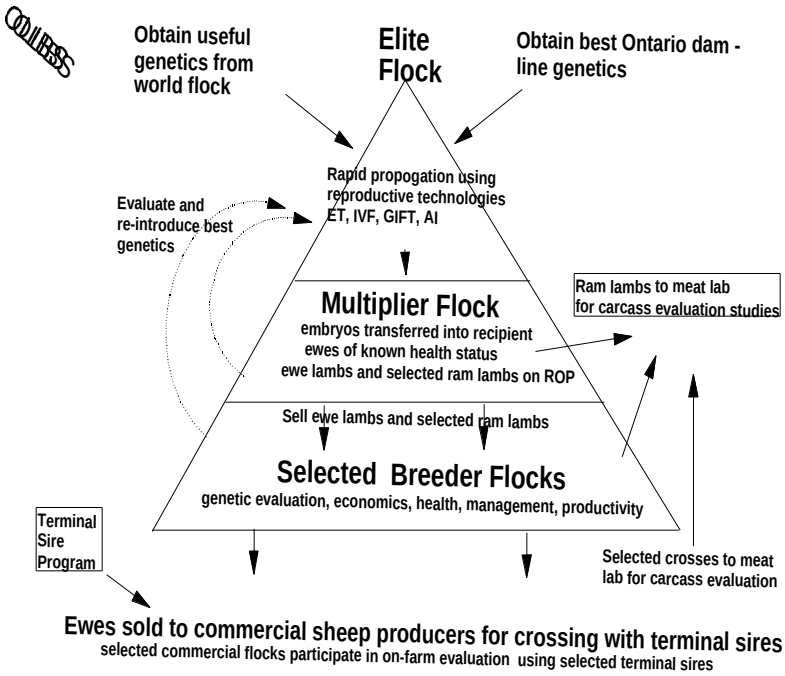
- Ovaries recovered at slaughter
- Taken to lab
- Unfertilized eggs (oocytes) removed
- Matured and fertilized
- Grown to 6days
- Transferred or frozen



IVEP Embryo production



The OLIBS Model



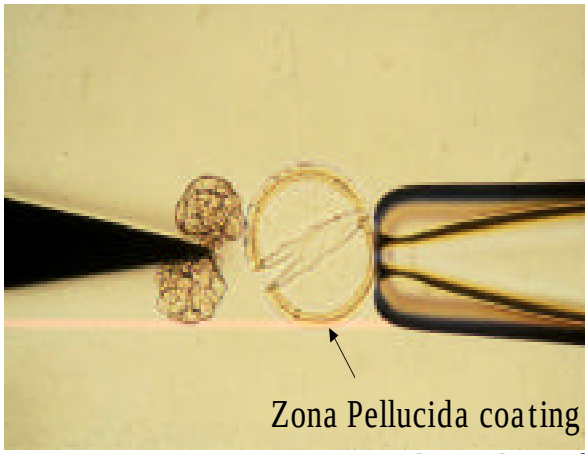
Disease Transmission from AI or ET

	Semen	Embryos
Disease risk	Medium to Low risk	Clean – no risk if managed correctly
Management	Isolate Test Correct handling Antibiotics	Isolate Test Wash embryos

Disease

SEMEN	EMBRYOS
Caseous lymphadenitis	**NO - confirmed**
Johnes	Bluetonge
Bluetongue	Maedi visna
Brucella ovis	Chlamydia
Maedi visna	Pulmonary adenomatosis
Tuberculosis	**YES/NO ?**
Leptospirosis	Scrapie
Mycoplasmas/ ureaplasmas	**RISK ?**
	Brucella ovis

Embryos and Disease Control



Zona Pellucida coating protects the embryo from disease

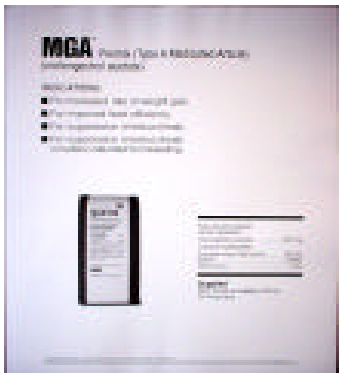
Washing removes all

Estrous Synchronization for AI or ET

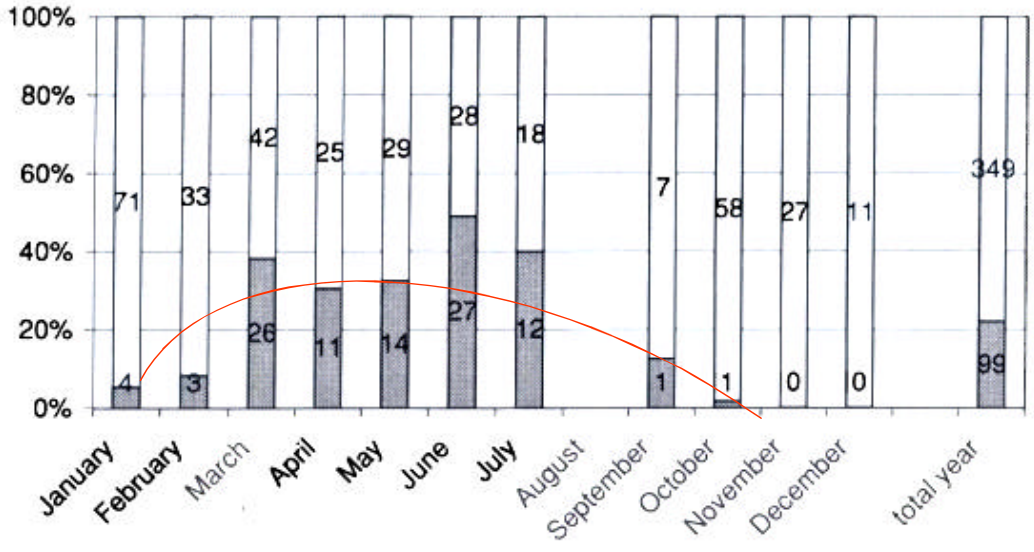
Progestagens plus PMSG

Melengesterol Acetate

- Oral
- Works as any other progestagen
- .125 mg BID 14 days
- Gonadotropin 6-8 hr after last feed during transition and anestrus
- Advantages
  - Cost
  - no drop out
  - no injury
  - reduced handling
- Milk withdrawl



Rejection rate in Rideau ET recipients by month



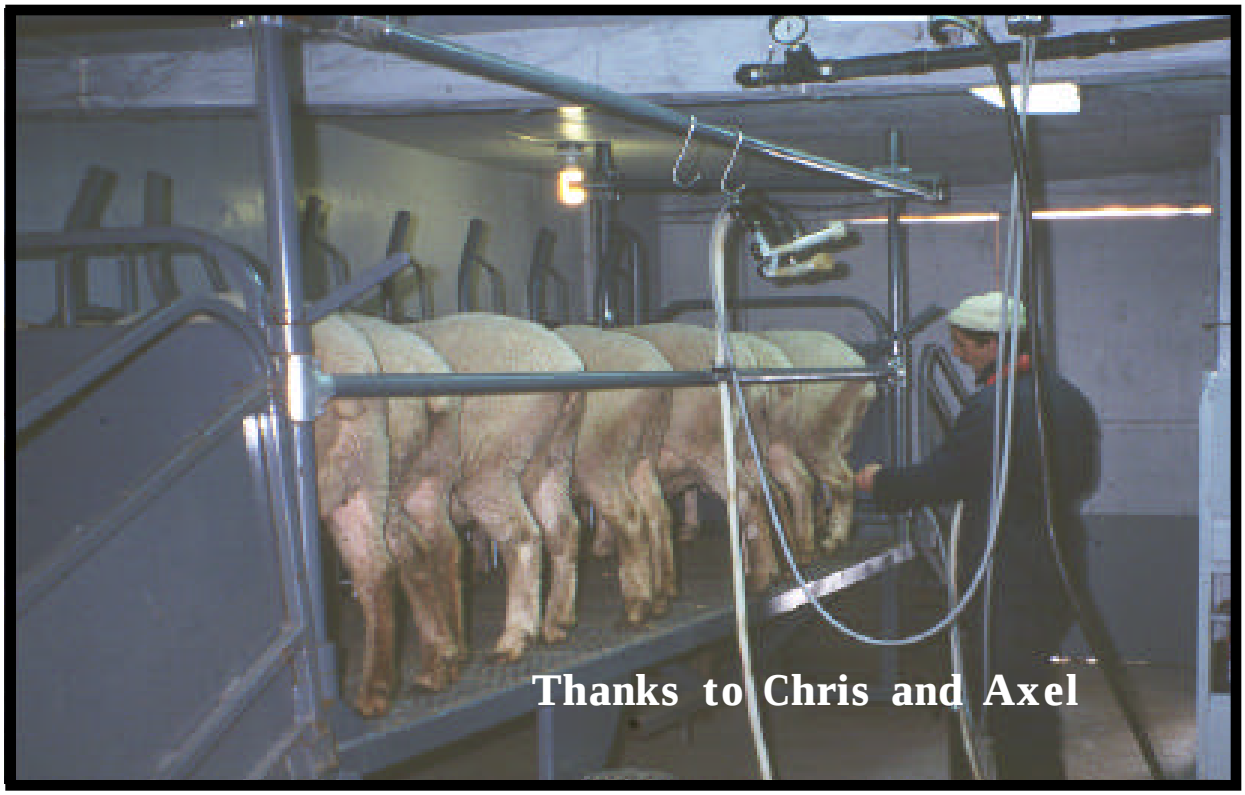
Rejects (no CLs)

Accepted

Gonadotropin Use/dose ?

Light Control Programs

- Interpretation of light/dark = melatonin
- System responds to decreasing day length(more melatonin per day) (short days – long nights)
- But, first needs long days to become sensitive to the reducing day length
- After period of months system becomes refractory to that stimulus



Thanks to Chris and Axel

PHYSIOLOGIC FACTORS THAT MODIFY THE EFFICIENCY OF MACHINE MILKING IN DAIRY EWES

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Introduction

The North American dairy sheep industry is young, yet there appears to be bone fide interest in its viability- not only from the side of the sheep producer, but also from the side of the consumer. Significant genetic progress has occurred in dairy sheep during the past decade. Importation of the East Friesian breed has improved milk yields, milk composition, lactation lengths, and lamb growth when crossed with domestic non-dairy breeds (Thomas et al., 2000). However, due to a large variation in the way that ewes give their milk to the machine, further selection on milk yield alone may not be adequate. Additionally, it is predicted that genetic selection programs based totally on yield will lead to undesirable changes in teat placement and udder morphology (Fernández et al., 1997). It has been proposed that machine-milking efficiency may be a more accurate assessment of an individual ewe and should be considered in future genetic selection programs. Machine milking efficiency can be defined as the recuperation of the maximum amount of milk that is rich in total solids in the shortest amount of time possible with the least amount of physical intervention of the milker, and without any deleterious effects on udder or ewe health. This is to say that once the teat cups have been placed on the dairy ewe, the milking machine should be able to quickly remove all of the secreted milk that has accumulated in the udder. Failure of the machine to remove all of the milk on its own in a timely manner increases financial loss due to less commercial milk yield, increases in parlor throughput time, and potentially more udder health problems due to over-milking. Moreover, when large amounts of milk are not removed at milking and are left behind in the udder, lactation lengths and total commercial milk yield are reduced (Labussière et al., 1974a). Finally, machine milking efficiency can also be influenced by other physiological events that occur in early lactation, as well as during the interval between milkings.

For the past year, the University of Wisconsin-Madison dairy sheep research team has been collaborating with a French lactation physiology laboratory (Institut National de la Recherche Agronomique, UMR Production du Lait, Rennes, France). This paper will present some preliminary results of work done both at the Spooner Agricultural Research Station with our flock of East Friesian crossbred dairy ewes, and in France with the Lacaune breed. The objectives of this paper are to discuss the physiologic parameters which can be modified during early lactation in response to different weaning systems, as well as the physiologic parameters that allow the ewe to better store milk between milkings, and that permit the ewe to efficiently release milk at the time of milking.

I. Physiologic Factors Which are Important During the First 30 Days of Lactation

In dairy ewes, 25% of the total milk yield for the entire lactation is produced during the first month (Folman et al., 1966; Ricordeau and Denamur, 1962). This is primarily due to the fact that milk production is increasing from parturition to about 24 days in lactation when peak milk production is attained. To complicate matters, ruminants have the highest probability of mastitis during the first 45 days post-partum (Hamann, 2000). Therefore, early lactation management of the dairy ewe is critical to overall financial returns and udder health. A wide variety of weaning systems exist for dairy ewes that allow for either optimization of lamb growth, commercial milk production, or a combination of the two (Folman et al., 1966; Gargouri et al., 1993; Papachristoforou, 1990). The weaning system that favors lamb growth is the 30-day exclusive suckling system (DY30) where ewes are not machine milked during the first month of lactation and the lambs are weaned at about one month of age. The weaning system that favors maximum commercial milk yield is the day one system (DY1) where lambs are removed from their dams within 24 hours after birth and raised on artificial milk replacer; the ewes are machine milked twice daily for the entire lactation. Finally, a weaning system that attempts to find a compromise between acceptable lamb growth and commercial milk production is the mixed system (MIX). The MIX system allows for lambs to suckle their dams for 8 to 12 hours per day, after which they are separated for the night, and the ewes are machine milked the following morning (McKusick et al., 2000a). For the past three years, one of the primary research goals at the Spooner Agricultural Research Station has been to evaluate these three weaning systems in terms of commercial milk yield, milk quality, and lamb growth. More recently, we have been trying to characterize the physiologic changes in the udder during early lactation which explain the differences in milk yield and milk quality between weaning systems in early lactation and which also might better prepare the ewe for machine milking later in lactation.

Maximum milk production potential. Because dairy animals have been genetically selected for high milk production potential, milk production during early lactation often exceeds what is required to raise two or even three offspring (Bocquier et al., 1999). This surplus of milk, if not removed from the udder, causes a gradual cessation of milk secretion and greatly reduces the ewe's capacity to maintain her maximum milk production potential. There are two important physiological reasons for the reduction in milk yield. The first reason is due simply to the fact that as milk accumulates in the udder, the pressure exerted on the milk secretion cells increases. Eventually this pressure will reach high enough levels to cause either damage or "discomfort" to the milk secretion cells, and milk secretion will be slowed if not stopped (Labussière et al., 1978). In addition to the effects of pressure on these cells, is the presence of a hormone in milk called feedback inhibitor of lactation (FIL). This hormone has been studied extensively in goats and has been shown to directly inhibit milk secretion in a dose-dependent manner (Wilde et al., 1987). This is to say that as more milk accumulates in the udder, especially around the secretory cells, the amount of FIL increases and milk secretion is slowed. Therefore, for a dairy ewe to maintain her maximum milk production potential, frequent and complete evacuation of the udder is imperative, especially in early lactation when milk production is highest.

The three weaning systems studied at Spooner have distinctly different effects on milk production potential during early lactation. The weaning system most appropriate in terms of maintaining maximum milk production potential during the first 30 days of lactation is the MIX

system. This system allows for frequent udder evacuation during the day (lamb suckling), and one large evacuation every morning (machine milking). Because the MIX system permits the sale of at least some commercial milk during the first 30 days of lactation and requires no artificial rearing of the lambs, it is a more financially advantageous system compared to both traditional 30-day weaning and the DY1 system (McKusick et al., 2000a). The DY1 system is probably the least efficient in maintaining maximum milk production potential due to the fact that the udder is being emptied only twice per day. We have recently shown that when milking frequency is increased to three times per day for DY1 ewes, we see a significant increase in commercial milk yield in certain populations of ewes (Berger et al., 2000). This confirms our hypothesis that ewes which are selected for high milk production do not meet their maximal production potential when they are just machine milked twice per day in early lactation. An economic analysis will need to be performed to determine if three times a day milking is financially advantageous compared to twice daily milking or to the MIX system. The traditional DY30 system relies uniquely on the lamb to maintain milk production during early lactation. It is only when milk requirements of the lambs are great that maximal milk production potential is met in DY30 ewes. Thus, the DY30 system is not appropriate for ewes that rear only single lambs. In some parts of the world where the DY30 system is required by law (such as the Roquefort region in France), many dairy sheep producers are obliged to milk their ewes once per day and discard the milk because the ewes' milk production exceeds what twin or even triplet lambs can suckle (Autran, P., personal communication). One can appreciate that the DY30 system is the least financially attractive in terms of commercial milk sales. Although we see marked differences between the three weaning systems during the first 30 days of lactation in terms of milk production potential, these differences become non-existent after about 45 days in lactation (McKusick et al., 2000a). This is to say that DY1, DY30, and MIX ewes have similar milk yield and lactation lengths from 45 days onward. Other management factors, such as milking practices, become more important in allowing ewes to maintain their maximum milk production potential following weaning (when twice daily milking has been established for all ewes). These factors are discussed later in this paper.

Milk composition and milk quality. In addition to the significant differences in milk production observed for the three weaning systems, there are also marked differences in milk fat content and somatic cell count during the first 30 days of lactation. Compared to DY1 ewes, the commercial milk (milk extracted with the machine) of MIX ewes has significantly less milk fat content for as long as the ewes remain in contact with their lambs. The reasons for this are not yet completely clear. We know that this phenomenon is not due to nutritional insufficiencies because we have demonstrated that when MIX ewes receive daily fat supplements there are no increase in their milk fat content, however, there was a significant increase in fat content of DY1 ewe milk when they received the fat supplements (McKusick et al., 1999a). In France, it has been demonstrated that MIX ewes have much smaller releases of oxytocin during machine milking compared to during suckling during early lactation. After weaning, these ewes eventually have normal oxytocin release when machine milked (Marnet and Negrão, 2000). Oxytocin is a hormone released from the brain of mammals as a result of teat and udder stimulation, usually at the time of suckling (Ely and Peterson, 1941). Oxytocin is an integral part of "milk ejection": the contraction of the alveoli (groups of milk secreting cells) within the udder which causes secreted milk to flow down a system of ducts and canals into the storage part of the udder known as the cistern. During machine milking, if there is no release of oxytocin, secreted milk remains in the area of the alveoli along with large quantities of milk fat

(Labussière, 1969). This results in an incomplete evacuation of the udder as well as a less rich commercial milk. Many researchers feel that the low fat content of MIX ewes' commercial milk is simply due to a failure of milk ejection. However, we have recently shown that injections of oxytocin during machine milking of MIX ewes only increases milk fat content to 3/4 that of normal DY1 ewe milk fat content. Furthermore, when DY1 ewes are given a drug that blocks oxytocin and inhibits milk ejection, milk fat content is reduced to the same 3/4 level of normal DY1 milk fat content. This experiment will be repeated to verify these findings, however our preliminary conclusion is that the low fat content of MIX ewe commercial milk is not entirely due to a failure of the milk ejection reflex and might be due to stress and/or other factors which further disrupts milk ejection, fat storage and/or fat synthesis in the udder.

Somatic cell count (SCC) is often used in monitoring udder health in dairy animals. Although the probability of infection is higher as the number of SCC increases (Billon and Decremoux, 1998), it should be noted that SCC is not a direct indicator of infection, but moreover of inflammation. Weaning systems can have marked effects on SCC in dairy ewes. Our observations at Spooner indicate that MIX ewes maintain significantly lower SCC during the first 30 days of lactation compared to DY1 ewes. We feel that this is related again to more frequent udder evacuation during the time when milk production is the highest in lactation. When the udder is heavily distended and under high intramammary pressures, the small junctions between cells in the mammary gland begin to open which permit an influx of SCC (white blood cells and other cell types) into the mammary gland (Stelwagen et al., 1997). Furthermore, if the mammary gland does get infected (for example via entry of bacteria through the teat canal), more frequent evacuation of the udder decreases the chances of those bacteria from colonizing the udder and establishing an infection. Thus, it is to be expected that a weaning system that provides a period of partial or exclusive suckling would have less SCC and less incidence of mastitis compared to ewes that are exclusively machine milked immediately following parturition. While our observations at Spooner demonstrated this to be true for a partial suckling system (MIX system) during early and mid-lactation, we found contradictory results for the exclusive suckling system (DY30 system). DY30 ewes tend to have significantly higher SCC compared to both MIX and DY1 ewes around the time of weaning and during mid-lactation. In another experiment conducted in France where the DY1 and DY30 systems were compared within the same ewe (a half udder comparison that permitted suckling on one side of the udder only), we again found that the DY30 udder halves had consistently and significantly higher SCC, this time during a three-week suckling period and again during the three weeks following weaning. Because bacteriological analyses were not performed in the experiments, it is difficult to comment on whether or not any of the weaning systems are beneficial in reducing the mastitis incidence in dairy ewes. However, if in fact DY30 ewes were able to maintain high SCC without any increase in infection rate, we might conclude that suckling may actually be beneficial in the recruitment of white blood cells during early lactation which could be responsible in preventing mastitis. This hypothesis will be one of our primary research objectives for the next lactation season.

Local changes at the level of the teat. The idea of suckling prior to machine milking is currently receiving more and more discussion in the literature, not only for dairy ewes but also for dairy cows. Researchers have already reported lower mastitis incidence in cattle that are suckled for a brief period prior to machine milking (Krohn, 1999). In France, we hypothesized that suckling may actually induce some physical changes at the level of the teat end, teat canal, or teat cistern which might facilitate a lower incidence of mastitis in suckled animals and thus would be beneficial to machine milking later in lactation (see McKusick et al., 2000b). Using a half-udder comparison technique whereby one udder-half of a ewe was machine milked twice daily (DY1) and the other udder-half was exclusively suckled (DY30) for the first 3 weeks of lactation, we demonstrated significant local modification of the suckled teat and udder-half. The DY30 teat ends were less congested in response to suckling as well as during machine milking following weaning. We hypothesize that suckling was able to beneficially modify the way the teat responds to machine milking following weaning. Researchers have reported that increases in congestion of the teat during machine milking are one of the predisposing factors to new intramammary infection in cattle (Hamann and Stanitzke, 1990). Additionally, we demonstrated that the teat end itself was tougher and more durable when suckled during early lactation compared to teat ends that are only machine milked. One of the more important barriers to infection within the teat is the teat sphincter. This is a muscular layer of tissue that opens in response to suckling or machine milking when a vacuum is applied to the teat end. If the teat sphincter is naturally too relaxed, the entry of bacteria into the mammary gland is facilitated. If the sphincter is too tight, milk flow might be impeded during machine milking. Thus there exists a delicate balance in teat sphincter tightness or "resistance". In the half-udder experiment, we observed that although the suckled teat ends had no change in teat-sphincter resistance, they were able to achieve significantly higher milk flow rates compared to the machine-milked teat ends. Although the above experimental findings remain to be confirmed in partially suckled ewes (MIX system) and in conjunction with bacteriological analyses, we conclude that suckling does have some beneficial effects at the level of the teat in terms of physically preparing itself for machine milking.

II. Physiologic Factors Which are Important Between Milkings

One can think about the inside of the udder as having two compartments. One compartment is responsible for producing and secreting milk (the alveoli), and the other compartment is responsible for storing milk (the cistern). In ewes, there exists a dynamic relationship between these two compartments that greatly affects milk yield. Immediately following evacuation of the udder, either by suckling or the machine, the pressure within the udder (intramammary pressure) decreases significantly (Labussière, 1993). The removal of milk combined with the drop in pressure allows new secreted milk to reestablish normal accumulation in the udder. The alveoli begin to stretch as they accumulate newly secreted milk, and eventually they spontaneously contract in response to the tension within the alveoli. Milk then flows into a long system of small ducts, eventually traveling through a system of larger ducts, to finally arrive in the cistern. The whole process is repeated. Eventually, because of the large volume of milk that accumulates in the cistern, the intramammary pressure of the cistern becomes great enough to slow down the flow of milk from the small and large ducts. Milk begins to over-distend the alveoli because it can no longer be expelled into the small ducts. In response to the increased pressure within the alveoli, the neighboring secretory cells begin to shut down the production of milk. Additionally,

the feedback inhibitor of lactation hormone (FIL) concentration increases when there are large volumes of milk that stay within the alveoli. This hormone essentially tells the secretory cells that there is too much milk being produced and that milk synthesis should be slowed down. Thus when the interval between milkings (or sucklings) surpasses approximately16 hours, and cisternal milk storage capacity has been reached, milk secretion may be hampered because of milk accumulation within the alveoli (Davis et al., 1998). Prolonged periods of milk stasis in the udder, particularly at dryoff, is one of the factors that initiates apoptosis, or "programmed cell death.

In order to maintain maximum milk production potential following peak milk production and weaning, optimal milking frequency is actually determined by the ewe's ability to store milk between milkings. As it turns out, the ewe can store between 40 and 60% of her total secreted milk in the cistern; the rest being stored in the ducts and alveoli, further up in the mammary gland (Marnet, 1998). For a given level of milk production, the more milk the ewe is able to store in the cistern, the less often she would have to be milked. Provided that the ewe has correct udder morphology, these ewes would be in fact more efficient milkers. In fact, in France during the early 1970's, a fair amount of research was conducted to determine if one could omit the Sunday evening milking in order for the family to enjoy a long Sunday afternoon around the dinner table (Labussière et al., 1974a). Unfortunately, with the given genetic potential of dairy ewes at that time, there were too great of losses in milk yield for it to be financially viable. There was however, some evidence that the Sarda breed in Italy with its capacious cisterns could support the omission of one weekly milking (Casu and Labussière, 1972). Thirty years later, there is renewed interest in the ability of lactating animals to support the omission of one or more weekly milkings, or the omission of part of a milking (i.e. machine stripping). By the same token, ewes which are better adept at storing milk between milkings might also better support the abrupt switch in udder evacuation frequency (suckling to machine milking) at weaning. The capacity to store milk can be discussed as a function of two criteria: the ewe's udder anatomy and morphology, and the secondly, the ability of the ewe's udder to stretch between milkings. The latter criteria is referred to as compliance.

Udder anatomy and morphology. The size, shape, and form of the udder are determined genetically (Fernández et al., 1997), and play an important role in the storage of milk between milkings and the recuperation of milk at the time of milking (Labussière, 1988). We have studied our East Friesian crossbred ewes at Spooner for two lactations and find a strong positive correlation between udder height, udder circumference and commercial milk yield (McKusick et al., 1999b) which is in agreement with many reports on other European dairy breeds (Labussière, 1988). This is to say that, in general, ewes with larger udders produce more milk than ewes with smaller udders. We have also found a positive correlation between milk yield and the height of the cistern. Additionally, we demonstrated that ewe with taller cisterns (i.e. more udder volume below the teat canal exit) take significantly longer to milk than ewes with shorter cisterns. It is not surprising that ewes with more cisternal capacity produce more milk. These ewes have more storage volume which is one of the components which keeps intramammary pressures low and more easily avoids over distention of the alveoli between milkings. However, during milking, the udders of these ewes often have to be lifted or massaged during milking to allow all the milk to drain from the udder. This is a process which takes time, and therefore is a great detriment to the efficiency of machine milking. Recently, we have also found positive correlations between

cistern height and the amount of milk obtained at stripping and the time it takes to recuperate this milk (McKusick et al., 2000c). In Israel, because of the enormous milk production and large cisterns in Awassi and Assaf dairy ewes, a hook has been invented which supports the udder at the intramammary groove during milking (Sagi, 1978). Alternatively, and perhaps more realistically for American dairy sheep producers, genetic selection programs need to be implemented which allow for increased milk production without concurrent deterioration of udder morphology. This is not an easy task because as soon as milk production is increased, more physical demands are placed on the suspensory apparatus of the udder. The suspensory apparatus consists of a large sheet of ligaments that descend from the pelvis and divides the udder into two halves, forming the intramammary groove. There are also lateral ligaments which descend from the abdominal musculature to the sides of the udder. When milk production increases (or with age), the middle suspensory ligament becomes stretched and is no longer able to adequately support the weight of the milk. The result is a contraction of the lateral suspensory ligaments, and a horizontal deviation of the teats. Some researchers feel that the depth of the intramammary groove might be a good indication of the strength of the middle suspensory ligament: deeper grooves imply stronger ligaments (Barillet, 1999, personal communication). If this were to be the case, it would be desirable to select ewes with profound intramammary grooves. In any case, it is of paramount importance for producers to consider udder morphology as an important criterion when selecting the flock for the following lactation.

External measurements of the teat, udder, and cistern are cumbersome (de la Fuente et al., 1996). Furthermore, external measurements of the cistern are not reliable indications of actual internal cistern size, but are moreover a function of teat placement (Fernández et al., 1995). Therefore, many researchers are now using a linear evaluation system for udder traits which will be the basis for future genetic selection programs (de la Fuente et al., 1996; Marie et al., 1999). In Spain and France, subjective scores from 1 to 9 are made by trained technicians in the milking parlor just prior to milking (Marie et al., 1999). Up to five criteria are evaluated, however, at Spooner only three of the five were performed: teat placement, depth of the intramammary groove, and udder height. Both the left and right udder halves are evaluated for teat placement; only one score is assigned to the udder for depth of the intramammary groove and udder height. Teats that are completely vertical are assigned a score of 9. Teats that are at a 45° angle are assigned a score of 5, and teats that are completely horizontal are assigned a score of 1. Udders with no intramammary groove are assigned a score of 9, with a moderate intramammary groove are assigned a score of 5, and with a very strong demarcation between udder halves are assigned a score of 9. With respect to udder height, udders that hang to the level of the point of the hock are assigned a score of 5. Udders that surpass the level of the hock are assigned scores from 6 to 9, and udders that hang to levels closer to the abdomen are assigned scores from 1 to 4. This summer at Spooner, we have scored the entire flock with our traditional system of external measurements as well as with the linear evaluation system, and we found significant correlations (.70) between the two systems (McKusick et al., 2000c). It appears that a subjective score might be adequate in accurately assessing udder morphology in ewes.

Udder compliance. The term compliance is defined as the capacity of an organ to accept dilatation, and can be described mathematically as the change in volume:pressure ratio from when the organ is empty to when the organ is maximally full. Normally, this is a principle observed in many organs of the body which receive, manage, and expel fluids. It has been

proposed that the storage of milk may function also in terms of compliance (Davis et al., 1998). Udders that are capable of holding relatively large volumes of milk at lower pressures are considered to be better adapted for milk storage and could potential better withstand longer intervals between milking and/or the suppression of machine stripping. Furthermore, udders that are more compliant should also remain in lactation longer because they would be more adept at limiting the amount of over-distention of the alveoli.

In France, we conducted a series of compliance experiments with a group of 32 mid-lactation Lacaune dairy ewes. During the first experiment, we measured the intramammary pressure immediately prior to milking, during milking, and after injection of oxytocin along with the volume of milk that was stored in the cistern and alveolar compartments of the udder. A few weeks later in lactation, we conducted a second experiment, this time immediately after machine milking. During this experiment, we gradually filled-up the udders with sterile saline while periodically measuring intramammary pressure. Finally, a third experiment was conducted which involved repeating the first experiment, but after having omitted the previous night's milking. The experimental analysis has not yet been completely finished, however we have already found a random variation in intramammary pressure as a function of volume of milk in the udder just prior to milking. When we divided the ewes into two groups of 16 ewes (low and high) based on their milk volume:intramammary pressure ratios (v/P ratio), we found that high v/P ewes store up to 65% of their milk in the cistern, compared to low v/P ewes that are only able to store about 50%. When we extended the interval between milking to 24 hours by omitting the previous evening's milking, we found that the same ewes with low v/P ratios were not able to significantly modify their v/P ratio; in other words, these udders were relatively non-compliant. Conversely, ewes with high v/P ratios showed a significant degree of compliance in their udders because they were able to accommodate an increase in intramammary pressure of 30% when the milking interval was extended to 24 hours. These preliminary results suggest that there exists a population of ewes who are better adept at milk storage between milkings probably due to a higher degree of compliance within their udders.

III. Physiologic Factors Which are Important at Milking

Since the onset of mechanized milking of dairy ewes in the 1960's, it has been the industry's goal to develop methods for machine milking that completely remove all of the milk from the udder within the shortest amount of time without causing harm to the udder or ewe. Milking machines, along with specific recommendations on vacuum level, pulsation rate and ratio, have been extensively researched and developed for dairy ewes (Labussière et al., 1974b). Genetic selection has been successful in most countries with the average dairy ewe now capable of producing between 250 and 350 liters of commercial milk during a four to five month period. Machine milking efficiency has also improved because milk yields have increased and milking time spent in the parlor has decreased. In the Roquefort region of France, average milking cadence is between 350 to 400 ewes per hour and can be as high as 800 ewes per hour, depending on the type of milking parlor/machine installation (Autran, 2000, personal communication). Although we have achieved an acceptable level of milk production in dairy ewes and a reasonable parlor cadence, there exists a large variation in the way an individual ewe gives her milk to the machine. By further understanding the physiological mechanisms that influence the way a ewe ejects her milk, we can ultimately create new genetic selection criteria which would further improve machine milking efficiency.

The physiologic demands placed upon ewes during machine milking are quite different than those present during suckling. In addition to the beneficial effects of frequent milk removal during the suckling period, the physical presence of the ewe's own lamb (odor, sight, sound) and the suckling stimulus are extremely important for successful milk ejection in the ewe (Marnet, 1998). As soon as the ewe is weaned and is initiated into the machine milking routine, she no longer receives the usual natural stimuli, but must instead release her milk to a sucking, pulsating piece of silicon. This is initially a stressful event which can result in the immediate drop of 20 to 30% in total milk production (Folman et al., 1966; Labussière and Pétrequin, 1969; Ricordeau and Denamur, 1962). Eventually, usually within 5 to 7 days, ewes adjust to the milking routine. They begin to have normal oxytocin release and subsequent alveolar contraction which enables complete evacuation of milk from the udder (Marnet and Negrão, 2000). Generally, if the ewe is content during the milking process, she chews her cud. Feeding dairy animals in the parlor (Svennersten et al., 1990) and anecdotally, cud chewing, has been correlated to oxytocin release (Marnet, 1997), which usually occurs at 30 to 45 seconds after the teat cups have been placed on the ewe (Marnet, 1998). At Spooner, we observed 93% of ewes who chew their cud in the parlor.

This summer at Spooner, we initiated an evaluation of milk flow traits (refer to article in these proceedings, McKusick et al., 2000c) using a piece of equipment from our French collaborators (milk flow apparatus fabricated by the lab of P.-G. Marnet; data recorder from P. Billon, Institut de l'Elevage). To get an idea of how the dairy ewes at Spooner eject their milk during machine milking, we initially measured milk flow kinetics of 72 ewes (approximately 50% East Friesian breeding) during two consecutive morning milkings at approximately 90 days in lactation. From these original 72 ewes, 48 of them were chosen for a study on the effects of suppression of stripping on milk production, and were studied further during their fourth and fifth months of lactation. We chose only ewes with symmetrical udders, and average to above average milk production. The milk flow criteria evaluated include: milk flow latency, average milk flow rate, peak milk flow rate, milk yielded to the milking machine (machine milk), stripping milk yield, total commercial milk yield, and milking procedure time. At this point, we have made only a preliminary assessment of the raw data. We observed that the average ewe at mid-lactation during a morning milking gave 1.2 L of milk in approximately 2 min and 15 sec with an average milk flow rate of .50 L/min. The milking machine was only able to remove approximately 80% of that milk (.9 L), taking about 1 min 45 sec. The remaining 20% of the milk had to be removed by the milker using machine stripping which took another 30 sec. Further analysis of the milk flow curves demonstrated that milk began flowing 13 seconds after placement of the teat cups on the udder. Peak milk flow rate was 1.2 L/min and was usually attained within the first 30 seconds of milking.

Machine milking efficiency is thus optimized when milking procedure times decrease, the amount of milk given to the machine without intervention increases, and the amount of stripped milk decreases. Of the milk flow parameters measured, it appears that maximum milk flow rate is one of the strongest indicators of machine milking efficiency (McKusick et al., 2000c). After looking at all of the milk flow curves and data, we began to appreciate consistent differences between ewes in the way that they give their milk to the machine. We identified four general types of milk flow patterns (also included below is a fifth type of milk flow pattern that can be seen experimentally in ewes with poor milk ejection, typically in early lactation). Moreover,

these patterns exist independent of total commercial milk yield. In other words, it is possible to find each of the following types of ewes all with a milk production of 1.5 liters, for example.

1. The “fast-milker”: a ewe which attains milk flow almost immediately after the teat cups have been placed on the udder. She achieves one or two very high peak milk flow rates (1.5 to 2 L/min) and has usually emptied her udder by 60 to 90 seconds. If the ewe has correct teat placement, she typically has only 10 to 15% stripping volume.
2. The “average-milker”: (see above).
3. The “slow-milker”: a ewe which generally requires a great deal of manual intervention in the parlor. Milk begins to flow 20 to 30 seconds after the teat cups have been placed on the udder. Peak milk flow rates rarely exceed .7 L/min, just 2/3 that of a typical ewe. Milking procedure times can exceed 4 minutes, and the milker has a tendency to spend significant amounts of time in udder massage and stripping. It is sufficient to have just one slow-milker in each wave of ewes to greatly slow parlor throughput time.
4. The “poor udder conformation/teat placement ewe”: a ewe with a large amount of udder volume located beneath the teat canal exit. This is more often seen in older ewes with relaxed medial suspensory ligaments. Commercial milk yield may be acceptable, however, milk flow rates are decreased and stripping percentages are high (30 to 40%) which significantly increase milking procedure time.
5. The “no milk-ejection ewe”: a ewe that does not release her alveolar milk fraction during milking. This is most often seen during the first 30 days of the MIX weaning system when oxytocin is not released at milking. However, this phenomenon can be seen in some ewes throughout lactation. In high producing ewes, producers may not even be aware of these ewes because milk flow rates can be acceptable and stripping percentages low.

The reasons for the differences in the way a ewe gives her milk to the machine is due to a complex interaction genetic as well as physiological factors initiated by the machine and the milking parlor environment. I will discuss two of the most important factors: the release of oxytocin and the control of the teat sphincter. Although the teat is the generally the first point of contact with which the ewe appreciates the actual milking process, many times physiological changes within the ewe have already occurred when the ewe hears the milking machine being turned on, or when she sees the milking parlor. These stimuli can all initiate the milk ejection reflex and cause a discharge of oxytocin from the brain. Because oxytocin causes contraction of the alveoli, intramammary pressure increases an average of 1.7 fold as milk is being forced out of the alveoli in the direction of the cistern (McKusick and Marnet, 2000, unpublished data). Thus oxytocin is responsible for not only eliminating the alveolar fraction of milk (rich in fat) but also for increasing intramammary pressure which could influence milk flow (Labussière et al., 1969).

At the other end of the mammary system is the teat sphincter, a ring structure near the teat end composed of smooth muscle fibers which allows milk to flow from the teat canal during suckling or milking, yet which closes firmly soon after the stimulus is over. These smooth muscles in the teat sphincter are also located higher up in the ducts and canals of the mammary gland and are under strong influences from the nervous system. When animals are disturbed or

stressed during milking, adrenaline and other related chemicals began to inhibit the expulsion of milk from the mammary gland by causing smooth muscle contraction (Bernabé, 1980), by interfering with oxytocin release from the brain (Bruckmaier et al., 1992), or by interfering directly with oxytocin's effects on alveolar contraction (Grosvenor and Mena, 1974). In France, we demonstrated that ewes with low milk flow rate have significantly "tighter" sphincters, and conversely ewes with high milk flow rate have sphincters that take less vacuum to open. When we injected adrenaline and other related drugs which either inhibit or enhance milk flow, we were only able to inhibit milk flow. In other words, when we administered drugs that would normally relax the sphincter, we did not necessarily see significant increases in milk flow, as has been reported in the cow (Blum et al., 1989). From these preliminary observations we conclude, with respect to the teat sphincter, slow-milking ewes have perhaps other physical constraints in their teat tissue itself which prohibit milk flow from increasing. When we measured oxytocin in the blood during milking, we observed that one class of adrenaline-like drugs (α_1-adrenergic agonists) caused circulating levels of oxytocin to be significantly reduced, which confirms the interaction between "stress" and milk ejection. Finally, another hypothesis that many researchers are working with is that certain ewes have higher densities of receptors in the mammary gland or higher circulating concentrations of certain inhibitory substances and thus are slow to milk. Undoubtedly, perception of the environment by the ewe is not consistent, and therefore some ewes may be more susceptible to stress during and between milkings. Further work on individual ewe variations of response to stress are merited.

In approximately 45% of the ewes monitored at Spooner, we observed a "two-peak" milk flow curve during milking. The first peak occurs between 10 and 40 seconds, followed by a sharp decrease in milk flow, finally followed by the second peak. The first peak corresponds to extraction of milk stored within the cistern (Labussière et al., 1969). If the amount of milk stored in the cistern is small or if the milk flow rate is large, the cisternal milk may be expelled from the mammary gland before oxytocin has a chance to act upon the alveoli (Labussière et al., 1969). Thus we see a trough in the milk flow curve when cisternal milk has been completely removed. If oxytocin release from the brain has occurred, we see a new sharp increase in the milk flow curve at 30 to 45 seconds which corresponds to alveolar milk flow. In some ewes we could actually externally visualize the impressive "second filling-up" of the udder when the alveolar milk arrived in the cistern. When ewes are in early lactation and/or when milk production is large, we see less "two-peak" ewes because cisternal milk is still being removed when oxytocin begins to cause alveolar contraction (Labussière et al., 1969).

Machine stripping requires the manual intervention of one or both of the milkers, decreases parlor throughput time, and may eventually habituate ewes to manual massage of the udder. In the Roquefort region of France, producers have abandoned the use of machine stripping in order to gain in parlor throughput time (Autran, 2000, personal communication). Average stripping percentages at the INRA laboratory in Rennes, France are on the order of 10% (compared with 14% in 1968 reported by Ricordeau and Labussière), both significantly lower than the 21% that we found for the Spooner flock. When stripping percentage is low, the small amount of milk gained during machine milking is not worth the labor input to extract it. Instead, flock size can be slightly increased to maintain the same level of production.

To evaluate the effects of no machine stripping on milk yield, milk composition and quality, and lactation length, we omitted machine stripping in 24 ewes in the Spooner flock from 90 days in lactation onward. We compared their lactation performance with 24 contemporary ewes which were machine stripped normally. Both groups contained ewes with high, medium and low stripping percentages. Our hypothesis is that for ewes with normally low or even average stripping percentages, it may be financially more viable to omit stripping because of gains in parlor throughput without significant loss in milk yield. Preliminary analyses of the data indicate that commercial milk yield for non-stripped ewes was about 15% less than that of stripped ewes (average daily milk yield of 1.15 vs 1.35 L/ewe/day, respectively). These results are somewhat surprising given the fact that average stripping percentage for both treatment groups was 22% before the experiment began. We had also periodically measured theoretical stripping percentage in the non-stripped treatment group to get an idea of how much milk we were leaving behind in the udders. We found that stripping percentage was similar between treatments, but machine milk yield of non-stripped ewes was higher than that of stripped ewes. Our results suggest that stripped ewes are habituated to the stripping process, and that approximately 1/3 of the stripped milk could be recuperated in the machine milk yield as a result of removing the stripping stimulus. Furthermore, leaving the small volume of "un-stripped" milk in the udder does not appear to perturb milk synthesis. Analyses of fat and protein content, somatic cell count, and lactation length is currently being conducted along with an economic analysis to further evaluate the effects of omitting machine stripping in dairy ewes.

Conclusion

This paper has introduced some of the physiologic factors that can affect machine milking efficiency. Machine milking efficiency in dairy ewes is measured in terms of the volume of milk received per unit of time. It is not unlikely, nor would it be desirable, that dairy ewes will achieve the large individual milk yields that are common today in dairy cows, for example. Ewe milk, however, is an extremely rich and valuable product, even in smaller quantities. Therefore, it is proposed that genetic selection programs begin to evaluate the dairy ewe in terms of machine milking efficiency, which allow for a larger total volume of milk to be recuperated in the shortest amount of time without causing harm to the udder or ewe. Further work is necessary at the Spooner Agricultural Research Station and at the University of Wisconsin-Madison in order for direct recommendations to be made to the producer concerning exact selection programs for North American dairy ewes.

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PRELIMINARY OBSERVATIONS ON MILK FLOW AND UDDER MORPHOLOGY TRAITS OF EAST FRIESIAN CROSSBRED DAIRY EWES

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Abstract

Milk yield, milk flow, and udder morphology traits were measured in 72 East Friesian crossbred multiparous ewes to estimate the variation in milk flow patterns present in this research flock, and to asses the repeatability of these measurements and their relationships with other lactation traits. A special milk flow apparatus designed for dairy ewes was used on two consecutive morning milkings at approximately 90 d in lactation to measure milk yield and flow rates. Udder morphology and teat placement traits were measured 4 hr prior to the evening milking. From the original 72 ewes, 48 of them were measured every two weeks during their fourth and fifth months of lactation with the milk flow apparatus only. Milk yield traits measured included: machine milk yield and time (the amount of milk extracted by the machine only); stripping yield and time (milk extracted by the milker during stripping); and total milk yield and time. Milk flow traits measured included: milk flow latency (the time it took for milk to begin to flow); maximum milk flow rate; and the time at which maximum milk flow occurred. From the milk yield and milk flow data, calculations were made to estimate average milk flow rate (total milk yield/total milking time), stripping percentage (stripping yield/total milk yield), and machine milking efficiency (machine milk yield/total milking time). The average ewe during mid-lactation yielded 1.14 L of milk in 2.25 min at the morning milking. Of the total milk, 20% of it was extracted by the milker during stripping. Rumination occurred in 93% of the ewes during machine milking. Milk flow traits had good estimates of repeatability between consecutive test days, and reasonable estimates of repeatability as lactation progressed. Machine milking efficiency was significantly positively correlated to maximum milk flow and average milk flow, and significantly negatively correlated to milk flow latency and stripping percentage. Cistern height and teat position score were positively correlated with stripping percentage and negatively correlated with machine milking efficiency. Regression analyses for some of the milk flow traits on machine milking efficiency indicate that average milk flow rate and stripping percentage can be used together to estimate machine milking efficiency. Bimodal or “two-peak” milk emission was observed in 43% of the ewes. These ewes had significantly higher machine milking efficiency, higher maximum milk flow rate, shorter milk flow latency, and shorter milking times. We conclude that this flock of experimental East Friesian-crossbred ewes is well adapted to machine milking and milk flow measurements along with subjective udder morphology scores appear to be reliable techniques for evaluating machine milking efficiency.

Introduction

Genetic selection in dairy sheep is commonly focused on eliminating ewes with inferior milk yield and undesirable somatic cell count (SCC). Recently there has been more interest in adding other dimensions to selection programs such as udder morphology (de la Fuente, 1996; Fernández et al., 1995), and now, milk flow traits (Marie et al., 1999; Marnet et al., 1999). Poor udder conformation and teat placement increase parlor throughput time because extra labor is required to massage or lift the udder to completely evacuate it. Ewes with low milk flow rate, also severely impede the cadence in the parlor. It has been proposed that machine milking efficiency, defined as the recuperation of the maximum amount of rich milk in the shortest amount of time by the milking machine with the least amount of human intervention and without causing harm to the udder, could also be used to assess dairy ewe lactation performance. Machine milking efficiency can be evaluated by studying the milk flow rate, stripping yield, and milk composition of dairy sheep. Special equipment for small ruminants has been developed to study the former two parameters in France. The dairy sheep research team at the University of Wisconsin-Madison maintains a flock of East Friesian (EF) crossbred ewes at the Spooner Agricultural Research Station and was fortunate to have been able to use this equipment during the summer of 2000. Many dairy sheep producers in the United States are using the EF breed (with similar genetic stock as the University of Wisconsin-Madison), yet very little current data is available on milk flow traits of this breed. The objectives of the project were to measure milk flow traits in EF crossbred dairy ewes and assess the variation in milk flow patterns. Furthermore, we also wanted to test the repeatability of these measurements and to estimate their relationships with other lactation traits.

Materials and Methods

Multiparous ewes with symmetrical udders (n = 72) at approximately 90 d in lactation were chosen from the flock of EF crossbred ewes maintained by the University of Wisconsin-Madison at the Spooner Agricultural Research Station. Udder morphology measurements and subjective teat and udder scores were made on the ewes at approximately 4 hr prior to an evening milking. Udder morphology measurements were made by one technician with a ruler and T-square and included udder height (the distance from the perineum to the bottom of the udder) and cistern height (the distance from the attachment of the teat to the bottom of the udder). Additionally, subjective scores were assigned to udder height and teat placement by a second technician based on the methods of de la Fuente et al. (1996) with the following scoring system. Udder height: 9 = base of the udder located much below the level of the hocks, 5 = base of the udder at the level of the hocks, and 1 = base of the udder much above the level of the hocks; Teat placement: 9 = vertical, 5 = 45º, and 1 = horizontal.

A few days following udder morphology measurements, milk yield and flow were measured during two consecutive morning milkings in groups of 24 ewes per morning over a 6 d period with a milk flow apparatus (Institut National de la Recherche Agronomique, Rennes, France) and a data recorder (Institut de L'Elevage, Le Rheu, France). Whole udder milk flow and milk yield data collected with the milk flow apparatus included: milk flow latency (the time it takes for milk to begin flowing at a rate of 50 ml/min after the teat cups have been placed on the ewe); maximum milk flow rate (the maximum flow rate recorded over any 3 sec interval during milking); time of maximum milk flow rate (the time at which maximum flow occurred); machine

milk yield and time (the amount of milk obtained by the machine from time 0 to when milk flow rate fell below 100 ml/min); stripping milk yield and time (the amount of milk obtained by the milker during machine stripping); total morning milk yield (machine milk yield + stripping milk yield); total milking time(machine milking time + stripping time); stripping percentage ([stripping milk yield/total milk yield] * 100); and machine milking efficiency (machine milk yield/total milking time). Instantaneous and cumulative milk flow curves were generated from the milk flow data. Each curve was subjectively evaluated for uni (one peak) or bimodal (two peak) milk emission. Ewes with consistent milk flow throughout machine milking were considered to be of the one-peak type (refer to Figure 1A). Ewes with a significant drop in milk flow, typically around 30 to 45 seconds, and then a reestablishment of strong milk flow, were considered to be of the two-peak type (refer to Figure 1B). It was noted if ewes ruminated during machine milking with the milk flow apparatus.

Milk yield, milk fat and protein percentage, and somatic cell count were measured monthly throughout lactation as part of the flock's milk-recording protocol by a State of Wisconsin certified laboratory. Commercial milk production, and milk fat and protein yield were estimated according to Thomas et al. (2000). Somatic cell count was transformed to base-10 logarithms, and average somatic cell count over the entire lactation was calculated by taking the simple mean of all test days.

Statistical analyses were preformed with SAS (1999). Sample statistics and raw correlation coefficients were calculated with the correlation procedure. Regression analyses of machine milking efficiency on maximum milk flow, average milk flow, milk flow latency, and stripping percentage were conducted with the simple regression procedure. Analysis of variance for milk emission data was conducted with the general linear models procedure. The model included total morning milk production as a covariable, the main effect of milk-flow pattern (one or two peak), and residual error.

Results and Discussion

General. Sample statistics of milk flow, milk yield, and udder morphology traits for the 72 EF crossbred ewes are summarized in Table 1. The average mid-lactation ewe during a morning milking gave 1.14 L of milk in 132 seconds with an average milk flow rate of .54 L/min. The milking machine was only able to extract .92 L of the total milk, which took 106 sec. The remaining .22 L of milk had to be removed by machine stripping which took an additional 26 sec and corresponded to 21% of the total milk yield. On average, it took 13 sec from the time the milking machine was placed on the ewe to when milk began flowing. Maximum milk flow rate was 1.24 L/min and occurred on average at 34 sec. Average udder height was 20 cm, of which 3 cm was located beneath the exit of the teat canal. Subjectively, the bottom of the udder did slightly surpass the level of the hocks and teat implantation was very close to 45º. Over the entire lactation, the average ewe produced 317 L of commercial milk, 17 kg of milk fat, 15 kg of milk protein, and lactated for 6 months. Average individual somatic cell count over the entire lactation was 4.88 log units, corresponding to 76,000 cells/ml.

Table 1. Sample statistics of milk flow, milk yield, and udder morphology traits in East Friesian crossbred dairy ewes[1].

Trait	Mean ± stdev	Range	
		minimum	maximum
~ 90 days in lactation[2]			
Maximum milk flow rate, L/min	1.24 ± .30	.60	1.90
Average milk flow rate[3], L/min	.54 ± .12	.22	.78
Milk flow latency, sec	13.1 ± 6.7	5	48
Time of maximum flow, sec	34.3 ± 19.1	12	108
Total milking time, sec	132.0 ± 42.2	71	317
Machine milking time, sec	105.9 ± 38.6	44	275
Stripping time, sec	26.0 ± 11.5	10	75
Total morning milk yield, L	1.14 ± .31	.54	2.09
Machine milk yield, L	.92 ± .31	.40	1.82
Stripping yield, L	.22 ± .08	.07	.49
Stripping yield, %	20.7 ± 8.8	7.5	47.6
Machine milking efficiency[4], L/min	.43 ± .12	.17	.68
Udder height, cm	19.7 ± 1.8	16	24
Udder height score[5], no.	5.7 ± .7	4	7
Cistern height, cm	2.8 ± 1.2	.5	6
Teat position score[6], no.	5.2 ± 1.9	1	8
Entire lactation			
Total commercial milk yield, L	316.6 ± 64.2	131.4	461.6
Lactation length, d	181.5 ± 16.4	108	209
Total fat yield, kg	17.4 ± 3.5	7.6	25.2
Total protein yield, kg	15.1 ± 2.8	6.2	21.3
Average somatic cell count, log units	4.88 ± .30	4.34	6.03

[1] 72 ewes chosen from the flock with symmetrical udders.
[2] The average of two consecutive morning milkings at approximately 90 d in lactation.
[3]Average milk flow rate = total morning milk yield/total milking time.
[4] Machine milking efficiency = machine milk yield/total milking time.
[5] Subjective score: 1 = much above the hocks, 5 = level of the hocks, 9 = much below the hocks.
[6] Subjective score: 1 = horizontal, 5 = 45º, 9 = vertical.

Correlation coefficients between test days for milk flow traits are summarized in Table 2. The majority of milk flow traits had high correlations between consecutive test days and reasonable correlations between test days later in lactation, which suggests that the measurements have good repeatability. Milk flow latency was the most repeatable trait at mid-lactation (.80) and at later times in lactation (.66 to .78), while time of maximum milk flow was the least repeatable. Milk flow latency and maximum milk flow rate have been shown to be highly repeatable traits in dairy ewes (Marie et al., 1999) and in dairy goats (Billon et al., 1999). It is recommended that milk flow measurements should be made on at least two consecutive days. To characterize a ewe in terms of her milk flow traits, the average of the consecutive daily measurements should be used. Furthermore, milk flow traits are influenced by milk production, and therefore comparisons between ewes need to be corrected for stage of lactation (Marnet et al., 1998).

Table 2. Correlation coefficients between test days for milk flow traits in East Friesian crossbred dairy ewes.

Trait	Correlation coefficient between two consecutive test days in mid lactation[1]	Range of correlation coefficients between mid and late lactation[2]
Maximum milk flow rate, L/min	.65	.38 - .64
Average milk flow rate[3], L/min	.62	.24 - .64
Milk flow latency, sec	.80	.66 - .78
Time of maximum flow, sec	.44	.29 - .65
Total milking time, sec	.70	.42 - .70
Machine milking time, sec	.82	.47 - .68
Stripping time, sec	.51	.04 - .29
Total morning milk yield, L	.81	.38 - .77
Machine milk yield, L	.80	.45 - .73
Stripping yield, L	.60	.12 - .51
Stripping yield, %	.64	.28 - .60
Machine milking efficiency, L/min[4]	.68	.32 - .64

[1] for 72 ewes measured on two consecutive morning milkings at approximately 90 d in lactation.
[2] for 48 of the original 72 ewes, measured every two weeks from 90 to 150 d in lactation.
[3] Average milk flow rate = total morning milk yield/total milking time.
[4] Machine milking efficiency = machine milk yield/total milking time.

Phenotypic correlation coefficients between milk flow and udder morphology traits are summarized in Table 3 and are in general agreement with those reported for dairy ewes (Labussière et al., 1981; Marie et al., 1999; Marnet et al., 1999). Maximum milk flow was positively correlated to average milk flow (.78) and machine milking efficiency (.74), and negatively correlated to milk flow latency (-.71) and stripping percentage (-.35). This implies that ewes with high maximum milk flow rate tend to be more efficient during machine milking because they take less time to begin milk emission, and subsequently take less time to be milked. Udder morphology traits generally had lower, although still significant, correlations with machine milking efficiency and stripping percentage. Cistern height and teat position score were both correlated with stripping percentage (.44 and -.38, respectively) and with machine milking efficiency (-.28 and .22, respectively). Because both subjective scores (teat position and udder height) had high correlations with actual cistern and udder height measurements (-.70 and .62, respectively), it would appear that the linear scoring system proposed by de la Fuente et al. (1996) is appropriate for evaluating EF dairy ewes. At least one author has suggested a major gene for milk flow rate in dairy goats (Ricordeau et al., 1990). Further work is necessary to establish whether or not milk flow traits are heritable in dairy ewes, and how milk flow rates can be most effectively used in genetic selection programs.

Milk flow curves. To give the reader an idea of the general types of milk flow patterns that were observed in the experimental flock of EF ewes, examples of individual ewe milk flow curves are displayed in Figure 1, panels A through D. Each of the four milk flow curves are from separate ewes all in the same stage of lactation (90 d) with a morning milk yield of 1.5 L. For each panel, the cumulative amount of milk (dotted line) and the instantaneous milk flow rate (solid line) are plotted against milking time (the teat cups were placed on the ewe at time = 0). The last spike in instantaneous milk flow occurs because of machine stripping. In Figure 1A, the "ideal" one-peak ewe is represented: a ewe that gives the majority of her milk to the machine in a timely manner and, provided she has good udder conformation, requires very little manual intervention in the form of stripping. Figure 1B represents a typical "two-peak" milk emission whereby milk flow ceases or is significantly reduced, usually between 30 and 45 sec, and then is quickly reestablished. Two-peak ewes generally have very high maximum milk flow rate and take less time to milk than one-peak ewes (two-peak milk emission is discussed later in this paper).

Figure 1C represents a ewe that requires much manual intervention in the form of stripping to fully evacuate her udder. Machine stripping is a management practice that allows for the recuperation of additional milk not extracted by the machine, but at the expense of the additional labor and time necessary to extract it. The volume of stripped milk for a given ewe is generally proportional to her total milk yield, and therefore, the stripping percentage remains relatively constant throughout lactation. Machine stripping is necessary in some ewes for two reasons: functionally, some ewes have large amounts of udder volume located below the teat canal exit and require the udder to be lifted for complete evacuation; or, physiologically, some ewes are poorly adapted to the milking machine, and are "habituated" to manual massage for milk ejection (Bruckmaier et al., 1997). With the latter reason, the stripping fraction is significantly higher in milk fat (Labussière, 1969). It may be possible to "dis-habituate" some ewes by omitting stripping entirely from the milking routine. This allows proportionally more milk to be recuperated in the machine-milk fraction and probably increases parlor throughput time and machine milking efficiency (McKusick et al., 2000, unpublished data).

Table 3. Phenotypic correlation coefficients for milk flow and udder morphology traits in East Friesian crossbred dairy ewes[1].

Measurement	1	2	3	4	5	6	7	8	9	10
1. Time of maximum flow	-	**-.57**	**.81**	**-.38**	ns	**-.27**	ns	ns	ns	ns
2. Maximum milk flow		-	**-.71**	**.78**	**-.35**	**.74**	ns	ns	ns	ns
3. Milk flow latency			-	**-.60**	ns	**-.51**	ns	ns	ns	ns
4. Average milk flow[2]				-	**-.44**	**.94**	ns	ns	ns	ns
5. Stripping percentage[3]					-	**-.71**	ns	**.26**	**.44**	**-.38**
6. Mach. milking efficiency[4]						-	ns	ns	**-.28**	**.22**
7. Udder height							-	**.62**	**.32**	ns
8. Udder height score[5]								-	**.22**	ns
9. Cistern height									-	**-.70**
10. Teat position score[6]										-

[1] 72 ewes measured at approximately 90 d in lactation.
[2] Average milk flow = total milk yield/total milking time.
[3] Stripping percentage = stripping milk yield/total milk yield.
[4] Machine milking efficiency = machine milk yield/total milking time.
[5] Subjective score: 1 = much above the hocks, 5 = level of the hocks, 9 = much below the hocks.
[6] Subjective score: 1 = horizontal, 5 = 45°, 9 = vertical.
Level of significance used: $P < .05$, ns = non significant.

Figure 1. Examples of milk flow curves from a typical individual mid-lactation ewe (A), a ewe with two-peak milk emission (B), a ewe with a large stripping percentage (C), and a ewe with a low milk flow rate (D). Morning milk yield was similar (1.5 L/ewe).

In Figure 1D, a ewe that is an extremely "slow-milker" is represented. This type of ewe has a long delay in milk flow latency, subsequently very poor milk flow rate (both maximum and average), and can require large amounts of udder massage, making her an extremely inefficient dairy ewe. It is hypothesized that these ewes may be under the influence of higher sympathetic tone within the udder and/or teat which could greatly reduce milk flow rate, and might also influence oxytocin concentrations or the interaction of oxytocin with the alveoli (McKusick and Marnet, 2000, unpublished data).

Machine milking efficiency. To further describe the relationship between machine milking efficiency and maximum milk flow rate, average flow rate, milk flow latency, and stripping percentage, regression analyses were performed and the data are summarized in Figures 2 and 3. Sixty-four percent of the observations on maximum milk flow were within ± 1 standard deviation of the mean indicating a relatively normal distribution of maximum milk flow rate in relation to machine milking efficiency (Figure 2A). For each increase in maximum milk flow rate of .1 L/min for a ewe, it is estimated that her machine milking efficiency would increase by .03 L/min. In other words, an average ewe of high maximum milk flow rate (1.8 L/min) is estimated to be .3 L/min more efficient than the average ewe of low maximum milk flow rate (.8 L/min). One precaution concerning high milk flow rate should be noted. It has been reported that high milk flow rates are significantly positively correlated with increased new intramammary infection rates in dairy cows (Grindal et al., 1991). Concurrent with these findings in dairy cattle, are the present experiment's observation of higher average SCC in the two-peak ewes that additionally had the highest maximum milk flow rate (discussed later in this paper, Table 4). However, it remains to be determined if the magnitude of flow rate differences between high flow-rate and low-flow rate ewes is significant enough to have an effect on the teat canal diameter, teat canal integrity, and infection rate. Because of smaller milk yields in dairy ewes, it is likely that milk flow rate does not impact the teat canal in the same way as in dairy cattle. This point remains to be investigated experimentally.

A normal distribution was also demonstrated for observations on average milk flow rate in relation to machine milking efficiency (69% of observations within ± 1 standard deviation of the mean, Figure 2B). The good fit of the data (r^2 = .88) is not surprising given the fact that average milk flow rate and machine milking efficiency are calculated by dividing machine milk yield or total milk yield, respectively, by the total milking time. For each increase in average milk flow rate of .1 L/min for a ewe, it is estimated that her machine milking efficiency would increase by .09 L/min (almost a 1:1 relationship). Because average milk flow rate could easily be calculated on a test day, with normal milk recording collection jars and a stopwatch, producers could estimate the relative efficiency of an individual ewe.

Although milk flow latency was the milk flow trait with the highest repeatability, it is a trait that is unfortunately not highly correlated with machine milking efficiency. The relationship between milk flow latency and machine milking efficiency was the most variable (r^2 = .26), and exhibited non-normal distribution with 81% of the observations within ± 1 standard deviation of the mean (Figure 3A). Furthermore, upon consulting a residual plot of data, it is likely that a transformation would be necessary due to heteroscedasticity. Nevertheless, a significant regression was found which estimates that an increase in milk flow latency of 10 sec for a ewe would decrease her machine milking efficiency by .1 L/min. Given the preliminary results of this experiment, the use of milk flow latency data alone to estimate machine milking efficiency would seem unwise.

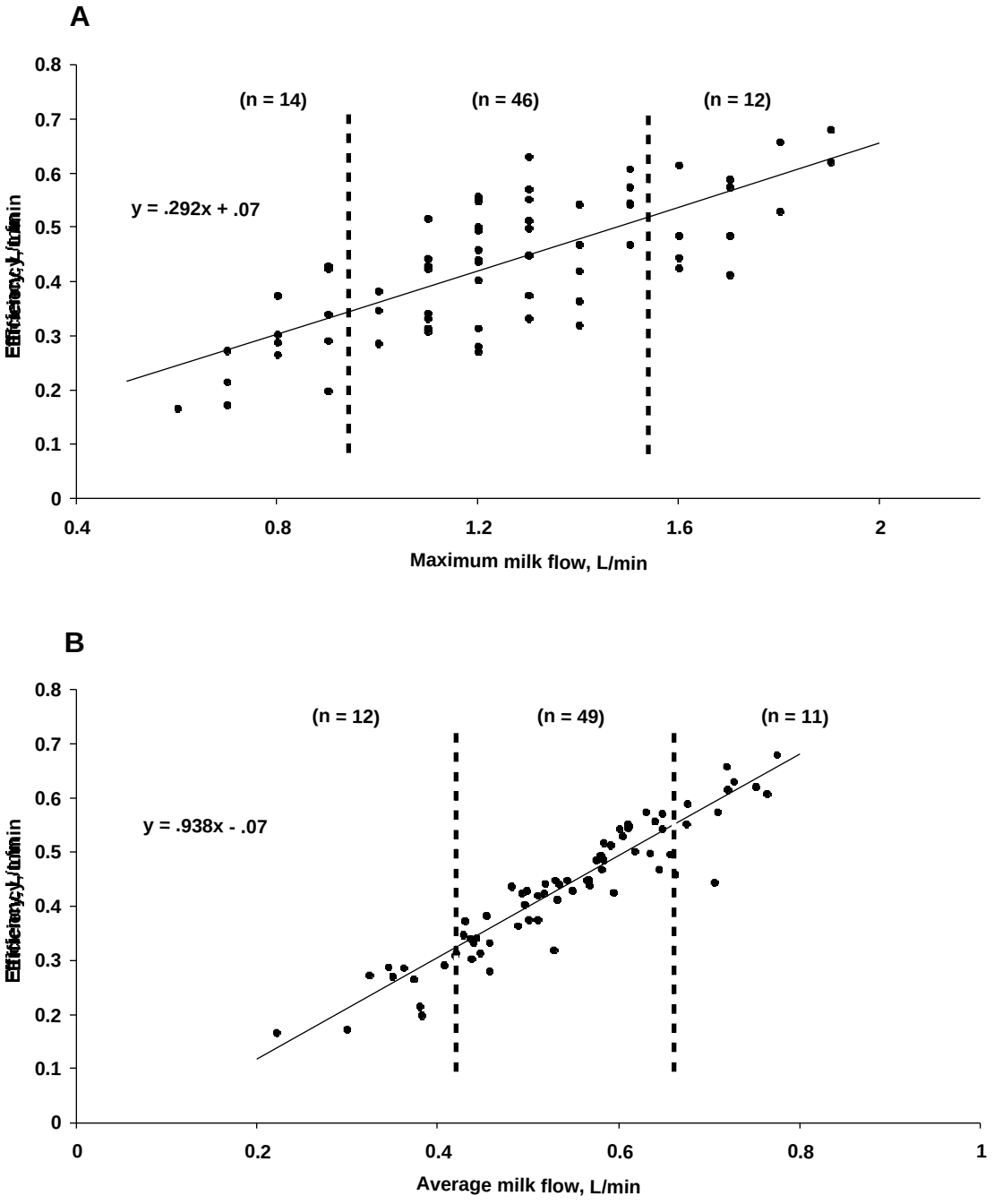

Figure 2. Maximum milk flow rate (Panel A) and average milk flow rate (panel B) data plotted against machine milking efficiency (efficiency = machine milk yield/total milking time). Each point represents the mean of two consecutive test days for a ewe. Significant regression lines were fitted for the data from their respective regression equations. Dotted lines demarcate the boundary of one standard deviation of the mean (1.2 ± .3 and .54 ± .12 L/min, for panels A and B, respectively). Data points outside of the area bounded by the dotted lines are more than one standard deviation from the mean.

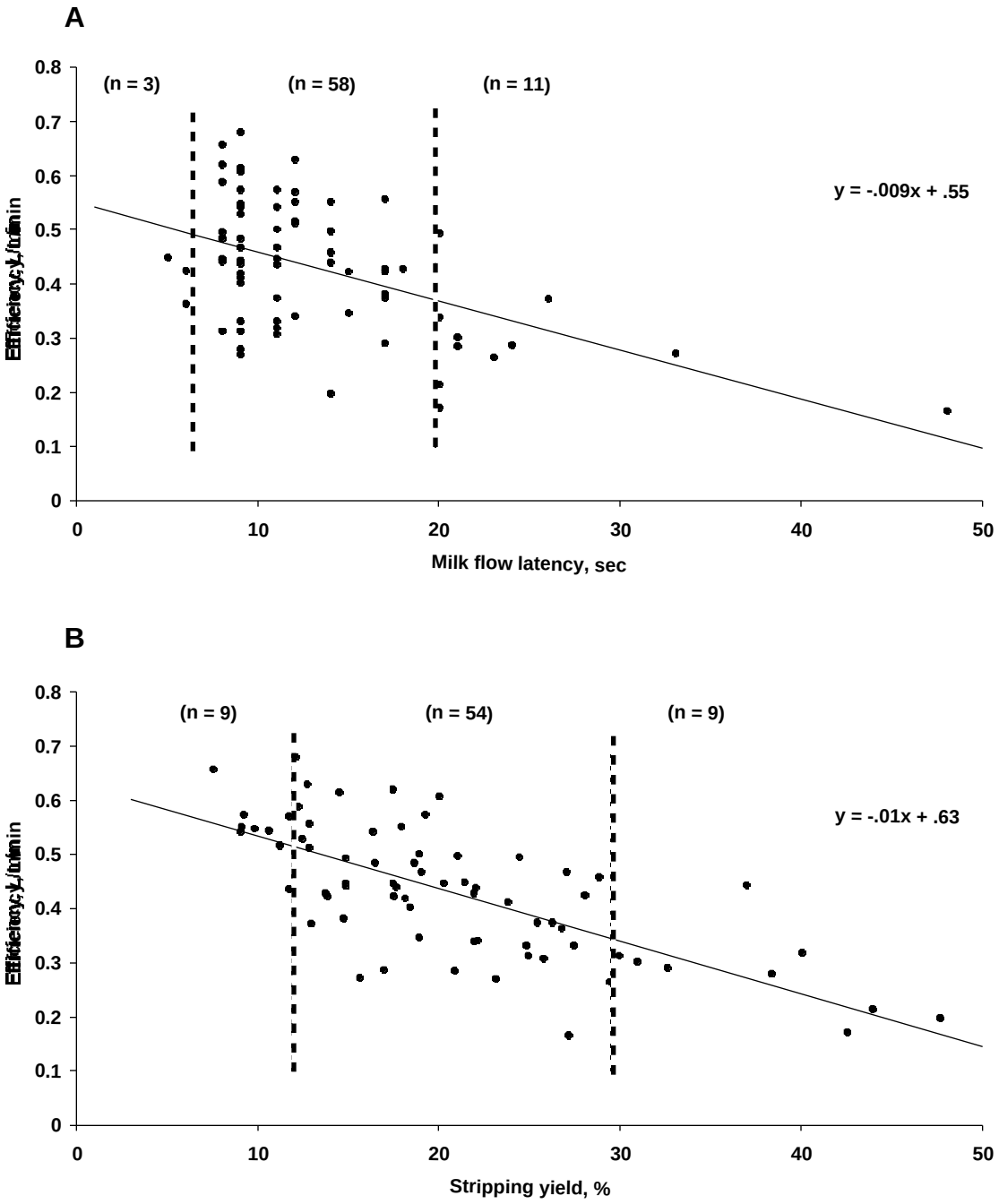

Figure 3. Milk flow latency (Panel A) and stripping percentage (panel B) data plotted against machine milking efficiency (efficiency = machine milk yield/total milking time). Each point represents the mean of two consecutive test days for a ewe. Significant regression lines were fitted for the data from their respective regression equations. Dotted lines demarcate the boundary of one standard deviation of the mean (13 ± 7sec and 21 ± 9%, for panels A and B, respectively). Data points outside of the area bounded by the dotted lines are more than one standard deviation from the mean.

Seventy-five percent of the observations on stripping percentage were found within ± 1 standard deviation of the mean (Figure 3B). It is estimated that an increase in stripping percentage of 10% for a ewe would decrease her machine milking efficiency by .1 L/min. When multiple regression was performed by regressing average milk flow and stripping percentage, respectively, on machine milking efficiency, a very good fit of the data was obtained (r^2 = .99, efficiency = $.777X_{avgflow}$ - $.005_{strip}$ + .117). Therefore, if producers had the equipment and techniques to accurately estimate stripping percentages, this data in conjunction with average milk flow rate, could be used to achieve very good estimations of machine milking efficiency for an individual ewe.

Knowledge about machine milking efficiency of ewes within a flock would permit more efficient organization of the milking routine (i.e. within a stage of lactation, ewes could be grouped on the basis of their machine milking efficiency). Furthermore, ewes that are extremely inefficient could be culled. In the present experiment, 12 ewes were observed to have average milk flow rates less than 1 standard deviation from the mean (Figure 2B), and could be considered as inefficient. Because all 72 ewes used in the experiment were housed together, it is possible that there could be at least one or two of these inefficient ewes in every wave of 12 ewes in the parlor (72/12 = 6 waves of ewes; 12 inefficient ewes ÷ 6 waves = 2 ewes/wave). Because a wave of ewes cannot be released from the parlor until the last ewe is done milking, this group of 72 ewes can only be milked at a cadence equivalent to that of the slowest ewes. Therefore, the machine milking efficiency of the flock is actually determined by the machine milking efficiency of the most inefficient ewes. It seems reasonable that producers will want to consider grouping ewes with respect to machine milking efficiency and to remove inefficient ewes from the flock.

Two-peak vs one-peak ewes. Approximately 43% of ewes exhibited at least one “two-peak” milk emission pattern (Figure 1B) during the two consecutive morning milkings. When two-peak milk emission was recorded, maximum milk flow almost always occurred during the first peak and about 45% of the total milk was recuperated within the first peak (data not shown). When data were compared between one- and two-peak ewes, significant differences were found for milk flow traits between the two patterns of milk emission (Table 4). Ewes with two-peak milk emission had significantly higher maximum milk flow rate, shorter milk flow latency, and shorter milking times than one-peak ewes, and therefore had higher ($P < .10$) machine milking efficiency. Conversely, commercial milk yield, average milk flow, and stripping percentage were similar between groups. Two-peak ewes tended ($P < .10$) to have less pendulous udders when judged subjectively, however, measured udder height did not differ between groups. There were no differences between milk emission pattern groups for total commercial milk yield, lactation length, or milk component yields, however, two-peak ewes did have higher ($P < .05$) average SCC over the entire lactation compared to one-peak ewes.

Table 4. Least squares means ± SEM of lactation traits for East Friesian crossbred dairy ewes by milk flow pattern.

	Milk flow pattern[1]	
Trait	One-peak	Two-peak
Number of ewes, no.	41	31
~ 90 days in lactation[2]		
Maximum milk flow rate, L/min	1.13 ± .04[a]	1.38 ± .05[b]
Average milk flow rate[3], L/min	.52 ± .02	.56 ± .02
Milk flow latency, sec	14.6 ± 1.0[a]	11.0 ± 1.2[b]
Time of maximum flow, sec	38.4 ± 2.8[a]	28.9 ± 3.1[b]
Total milking time, sec	137.9 ± 5.4[c]	124.1 ± 6.2[d]
Machine milking time, sec	111.1 ± 4.8[c]	99.1 ± 5.5[d]
Stripping time, sec	26.8 ± 1.8	25.1 ± 2.1
Total morning milk yield, L	1.17 ± .05	1.10 ± .05
Machine milk yield, L	.92 ± .01	.93 ± .05
Stripping yield, L	.23 ± .01	.22 ± .01
Stripping yield, %	20.8 ± 1.4	20.5 ± 1.6
Machine milking efficiency[4], L/min	.41 ± .02[c]	.46 ± .02[d]
Udder height, cm	19.9 ± .3	19.4 ± .3
Udder height score[5], no.	5.8 ± .1[c]	5.5 ± .1[d]
Cistern height, cm	2.7 ± .2	2.9 ± .2
Teat position score[6], no.	5.0 ± .3	5.4 ± .3
Entire lactation		
Total commercial milk yield, L	312.7 ± 7.8	321.7 ± 9.0
Lactation length, d	181.2 ± 2.6	182.8 ± 3.0
Total fat yield, kg	17.3 ± .5	17.4 ± .6
Total protein yield, kg	14.8 ± .4	15.5 ± .5
Average somatic cell count, log units	4.82 ± .05[a]	4.96 ± .05[b]

[1] Ewes were classified as two-peak ewes if they exhibited bimodal milk emission during milking (see Figure 1B).
[2] The average of two consecutive morning milkings at approximately 90 d in lactation.
[3]Average milk flow rate = total morning milk yield/total milking time.
[4] Machine milking efficiency = machine milk yield/total milking time.
[5] Subjective score: 1 = much above the hocks, 5 = level of the hocks, 9 = much below the hocks.
[6] Subjective score: 1 = horizontal, 5 = 45º, 9 = vertical.
[a,b] Within a trait, means with different superscripts differ ($P < .05$)
[c,d] Within a trait, means with different superscripts differ ($P < .10$)

Frequency of two-peak milk emission have been reported by other researchers for the Manchega (38%, Such et al., 1999), the Lacaune (83%, Such et al., 1999; 56%, Marnet et al., 1998), and the Rouge de l'Ouest (48%, Malher and Vrayla-Anesti, 1994). It is generally agreed upon that the reason some ewes display two-peak milk emission is because the cisternal milk is completely evacuated from the udder prior to oxytocin's effect on alveolar contraction (approximately 30 to 45 sec during milking, Marnet et al., 1998). In ewes that do not exhibit bimodal milk emission, there are three possible physiologic reasons that the second "peak" is not observed. The first is that even though there is normal oxytocin release and alveolar contraction, cisternal milk volume is sufficiently large so that it takes longer than 45 seconds for its removal (effectively "masking" the two peak milk emission, Bruckmaier et al., 1993). The second reason is that if milk flow rate is low enough, cisternal milk removal is delayed and the second peak is again "masked" by the cisternal milk still in the udder. The third reason, is that oxytocin is not released from the brain, and therefore there is no alveolar contraction; only the cisternal milk is removed from the udder (Labussière et al., 1981; Labussière, 1987; Bruckmaier et al., 1997), resulting in a reduction in commercial milk yield of 14 to 31% compared to two-peak ewes (Labussière, 1969; Labussière et al., 1969). Thus if a ewe displays two-peak milk emission, a producer can be quite certain that milk ejection occurred during machine milking. However, lack of two-peak milk emission does not necessarily imply that milk ejection was inhibited (Marnet et al., 1998).

Failure of milk ejection in EF dairy ewes is a significant problem in some countries where 30 to 45% of ewes were found not to be stimulated by the milking machine (Labussière, 1987; Bruckmaier et al., 1997). Labussière et al. (1981) demonstrated that one-peak ewes had significantly less commercial milk yield than two-peak ewes, suggesting inhibition of the milk ejection reflex in a majority, if not all, of one-peak ewes. This was not the case for the present experiment where we believe the majority of the ewes were sufficiently stimulated by the milking machine. It is likely that most of the one-peak ewes had normal release of oxytocin (thus normal milk ejection) during machine milking because there were no differences in commercial milk yield, nor were there any differences in milk fat or protein over the entire lactation. The explanation for only 43% of the ewes demonstrating two-peak milk emission, is probably due to the fact that the second peak was masked by the large amount of cisternal milk in the udder, and the fact that milk flow rate was not high enough during the first 30 seconds for a significant proportion of ewes, to effectively empty the cistern prior to alveolar milk ejection. Furthermore, 93% of the ewes ruminated during machine milking (data not shown). Because rumination (or cud-chewing) is indicative of good parlor management and ewe comfort during the milking routine, and is anecdotally correlated to oxytocin release (Marnet, 1997), it is likely that ewes in this experiment are sufficiently adapted to machine milking.

Conclusions

Milk flow traits in East Friesian dairy ewes have reasonable repeatability and could be useful in evaluating differences in the ways ewes give their milk to the machine. The incorporation of milk flow data into genetic selection programs of North American dairy ewes should be considered, specifically for traits such as milk flow latency, maximum milk flow rate, average milk flow rate, and stripping percentage. Increasing machine milking efficiency and improving udder morphology traits of dairy ewes should presently be a priority for North American dairy sheep producers.

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FACTORS AFFECTING MILK TRAITS AND UDDER HEALTH IN EAST FRIESIAN MILK SHEEP

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Summary

Milk yield, composition and udder health are influenced by many factors of both biological and non-biological origin. Aim of the following study was to determine the influences of number and stage of lactation, number and weight of born and weaned lambs, and ewe body weight.

Milk samples were taken in a flock of 40 East Friesian dairy ewes in intervals of 14 to 35 days throughout lactation.The characteristics analysed were yield (milk yield at evening milking) and milk composition (fat, protein, lactose) as well as electrical conductivity, somatic cell count and bacterial count. Flock average in 236 days of lactation was 0.73 kg milk per evening milking. Percentage of fat, protein and lactose were 5.60%, 5.25% and 5.05%, respectively.

There is a strong correlation between milk yield and composition (r = -0.61, -0.67 and 0.62 for fat, protein and lactose, respectively). Correlations between the milk contents are slightly lower (0.61, -0.48 and -0.54 for fat-protein, fat-lactose and protein-lactose respectively). Correlation between decadic logarithm of SCC and lactose is r = -0.48. Stage of lactation had the greatest effect on milk yield, milk composition, somatic cell count and electrical conductivity.

SCC (logSCC) throughout lactation is partially strong correlated with SCC (logSCC) at the beginning of lactation (r = 0.42 to 0.73 for logSCC). Number of lactation has no major influence on SCC. Two different types of ewes could be characterised depending on SCC. Type 1 includes all ewes whose SCC is at all or nearly all test days below a threshold of 600,000 cells per ml and type 2 ewes have always a much higher SCC. SCC at the end of the previous lactation also influenced SCC at the beginning of the following lactation (r = 0.44 for logSCC).

Introduction

In many countries demand of sheep dairy products is rising. There are different reasons for this. On the one side there is the fact of sheep milk being an important source of crude protein (Near and Middle East, Africa, Asia), on the other side sheep milk products are an alternative to cows milk products. With global migration, people from traditional sheep milk products prefering nations were spread throughout the world and as a result cheeses and yoghurts of ewe’s milk became known to many other parts of the world (North America, Australia). Sheep milk products are not only a good tasting alternative for consumers but can provide an alternative income for farmers, too. Demand in “new consumer” countries is rising and high importations of those products are resulting. In 1998 the United States of America imported 28.3 thousand (metric) tons of sheep cheese (FAO, 1999). At least a part of the demand can be met by local farmers. But as efficiency and quality become more and more important today, influences on

milk yield, composition and udder health must be known. Characteristics of lactation as well as udder health are influenced by many factors of biological and non-biological origin. Aim of the following study was to determine influence of number and stage of lactation, and number and weight gain of reared lambs.

Materials and methods

The study was conducted in 1999 in a flock of 40 East Friesian dairy ewes. Milking took place on a 12 ewe, side-by-side parlour. Milk samples were taken from March to October, beginning forthnightly and later on in intervals of four to five weeks.

First squirts of each udder half were used to measure electrical conductivity using a *Mastitron plus V* device. Afterwards foremilk samples were taken from each udder half. Those were analysed for somatic cell count (SCC) and bacterial count. Each ewe was milked in a bucket and after weighting milk yield, a sample of the complete milking was taken. Those samples of a ewe's complete milking were analysed for contents of fat, protein and lactose and for SCC.

Data analysis

Only evening milking samples were taken. Because of different reasons, no regression on total day's yield was possible. All lactation yields refer to yield of evening milkings throughout lactation. Two different formulas are used to estimate total production of milk, fat, protein and lactose of total lactation and of milking period, respectively. Following formula was used to calculate an estimate of total production for a *lactation*:

Estimated (evening) lactation yield = [production 1st test day * no. days between parturition and 1st test day] + [prod. 2nd test day * no. days between 1st and 2nd test day] + ... + [prod. last test day * no. days between next to last and last test day]

In oder to have a production based selection criteria, an estimate production of milk, fat, protein and lactose during *first 100 days of milking* following formula was used:

Estimated (evening) 100 days milking yield = [production 1st test day * (no. days between weaning and 1st test day + (no. of days between 1st and 2nd test day)/2)] + [prod. 2nd test day * (no. of days between 1st and 2nd test day + no. of days between 2nd and 3rd test day)/2] +...+ [prod. last test day * ((no. of days between next to last and last test day)/2) + no. days between last test day and day 100 of milking)]

Stage of lactation was based upon 50 day periods (lactation stage 1: milking days 1 to 50, stage 2: days 51 to 100, stage 3: 101-150, stage 4: 151-200, stage 5: more than 200 days of milking). Stage of lactation means are LSmeans.

Body weight of the ewes was recorded after parturition and throughout second half of lactation. Weight of weaned lambs (litter weight) was adjusted to 40 days rearing.

Data analysis was carried out by use of MS Access 97 (Microsoft Corp., 1997) and STATISTICA (StatSoft Inc., 1999).

SCC was transformed into decadic logarithm of SCC (logSCC), in order to reduce the coefficient of variance. Whereas distribution of SCC is left centered the logarithm of SCC is close to a normal distribution (Schulz et al., 1999).

Flock characteristics

Within the flock are five different ewe families with varying numbers of animals. Whereas two lines consist of 17 and 12 ewes, respectively, only 7, 3 and 1 ewes belong to the other three lines, respectively. Sires are bought and used up to 3 years.

Lambing period was from middle January to end of March. Ewes lambed in two major groups (first lambing ewes and older ewes) as a result of breeding management. First lambing ewes were mated in October at the age of eight months and lambed in March. Older ewes were mated about one month earlier and lambed from middle of January to middle of February. Because of the small number of ewes, first lambing ewes are one class and ewes in second or higher lactation are put together in a second class.

Table 1. Number of ewes and lambs within the different lactations

	no. of lactation						
	1	**2**	**3**	**4**	**5**	**6**	**total**
no. of ewes (n)	**18**	**9**	**6**	**2**	**3**	**2**	**40**
no. of living lambs born (n)							
- no lamb	1			-			1
- singles	5			3			8
- twins	8			9			17
- triplets	4			9			13
- quadruplets	-			1			1
no. of lambs weaned (n)							
- no lamb	1			-			1
- singles	5			4			9
- twins	9			9			18
- triplets	3			9			12

Total prolifacy of the flock was 213 %, with 183% and 236% for first lambing ewes and older ewes, respectively. Lambs were weaned after 37.5±7.0 days of suckling. If the one ewe that had no living lamb is not taken into account, then there is no difference in duration of suckling period between young and older ewes. Milking was terminated in early November. At the time of drying off, all ewes were only milked once a day.

Results

Ewes in this flock yielded in a 236 days lactation, 0.73 kg milk per evening milking. Percentage of fat, protein and lactose were 5.60%, 5.25% and 5.05% respectively (Table 2).

Of the 362 examined udders only 41 (11.3%) had no infection in both udder halves, 64% were infected in both udder halves. Only 24% of the 724 foremilk samples were without any infections. 7% (n=51) of the samples were positively tested for mastitis-causing bacteria (staphylococcae: n=7, streptococcae: n=44). In most cases, this infection was restricted to one half of the udder. Incidences of other bacteria were 441, 5, 22, and 8 for micrococcae, coliformic bacteria, pasteurella, and others, respectively.

This extremely high incidence of infections of both mastitis-causing and non-mastitis-causing bacteria has a consequence for somatic cell count without difference between left and right udder halves (Table 3).

Table 2. Evening milk yields and composition for total lactation and 100 days milking period (Means±sd)

Estimate	No. of ewes	Milk yield (kg)	Fat (%)	Protein (%)	Lactose (%)
lactation yield					
total flock	40	0.73±0.13	5.60±0.53	5.25±0.31	5.04±0.16
1st lactation	18	0.72±0.12	5.49±0.54	5.30±0.33	5.13±0.15[a]
≥2nd lactation	22	0.75±0.15	5.70±0.57	5.21±0.30	4.98±0.12[b]
100 day milking yield					
total flock	40	0.95±0.17	5.14±0.48	5.10±0.35	5.13±0.15
1st lactation	18	0.92±0.18	5.02±0.52	5.14±0.38	5.19±0.16[c]
≥2nd lactation	22	0.98±0.17	5.23±0.44	5.06±0.34	5.07±0.13[d]

Within a column and estimate, means with a different superscript are different: [a,b]($p \leq 0.005$), [c,d]($p \leq 0.05$).

Table 3. SCC, logSCC and electrical conductivity (median, mean and standard deviation) in samples of foremilk and complete milking

	Median	Mean	sd
samples of complete milking			
SCC (10^3)	470	2 800	5 600
logSCC	5.67	5.78	0.78
foremilk samples			
electrical conductivity (mS/cm)	5.0	5.1	0.78
SCC (10^3)	87	2 100	6 300
logSCC	4.94	5.27	0.88
left udder half			
electrical conductivity (mS/cm)	5.0	5.15	0.87
SCC (10^3)	84	2 350	6 800
logSCC	4.92	5.28	0.91
right udder half			
electrical conductivity (mS/cm)	5.0	5.07	0.62
SCC (10^3)	91	1 800	5 800
logSCC	4.96	5.26	0.85

In physiological sheep, SCC in complete milking samples is 2.7 times as high as in foremilk samples.

Effect of stage of lactation

The effect of stage of lactation can not be distinguished from the effect of season. No data was accessible for the period of suckling. Therefore only *milking period* was investigated by dividing it into five parts of 50 days length each. Two ewes do not have a milking period longer than 150 days and only 19 ewes do have more than 200 days of milking (lactation stage 5).

In the course of lactation, milk yield and lactose content decrease by 71% and 13%, respectively, whereas fat and protein contents increase by 75% and 24%, respectively. The day of lactation is very strongly correlated with milk yield (-0.82) and fat %, protein % and lactose % (0.76, 0.67 and –0.68, respectively).

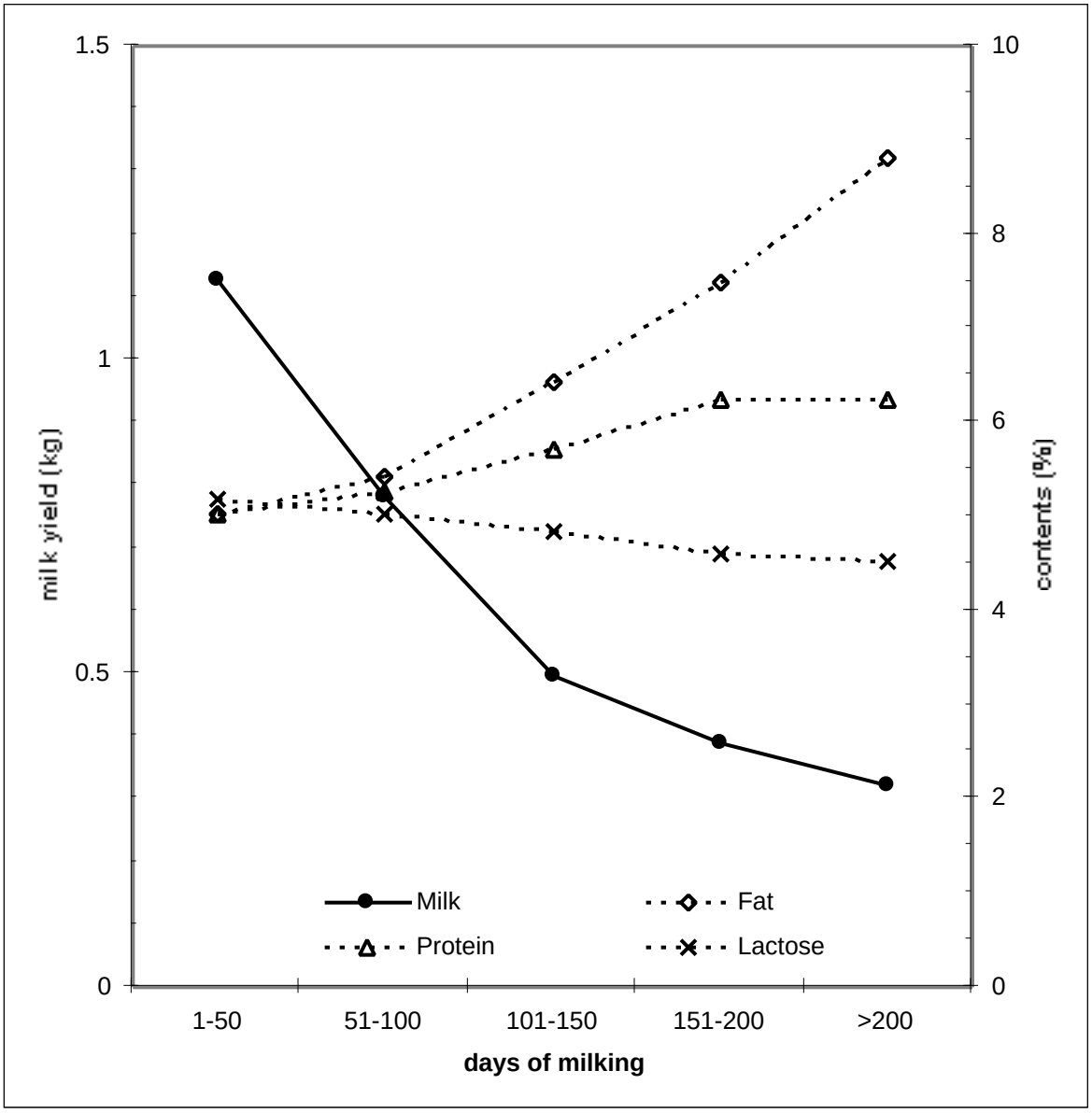

Figure 1: Development of milk yield and composition during milking period

Phenotypic correlations between milk yield and fat %, protein % and lactose %, respectively, are –0.61, -0.67 and 0.62, respectively. Correlation between fat % and protein % is 0.61. These correlations are comparable to Sanna et al. (1997).

The logSCC throughout lactation is partially strongly correlated with logSCC of the first sample taken (0.42 to 0.73). This indicates that an ewe maintains its level of SCC.

There are two different types of ewes regarding SCC. Throughout lactation, Type 1 ewes have nearly always a SCC below a threshold whereas SCC of Type 2 ewes is always above this threshold. This threshold was put to 600,000 cells per ml after previous studies in the same flock (Süß et al., 1999). 67% of ewes in first lactation and 45% of ewes in higher lactation belong to SCC Type 1. A few ewes started lactation as Type 1 ewes and because of infections they had an increase in SCC and stayed above the threshold for the rest of lactation. Because of the low number of these animals (n=3), they were not investigated further and not included in comparisons between the two SCC types.

Table 4. Comparison of SCC Type 1 and Type 2 ewes

	Type 1 SCC*10³ / logSCC	Type 2 SCC*10³ / logSCC
median	170 / 5.22	2 870 / 6.46
mean	346 / 5.28	6 620 / 6.51
sd	500 / 0.45	7 525 / 0.58

Type 1 ewes are considered physiological (Bergonier et al., 1997; cited in Billon and Decremoux, 1998).

Correlation betwen logSCC and electrical conductivity is r=0.50. Both SCC types of ewes show an increase in SCC during lactation. The course of electrical conductivity of the whole flock is similar to the course of SCC except for lactation stage 5, where electrical conductivity decreases (Table 5). But only SCC Type 1 ewes decrease in electrical conductivity (Figure 2).

Table 5. Somatic cells and electrical conductivity throughout milking period (LSmeans±se)

no. of days milking	no. of ewes	logSCC	electr. conductivity (mS/cm)
1-50	40	5.56±0.09[a]	4.90±0.0[d]
51-100	40	5.67±0.11[a,b]	5.06±0.06[e]
101-150	40	5.88±0.12[b,c]	5.23±0.08[f]
151-200	38	6.06±0.11[c]	5.36±0.15[f]
>200	19	6.07±0.18[c]	5.04±0.23[d,e,f]

Within a column, means with a different superscript are different: [a,b,c](p≤0.05), [d,e,f](p≤0.1).

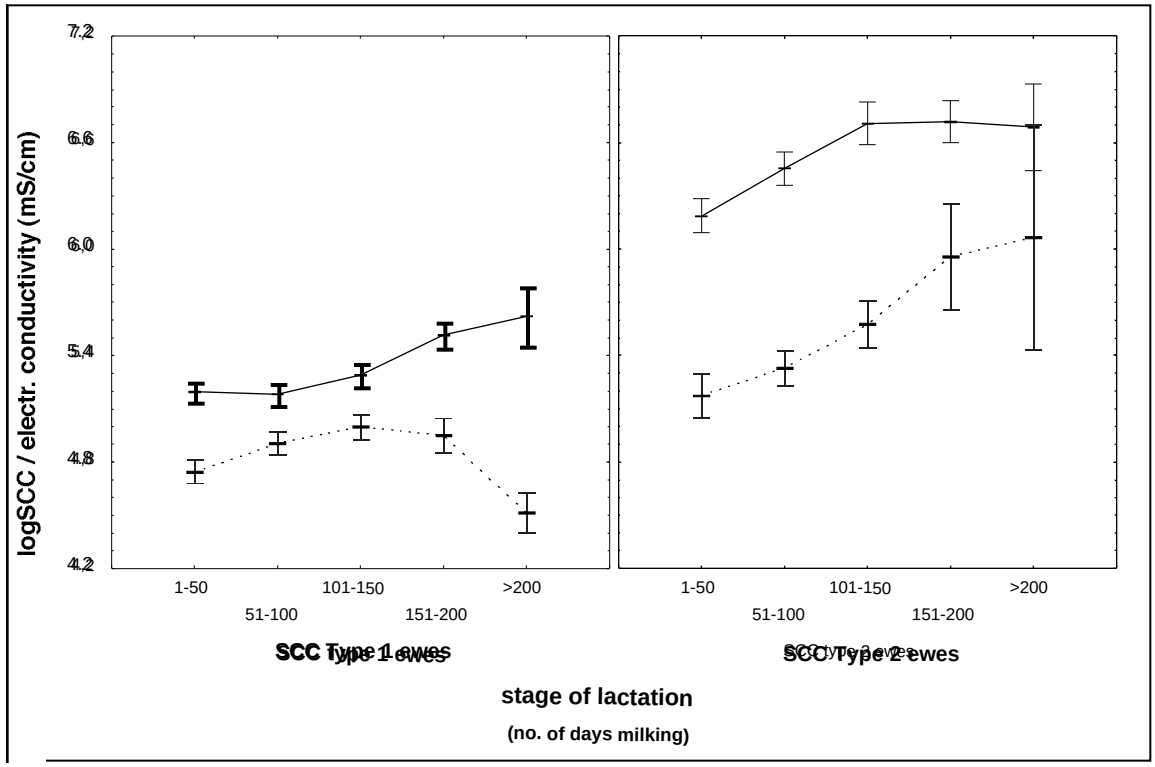

Figure 2: Electrical conductivity (dotted line) and logSCC (full line) throughout milking period depending on SCC types (LSmeans±se)

Effect of number of lactation

In the investigated flock the number-of-lactation effect is comparable to the age-of-ewe effect, because all animals lamb first time at the age of about one year and there is only one mating season. Neither milk yield nor fat or protein content differ between young and old ewes. Only lactose content is significantly higher in 1st lactation ewes than in ≥2nd lactation ewes (Table 2). In general, young ewes have lower SCC than older ewes ($p<0.10$), but within SCC Type 1, logSCC in first lambing ewes is significantly higher than in older ewes (5.35 vs.5.22, that is $225*10^3$ vs. $166*10^3$ cells ml^{-1}, respectively; $p<0.05$).

Using the 1997-1999 data of the official ewe recording, the hypothesis was tested that animals that end a lactation with a high SCC start the following lactation high. In all but two cases the sheep remained in their SCC type. The correlation between logSCC at the end of the previous lactation and logSCC at the beginning of the recent milking period is r=0.44.

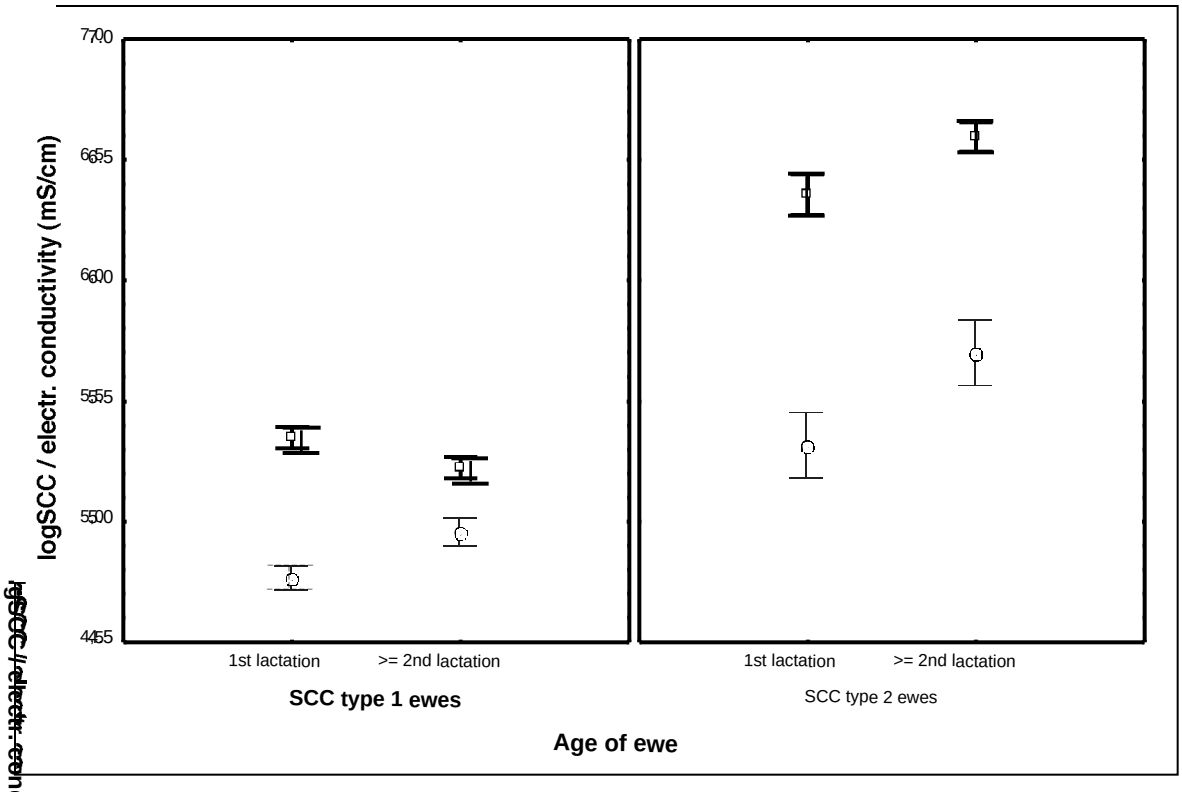

Figure 3: Effect of number of lactation on logSCC (full line whiskers) and electrical conductivity (dotted whiskers) depending on SCC types (LSmeans±se)

Effect of lambs

As previously reported, weight of lambs at birth (Pulina et al., 1996; Süß et al, 1997) and weaning (Süß et al. 1999) have an influence on milk yield. Correlation coefficients between milk yield at the first test day and weight at birth, weight at weaning and rearing performance (g litter weight gain per day

suckling), respectively, are 0.38, 0.44 and 0.42, respectively ($p<0.05$). Significant correlations ($p<0.10$) between protein % and weight at weaning and rearing performance, respectively, are a result of the much closer correlation between milk yield and milk contents.

Number of lambs raised had no significant influence on milk yield or udder health. Nevertheless there are some tendencies to be seen (Figure 4). During first 50 days of milking ewes, that reared more than one lamb had a higher milk yield (1.15 kg vs. 1.07 kg) but lower lactose content (5.15% vs. 5.25%). Electrical conductivity increased with number of lambs, whereas logSCC was not influenced. In contrast, SCC is highest in ewes rearing one lamb or having a rearing performance of less than 550 g/day (non significant). Difference of electrical conductivity between left and right udder halves were largest in ewes that reared 3 lambs (0.42 vs. 0.17 in ewes that reared one or two lambs).

Similar effects can be seen by using rearing performance. Rearing performance was divided into three classes by use of litter weight gain per day suckling: 550 g or less, 551-800 g and more than 800 g.

Table 6. Effect of daily litter weight gain on milk yield, lactose and udder health during first 50 days of milking (LSmeans±se)

Daily litter weight gain	**≤550g**	**>550g ... ≤800g**	**>800g**
no. of ewes	12	14	12
milk yield (kg)	1.05±0.06	1.18±0.06	1.15±0.05
lactose (%)	5.26±0.06a	5.12±0.04b	5.13±0.02b
logSCC	5.62±0.18	5.57±0.15	5.51±0.18
electr. conduct. (mS/cm)	4.73±0.13c	4.90±0.06c,d	5.09±0.16d
difference of electr. cond.	0.21±0.06	0.16±0.04	0.38±0.20

Within a row, means with a different superscript are different: [a,b]($p\leq0.05$), [c,d]($p\leq0.1$).

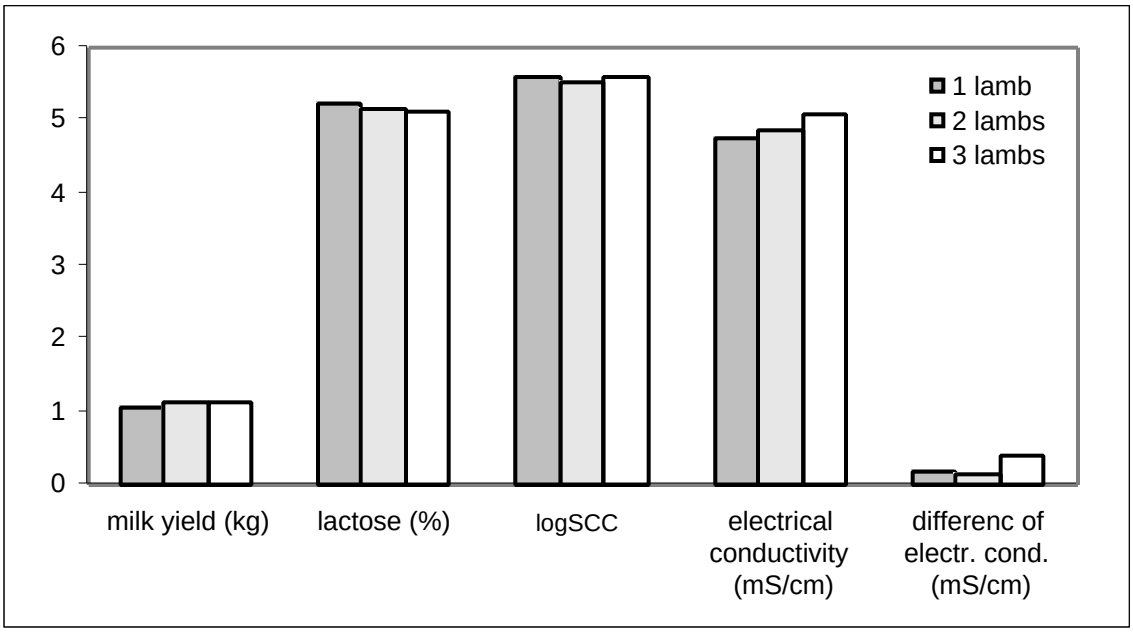

Figure 4: Effect of number of raised lambs on milk yield, lactose and udder health during first 50 days of milking

Discussion

The investigated flock had a high incidence of subclinical mastitis, which causes a decrease in milk yield (Saratsis et al. 1999). Because of this, results may not be comparable to results of other, healthy flocks.

Honegger (1994) reported $280*10^3$ cells per ml as an Average of a flock of East Friesian and Lacaune sheep. Udder healthy ewes had a mean of $103*10^3$ cells per ml. El-Said et al. (1998) defined Churro ewes with a SCC below $250*10^3$ as udder healthy. Bergonier et al. (1997, cited in Billon and Decremoux, 1998) suggested to divide a population into 3 categories: uninfected udders (SCC throughout lactation except for two test days do not exceed $500*10^3$ cells), infected udders (at least two SCC measurements exceed $1{,}000*10^3$ cells) and uncertain infection status (all other cases). In spite of the threshold in this study being $600*10^3$ cells, SCC Type 1 ewes fulfill the requirements of Bergonier's uninfected udder status. So SCC Type 1 ewes can be looked at as physiological or udder healthy. All ewes of SCC Type 2 do have more than two SCC measurements exceeding $1{,}000*10^3$ cells.

Beside infections, other factors can influence SCC. In the course of lactation, SCC is increasing independent from the level of SCC. Saratsis et al. (1999) reported declining SCC towards end of lactation after inducing a subclinical mastitis and thus a high SCC at beginning of lactation.

Electrical conductivity follows the course of SCC, especially in ewes with high SCC. It decreases at the end of lactation (lactation stage 5) in ewes with low SCC. This effect results of a healthy udder, the increase in SCC in the same animals is due to concentration effects (low milk yields at this stage of lactation).

Electrical conductivity can not simply be applied as a mastitis detector because it is affected by various factors, such as breed, milking interval, milk composition, and individual factors (Hamann and Zecconi, 1998).

Regeneration processes in dry dairy cows have been reported by Michel and Schulz (1996). It is very probable that such processes exist in dry ewes, too. No such effect could be proved but this might be due to data sampling, for the first sample was taken after suckling period and more recent factors have had an effect.

Increase of SCC with age of ewe and number of lactation, respectively, as reported by de la Fuente (1997), could only be shown within the whole flock or within ewes that were infected. SCC type 1 ewes showed a lower SCC in second or higher lactation than in first lactation. This might be due to a comparatively high prolificacy in first lambing ewes. Süß et al. (1999) reported litter sizes of 1.7 and 2.6 lambs for first lambing and mature ewes, respectively.

Litter size and rearing performance do have an influence on udder health. Electrical conductivity increases with number of reared lambs and daily litter weight gain during suckling period, but SCC seems not affected.

Milk yield and milk composition are markedly influenced by stage of lactation in accordance with Gosling et al. (1997), Ploumi et al. (1998), Labussiere (1988) and Wohlt et al. (1981). As reported by Wohlt et al. (1981), no significant differences could be detected in the effect of number of lactation. This is in contrast to other authors (Ploumi et al., 1998; de la Fuente et al.,1997; Gosling et al., 1997) who stated an increase in milk yield from first to fourth and fifth lactation , respectively. Varying reports are given on milk composition by the same authors. Because of the limited flock size a further differentiation of number of lactation was not possible.

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DESIGN AND IMPLEMENTATION OF A GENETIC IMPROVEMENT PROGRAM FOR COMISANA DAIRY SHEEP IN SICILY

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Introduction

In Italy, the Comisana is the second most important dairy breed of sheep, after the Sarda. The breed is native to Sicily and mostly raised in the marginal Central and Southern areas of the country. The importance of the breed is related to its high genetic potential to produce milk in the extreme environmental conditions of the Mediterranean. Its resistance to diseases and heat is very high. Milk from Comisana sheep is mostly processed on-site to produce a variety of traditional high quality homemade cheeses of which the most popular is Pecorino Siciliano. High fertility and prolificacy makes the Comisana an excellent dual-purpose breed with about 1/3 of the total income coming from meat. These products represent a precious economic resource for the marginal areas where they are produced.

There is growing interest in dairy sheep production systems in Europe, where present CE agricultural policy is actively supporting development of sustainable agricultural production systems to ensure the longevity and economic vitality of marginal rural communities. Moreover, the potential for expanding the dairy products market within and beyond the European Community is very high.

Genetic improvement of local dairy sheep breeds and populations is an important component of the development of a viable dairy sheep industry. At present, the genetic progress for milk production in the population of Comisana sheep is very small, probably close to zero, and the observed phenotypic change in milk production, if any, is mostly environmental. Poor animal identification, a very small proportion of animals and flocks enrolled in a production recording system and small flock size hamper the opportunity for genetic improvement. Though artificial insemination with fresh semen and induced estrus is possible in dairy sheep, there is no infra-structure to facilitate its utilization in the Comisana breed. Consequently, the only tool available for genetic improvement is within-flock selection. The within-flock selection that is occurring is not effective for the following reasons:

- The selection practiced is of a very low intensity and accuracy. This is true especially for rams, which are selected from the "best" ewes without adjusting for non-genetic effects. The accuracy of estimated genetic merit of a ram from the production of his mother is only $\sqrt{1/4h^2} = 0.25$ (if $h^2 = 0.25$);
- Multiple rams are generally used simultaneously in the flock, so paternity is not known;
- The criteria used in selection are different from farm to farm;
- Much attention is given to morphological traits, which have unknown (probably low) genetic correlation with milk production;

Last but not least, at the present time there is no genetic structure in the population to facilitate the dissemination of genetic progress, even if it was somehow generated. Under these conditions, an effective genetic improvement program needs to be developed within the framework of a pyramidal management of the population (Barillet, 1997). With such a structure, breeders are divided into at least two groups: the selection breeders of the nucleus flocks and the breeders of the commercial flocks. The tools required by the breeding program, such as animal identification, control of production, data collection and storage, progeny testing, elite mating, etc., could be concentrated in the nucleus flocks. Such a program has been developed and is being implemented for the Comisana breed by the Istituto Sperimentale Zootecnico per la Sicilia and Cornell University. The characteristics of the program as well as the results of the last three years of activity are presented in this paper.

Breeding program.

Objective: Genetically improve the dairy traits (milk yield and composition) for the entire population of the Comisana breed in Sicily. To accomplish this objective a pyramidal breeding program is needed. In such a program, the population is divided in several strata with a nucleus, where the genetic progress is generated, and a mechanism to ensure the dissemination of the genetic progress through the rest of the pyramid.

A dairy sheep breeding program, to be effective, must be based on progeny test, must be able to accurately evaluate the genetic merit (breeding value) of males and females, select the superior males and females to be parents of the next generation and disseminate the genetic superiority to the entire population. The major components of the breeding program are:

1. Create a nucleus flock (top of the pyramid) in which the genetic improvement is generated via intense selection of males and females to be parents of the next generation.
2. Implement a good on-farm animal identification and production recording system for the nucleus.
3. Implement a progeny-testing program for young rams produced by elite matings in the nucleus.
4. Implement an evaluation program to estimate the genetic merit of all males and females in the nucleus and use it to identify genetically superior individuals as parents for the next generation.
5. Create a multiplication flock to produce young rams for the next cycle (best 100 ewes mate with best 2 proven rams) and breeding rams to be used to disseminate the genetic superiority to the whole breed (all other ewes in the multiplication flock mate with top 6 proven rams).
6. Develop a strategy to ensure the gene flow from the apex (nucleus) through the rest of the genetic pyramid.

Nucleus flocks. The Comisana nucleus was started in 1994 when Istituto Sperimentale Zootecnico per la Sicilia purchased about 600 ewes from the expansion area of the breed (Sicily,

Lazio, Toscana, and Abruzzo). The nucleus was expanded in 1998. Today it consists of seven flocks of which one flock of about 450 milking ewes belongs to the Istituto Sperimentale Zootecnico, five flocks of 600, 500, 220, 150 and 120 milking ewes are typical commercial farms, and one flock of 100 milking ewes belongs to an agro-tourist farm.

Animal identification and milk recording. Initially, a standard A_4 testing program (ICAR nomenclature) consisting of monthly recording of the two daily milkings for milk quantity and composition was adopted. Individual milk samples were collected at each milking and milk composition (fat %, protein %, lactose % and somatic cells count) was determined by the Istituto Zooprofilattico Sperimentale della Sicilia "A. Mirri". Starting with fall 2000 a hybrid system consisting of A_4 testing for milk yield and AC testing for milk composition (corrected monthly test with individual samples for morning milking corrected for evening/morning differences in milk composition using bulk tank samples from morning and evening milk produced by the whole flock) has been adopted. Records are collected and stored using "Progecom" software package developed by A. Carlucci from the Associazione Allevatori di Matera, Italy. The package consists of a data base management program, an electronic animal identification system and a filed interface program that interrogates the animal identification system and facilitates the collection of records on farm and their transfer to the data base management program. The electronic animal identification system consists of a microchip type ISOHCX stored in a passive, battery-less device named "rumen bolus". The rumen bolus is orally introduced and resides permanently in the animals' reticulum. This system should greatly simplify and improve the accuracy of the control of production activity.

Genetic theory tells us that the genetic change we can achieve through selection depends on selection intensity, accuracy of selection and the amount of genetic variation present in the population. Selection intensity, i, is a prediction of the superiority of selected parents, expressed in units of standard deviation, and is a function of the proportion selected. The accuracy of selection, $r_{BV,EBV}$, is an indicator of how well we can estimate true genetic merit and is measured by the correlation between true and estimated breeding value. Therefore:

ΔG = (selection intensity) (accuracy of selection) (Additive Genetic Standard Deviation)
$= (i)\ (r_{BV,EBV})\ \sigma_{BV}$

In a program with 4-pathways structure, each path contributes to the total genetic change and, because selection intensity, accuracy of selection and generation interval are different for each path, they need to be considered simultaneously in order to optimize the entire program. The expected genetic change per year, Δg, is:

$$\Delta g = (\Delta G_{SS} + \Delta G_{SD} + \Delta G_{DS} + \Delta G_{DD})/(L_{SS} + L_{SD} + L_{DS} + L_{DD})$$

Progeny testing of young rams. A progeny test based program was designed to optimize the rate of genetic progress in the nucleus given its size and the biological parameters of the population (pregnancy rate, survival rate from birth to milking string, prolificacy, etc.). Such a breeding program has a 4-pathway structure:

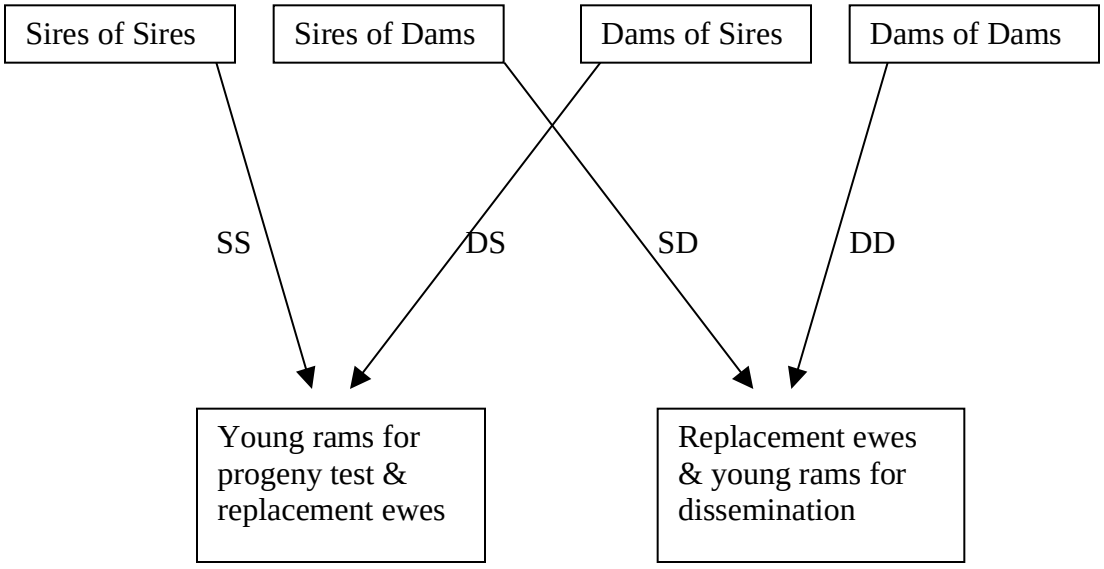

Figure 1. Gene flow diagram in 4 pathways breeding program.

With breeding restricted to natural mating and higher prolificacy in sheep, the sire-son and sire-daughter pathways are not as dominant and the dam-daughter pathway is not as negligible as in dairy cattle.

The first step in the design of a breeding program is to determine the testing capacity of the nucleus, i.e., the number of daughters completing the first lactation that can be generated. To determine it, we need to consider the production system and its management practices. In commercial flocks there are two breeding seasons each year. Spring breeding is in March, April and May when all pluriparous ewes are covered and Fall breeding is in September, October and November when all primiparous ewes born the previous fall and pluriparous ewes still open are covered. Ewes pregnant from fall breeding are lambing in February, March and April, have a short lactation of about 150 days, are re-bred the next spring and all lambs are sold for meat at Easter. Ewes pregnant from spring breeding are lambing in September, October and November, have a long lactation of about 250 days, are re-bred the following spring and the female lambs born are kept as replacements while the male lambs are sold for meat at Christmas. With this production system, young rams in progeny test should be used only during spring breeding season to ensure that their daughters are kept as replacements for the milking flock. Breeding is limited to natural mating and, because the production system is based on natural pasture, it is difficult to create and maintain isolated small breeding groups. To be able to produce groups of daughters with known paternity needed for progeny test, we had to resort to sequential estrus synchronization and breeding of groups of ewes. Given these limitations, the testing capacity of the nucleus is about 400 daughters.

The nucleus is structured in a multiplication group of about 500 ewes and a progeny-testing group consisting of all other pluriparous ewes in the nucleus. We need 6 rams each year to cover the multiplication group of 500 ewes; best 2 rams for elite mating to produce the next batch of young rams for progeny test (Sires of Sires, SS) and all 6 rams to produce the replacements for the multiplication group (Sires of Dams, SD) and the rams to be used to disseminate genetic superiority through the rest of the population (breeding rams for the second stratum of the genetic pyramid). With 6 proven rams needed and the testing capacity of 400 daughters, an optimum program needs to balance the number of young rams progeny tested (selection intensity) and the number of daughters per ram (accuracy) to maximize the genetic superiority of the rams selected. In Table 1 the magnitude of ΔG_{SS} and ΔG_{SD} is presented for various selection intensities.

Table 1. Genetic superiority of the best 6 rams to be used as sires of dams (ΔG_{SD}) and the best 2 rams to be used as sires of sires (ΔG_{SS}) calculated as a function of selection intensity[1] and accuracy[2], given a testing capacity of 400 daughters.

			Top 6 rams as Sires of Dams SD			Top 2 rams as Sires of Sires SS		
Nr. Rams tested	Nr. Daughters per ram	Accuracy	% selected (p)	Selection intensity (i)	ΔG_{SD}	% selected (p)	Selection intensity (i)	ΔG_{SS}
10	40	.853	.600	0.646	$0.551\sigma_{BV}$	.200	1.399	$1.193\sigma_{BV}$
16	25	.791	.375	1.012	$0.800\sigma_{BV}$	.125	1.647	$1.303\sigma_{BV}$
20	20	.756	.300	1.156	$0.874\sigma_{BV}$	.100	1.754	$1.326\sigma_{BV}$
25	16	.718	.240	1.298	$0.932\sigma_{BV}$	.080	1.854	$1.331\sigma_{BV}$
30	13	.681	.200	1.399	$0.953\sigma_{BV}$	.067	1.939	$1.320\sigma_{BV}$
40	10	.632	.150	1.557	$0.984\sigma_{BV}$	.050	2.059	$1.301\sigma_{BV}$
50	8	.600	.120	1.663	$0.998\sigma_{BV}$	.040	2.154	$1.292\sigma_{BV}$

[1] $i = z/p$ where p is the proportion of rams selected and z is $f(x=p)$ when $f(x) \sim N(0,1)$

[2] $r_{BV,EBV} = \{nh^2/[4+(n-1)h^2]\}^{1/2}$

Table 1 shows that ΔG_{SS} and ΔG_{SD} are highest when 25 and 50 young rams are tested, respectively. Our objective is to maximize ($\Delta G_{SS} + \Delta G_{SD}$) and its value is essentially equal if 40 or 50 young rams are tested each year. The cost of progeny testing is high and it depends entirely on the number of rams tested. Therefore, implementing a program in which 40 rams are progeny tested each year makes genetic as well as economic sense.

With the nucleus made up of 7 separate flocks, an effective progeny-testing program has to be carried out between flocks and this is possible only if genetic ties between all flocks of the nucleus are created. Using rams uniformly across all flocks is the best way to create genetic connections between flocks. Short of using AI, this is impossible to achieve. A strategy was developed to create genetic ties between flocks with natural mating by assigning a limited number of rams to have daughters in two flocks. The diagram in Figure 2 illustrates this strategy.

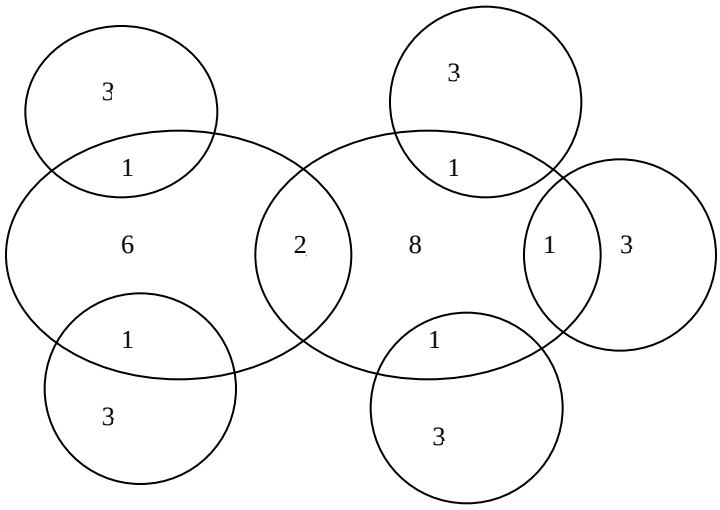

Figure 2. Design of breeding groups in the nucleus to create the genetic ties needed to perform between-flocks genetic evaluation for the young rams in progeny test. Each circle represents a different flock, and the numbers are the number of rams used exclusively in one flock or in two flocks.

The sequence of events and the time scale for progeny testing young rams is illustrated in Table 2.

Table 2. Time line for the progeny testing of young rams.

AGE OF THE RAM	EVENT
Month 0	The ram is born
Month 18	Start of breeding activity
Month 23	Daughters are born
Month 33	Daughters are covered
Month 38	Daughters are starting first lactation
Month 42	Daughters complete first lactation
Month 43	Genetic evaluation of the ram
Month >43	Superior proven ram used for breeding

After progeny test breeding, the young rams are kept in waiting until their daughters complete first lactation and their breeding value is estimated.

Genetic evaluation program. Best linear unbiased prediction (BLUP) applied to an animal model (AM) is the standard procedure for genetic evaluation. It has the advantage that all known information is optimally taken into account and selection or special mating has a small or no effect on the evaluation. This procedure is even more valuable in dairy sheep because, with natural mating, the number of progeny per ram is relatively small, which makes information from other relatives more important.

Control of production occurs on a monthly basis and milk yield as well as milk composition information are recorded on the day of control. Recent work on milk yield performance has indicated that additional information (and accuracy) is obtainable by analyzing test day records with an animal model (TDAM) for genetic evaluations of the parents of future generations of dairy ewes. More milk yield records per ewe (up to 10 per lactation instead of one record per lactation), permits a more unique definition of the contemporary groups (CG) of animal cohorts (the TD effect). Consequently, the accuracy of genetic evaluations using TDAM models is greater than using cumulative milk yield information.

An autoregressive test day animal model (TDAM) developed by J. Carvalheira (Carvalheira et al., 1998) is being used for the genetic evaluation of the animals in the nucleus. The computer software is based on a series of programs that build the incidence matrices according to the structure of the data, and compute the inverse of the genetic additive relationship matrices to be incorporated into the coefficient matrix of the BLUP mixed model equations.

Multiplication flock. The flock located at the Istituto Sperimentale Zootecnico performs this function. Elite mating of the 100 best ewes with the top 2 proven rams is used to produce the young rams for progeny test. The top 6 proven rams covers the remaining ewes to produce the replacement ewes for the multiplication flock and the breeding rams for disseminating genetic progress trough the rest of the population. A diagram describing the production of young rams for progeny testing and of breeding rams for dissemination of the genetic progress is in Figure 3.

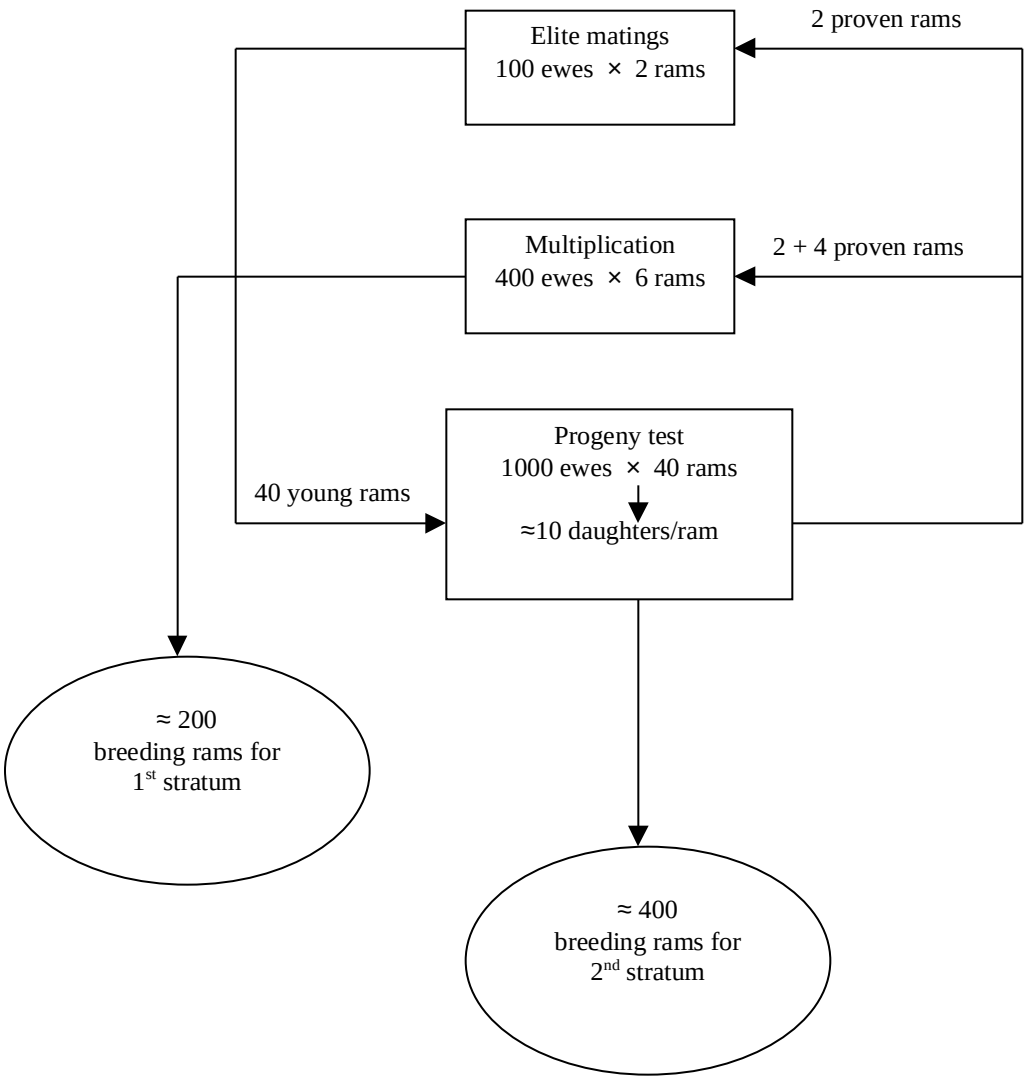

Figure 3. Production of young rams for progeny test and for dissemination of genetic progress through the population.

The genetic pyramid has a simple structure, with the nucleus group at its apex and two strata of flocks. The first stratum is represented by flocks enrolled in the National Production Recording program that also have good animal identification systems, adequate management, and with at least 50% of their animals registered in the Genealogical book of the breed. With these requirements, these flocks should be able to produce breeding rams, which we expect to be sold for use in the third stratum of the pyramid consisting of all other commercial flocks in Sicily. A diagram of the genetic pyramid is shown in Figure 4.

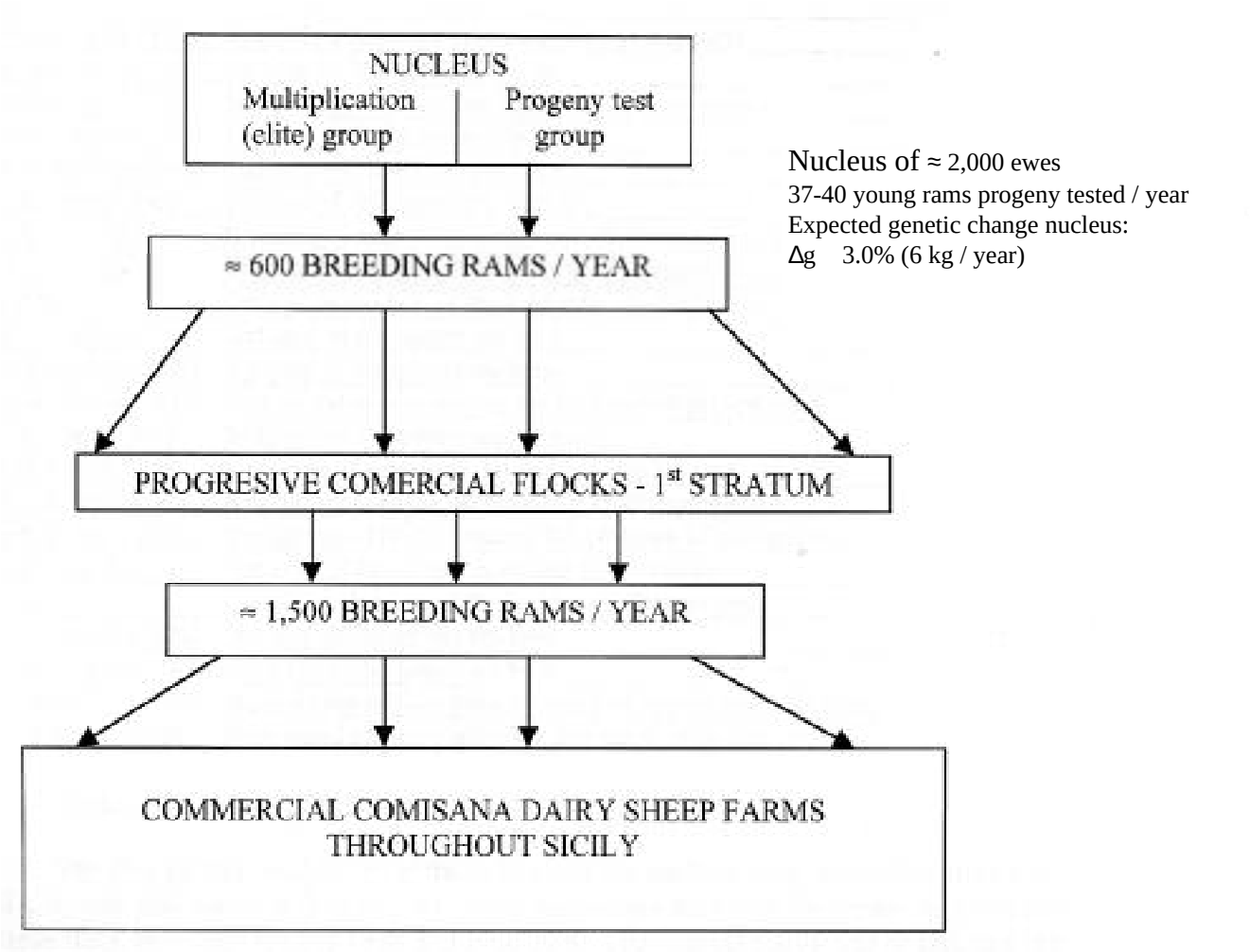

Figure 4. Diagram of the genetic pyramid

Results and Discussion.

The first cycle of progeny testing was carried out in a single flock in 1996 – 1998, with 30 rams being ultimately evaluated. The best 4 rams were used to cover the best 60 ewes (elite mating) and produced the second batch of young rams. In January 1999, the nucleus was expanded to include 6 new commercial flocks. A new group of 36 young rams started the progeny testing cycle in Spring 1999. This group consisted of 20 young rams from the previous cycle of elite mating and the others were rams from inside the new flocks added to the nucleus. The program has the sequence of activities well structured now, and it is expected to reach the steady state by Spring 2002. A time diagram of the expected events and activities in the nucleus for the 4-year period between 1999 and 2003 is shown in Table 3.

Table 3. Time line of events and activities in the nucleus.

March & April 1999	Breeding groups for 1st batch of 36 young rams
Sept. & October 1999	1st crop of Daughters are born
March & April 2000	Breeding groups for 2nd batch of 36 young rams
Sept. & October 2000	1st crop of Daughters are bred
Sept. & October 2000	2nd crop of Daughters are born
Feb. & March 2001	1st crop of Daughters are lambing
March & April 2001	Breeding groups for 3rd batch of 36-40 young rams
June & July 2001	1st crop of Daughters complete first lactation
July 2001	Genetic evaluation of the 1st batch of tested rams
Sept. & October 2001	2nd crop of Daughters are bred
Sept. & October 2001	3rd crop of Daughters are born
Sept. & October 2001	First round of elite mating for 1st batch of proven rams
Feb. & March 2002	2nd crop of Daughters are lambing
Feb. & March 2002	First crop of sons from 1st batch of proven rams are born
March & April 2002	Breeding groups for 4th batch of 36-40 young rams
March & April 2002	Second round of elite mating for 1st batch of proven rams
June & July 2002	2nd crop of Daughters complete first lactation
July 2002	Genetic evaluation of the 2nd batch of tested rams
Sept. & October 2002	3rd crop of Daughters are bred
Sept. & October 2002	4th crop of Daughters are born
Sept. & October 2002	Second crop of sons from 1st batch of proven rams are born
Sept. & October 2002	First round of elite mating for 2nd batch of proven rams

The first genetic evaluation of the animals in the nucleus using a test-day animal model (TDAM) was performed in August 2000 using production data collected from the ewes in the nucleus flock between October 1998 and June 2000. The first objective was to estimate the (co)variance components and genetic parameters for test day records of the Comisana ewes using an autoregressive test day model. The second objective was to perform a genetic evaluation for ewes and rams in the nucleus flock using all sources of information in an animal model using BLUP methodology.

The following model was used to describe the data:

$$Y_{ijkmnpqr} = YM_i + AGE_j + DIM_k(L_m) + A_n + LTE_p + STE_q + E_{ijkmnpqr}$$

where:

Y is test day observation,
YM is fixed effect of year-month ,
AGE is fixed effect of age at lambing,
DIM(L) is the fixed effect of days in milk nested within lactation,
A is the random effect of the animal,
LTE is the random long-term environmental effects accounting for the autocorrelations generated by the ewe across lactations,
STE is the random short-term environmental effects accounting for the autocorrelations due to the ewe within each lactation, and
E is the random residual effect assumed normally distributed.

Table 4 shows the size of the data set used in this study and the number of levels for each fixed effect in the model.

Table 4. Number of observations and levels of fixed effects for the test day milk data.

No. of animals with records	398
Total no. of animals	1228
Total no. of test day records	2439
No. of year-month levels	18
No. of age levels	10
No. of lactation-days in milk levels	62
Lactation 1:	
No. ewes with records	181
No. test day observations	751
Lactation 2:	
No. ewes with records	181
No. test day observations	857
Lactation >2:	
No. ewes with records	140
No. test day observations	831

The number of individuals in the pedigree file was 1228. In the pedigree file we had 111 sires of which 61 were foundation rams with unknown birth date, 596 dams of which 375 ewes were foundation ewes with unknown birth date, and 521 offspring. Foundation sires and dams were considered unrelated and were given arbitrary birth dates 3 years prior to the birth date of the first offspring. Year-month fixed effects consisted of year 1998, October to December, year 1999 January to April and August to December, and year 2000, January to June, for a total of 18 year-month levels. Age at lambing fixed effects consisted of < 15 mo., 15 to 16 mo., 17 to 18 mo., 19 to 20 mo., 21 to 22 mo., 23 to 26 mo., 27 to 30 mo., 31 to 36 mo., 37 to 42 mo., and > 42 mo., for a total of 10 levels. Days in milk by lactation fixed effects consisted of 10 day-intervals between 20 and 180 days for first lactation and between 20 and 240 days for second and for third or greater lactation, for a total of 62 levels.

The lactation curves for first, second, and third and greater lactation for the first 140 days of lactation are shown in Figure 5. These curves are constructed using the solutions for days in milk by lactation fixed effects. These solutions represent test day production adjusted for all effects in the model, including genetic differences, so what remains is almost entirely nutritional management. It is interesting to note lower production and higher persistency for first lactation relative to lactation 2 or greater, very similar to what occurs in dairy cattle. The production system is based on a seasonal pattern of lambing, with most of first lactation ewes lambing in February, March and April and most of second or greater lactation ewes lambing in September, October and November. Consequently, the differences in milk yields and shape of lactation curves between first lactation and second or greater lactation for the Comisana ewes are due to biological factors associated with maturity as well as nutritional factors associated with different seasons of lambing. The 140 days cumulative milk yield for first, second and third and greater lactation is 83 kg, 225 kg and 200 kg, respectively. These yields are in line with average production for the Comisana ewes in Sicily.

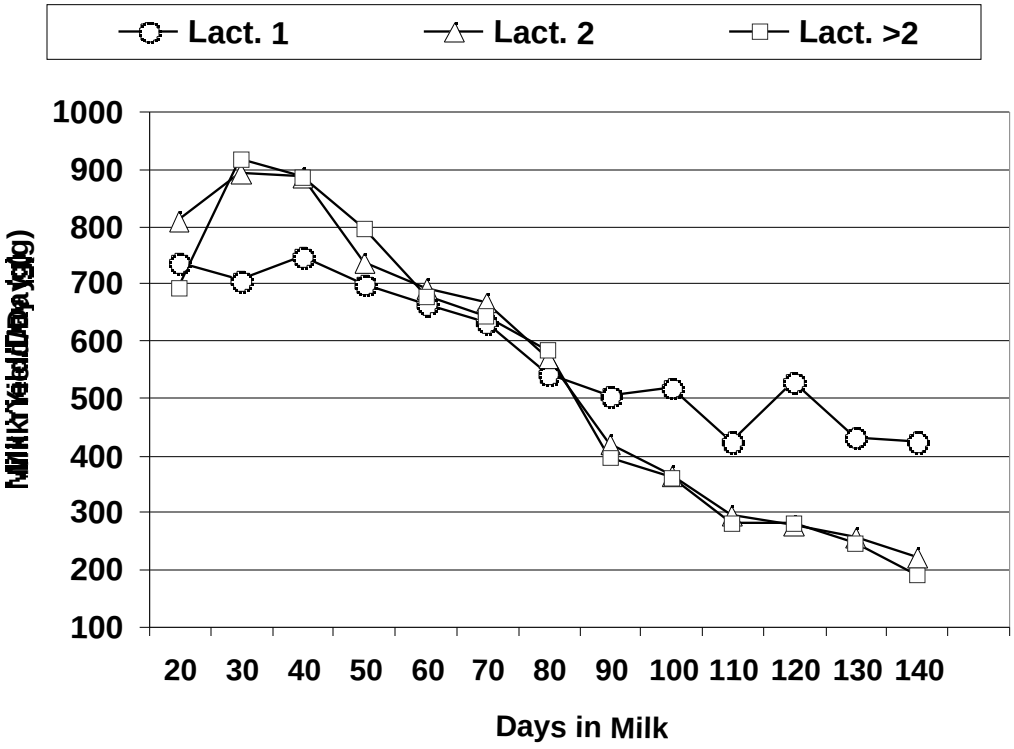

Figure 5. Lactation curves for first, second, and third and greater lactation for Comisana ewes in the breeding nucleus, 1998-2000 data.

The variance components and the genetic parameters were also estimated and are presented in Table 5. The estimated variance components are used as inputs for subsequent genetic evaluation analysis, which includes the genetic ranking of all individuals in the data set. The genetic variance is small relative to phenotypic variance, resulting in heritability values lower than 0.2 for each parity considered. These values are somewhat lower then other estimates for heritability of milk yield for dairy sheep, which are in the 0.25 to 0.3 range, similar to heritability for milk production dairy cattle. These lower estimates are data related and a direct consequence of a relatively small data set with many animals in the population genetically unrelated. With the expansion of the size of the nucleus and a better genetic structure, we expect to obtain higher estimates of heritability in the next evaluation.

The size of the estimated short term environmental variance for each lactation indicates that an important part of the non-genetic variation due to the repeated effect of ewe within lactation was accounted for by this effect. The test day records were highly correlated within lactation, with STE autocorrelation of 0.47, 0.59 and 0.5 for first, second, and third or greater lactation, respectively. Long-term environmental effects had a negligible impact on milking performance with long-term environmental autocorrelation of essentially zero.

Table 5. Variance components and genetic parameters for daily milk yield (g) for the Comisana breed.

Genetic variance	14148.11
Error variance	10576.40
Long term environmental variance	8858.68
Long term environmental autocorrelation	0.0007
Short term environmental variance (Lact.1)	42966.82
Short term environmental autocorrelation (Lact.1)	0.47
Short term environmental variance (Lact.2)	66414.70
Short term environmental autocorrelation (Lact.1)	0.59
Short term environmental variance (Lact.>2)	55271.13
Short term environmental autocorrelation (Lact.>2)	0.50
Phenotypic variance (Lact. 1)	76550.02
Phenotypic variance (Lact. 2)	99997.90
Phenotypic variance (Lact. >2)	88854.33
Heritability (Lact. 1)	0.19
Heritability (Lact. 2)	0.15
Heritability (Lact. >2)	0.16

In the second stage of the analysis the breeding values (EBV) and accuracy of EBV were estimated for all animals in the data set. Using BLUP methodology, these estimates are pre adjusted for all other effects included in the model.

The EBV milk yield per day for all 1228 animals in the analysis has a mean of 3.8 g., standard deviation is 50.15 g. and minimum and maximum EBV values are –181.8 g. and + 169.0 g. for a total range of 350.8 g.

When only the 111 sires in the data set are considered, the mean EBV is –1.2 g., standard deviation is 45.05 g. and minimum and maximum EBV values are –121.0 g. and + 126.9 g. for total range of 247.94 g. For 596 dams and for 521 offspring in the data set the values for the same statistics are 3.7 g., 50.0 g., -183.6 g., +190.6 g., 374.2 g. and 4.9 g., 51.4 g., -183.6 g., +190.6 g. and 374.2 g., respectively.

These results indicate that good opportunity exists for selection and, therefore, for genetic progress. For example, the EBV for the top 90% of the dams is between 68.3 and 190.6 g of milk per day. This is equivalent to a genetic superiority between 10.2 and 28.6 kg of milk per 150 days lactation.

In Figure 6, the distribution of EBV for all animals is presented and in Figure 7 the distribution of EBV is presented separately for dams, sires and offspring in the data set.

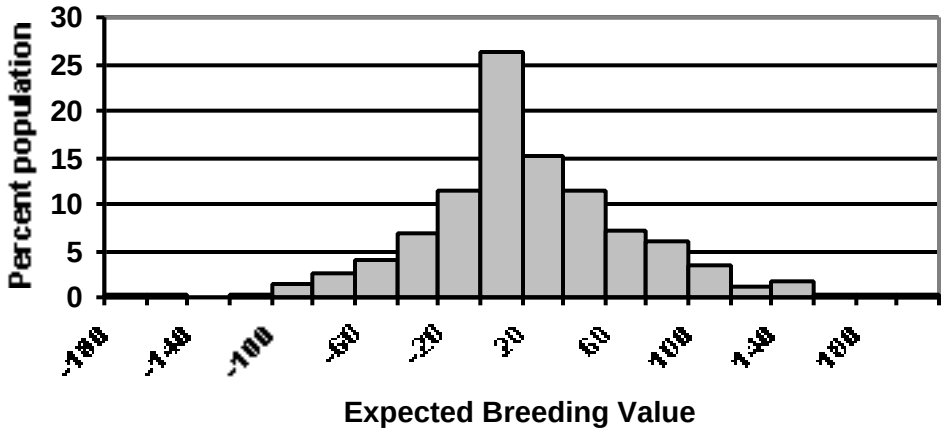

Figure 6. Distribution of EBV for all animals in the data set

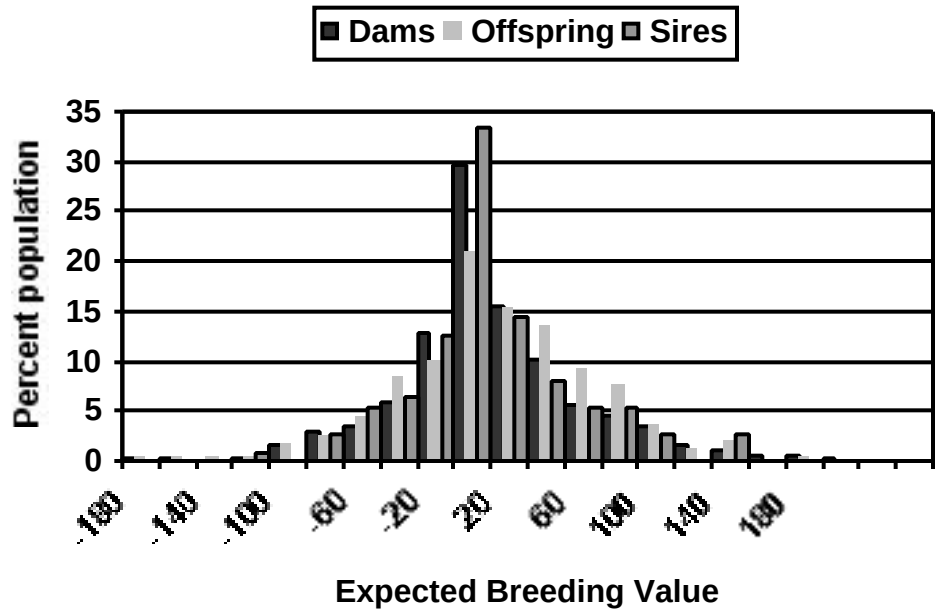

Figure 7. Distribution of EBV for dams, sires and offspring in the data set.

To estimate the genetic trend for the animals in the evaluation, the regression of EBV on the year of birth was evaluated. The estimated regression coefficient was 2 g/day/year, indicating a genetic trend of 300 g of milk for 150 days lactation. This data set reflects the initial phase of the breeding program and a low within flock selection was applied. When the information from the progeny testing of rams becomes available, it will greatly increase the contribution of the SS and SD paths. It is therefore expected that the genetic trend in the nucleus will be 2.5 to 3% of the mean, or about 6 kg of milk per year as indicated in Figure 4.

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DEVELOPMENT OF A COMPUTERIZED DAIRY RECORD KEEPING SYSTEM

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In 1999 the Ontario Dairy Sheep Association and the EweByte sheep flock recording system received a grant from the CanAdapt Small Projects Initiative to develop a record keeping system for dairy sheep. The project included a survey of dairy sheep farmers to get a profile of the management and record keeping methods currently in place and to find out what producers would want from a computerized record keeping system.

The goal was to develop a program that is flexible enough to be useful in a wide variety of management systems by providing reports suited to the individual producer. The existing EweByte program already collects breeding and lambing dates, health records, vaccinations and other maintenance procedures and performance records (ADG, EPDs, indexes). The milk module taps into these existing records to create reports specific for milk production.

The milk module integrates fully with the existing management portion of the EweByte program. The producer enters dates for beginning and end of milking and weaning as well as test dates and results. The program assigns a lactation number, calculates the days in milk, yield, fat, protein, somatic cell count and linear score. It also provides room to track two additional parameters that can be defined by the producer (e.g. bacterial count, pH, acidity).
A variety of reports are generated from this database. Customizing screens allow the producer to specify the time frames, animals to be included in the report and the sorting options. This gives the program the necessary flexibility to be useful under different management styles and to accommodate individual producers goals and preferences.

Currently the program has five main dairy report screens:

- A management list provides information on the current dairy status of the ewes (dry, nursing, milking, milking and nursing).
- The ewe flock summary gives the current number of ewes in the various possible management groups; it can be further customized to be divided by breed or group.
- The dairy ewe management report gives detailed information on individual animals. It lists individual test results and gives a summary of production for each lactation. This includes lactation number, days in milk, avg. daily milk production, avg. fat and protein percentages, total milk production, kg of fat and protein produced, avg. somatic cell count (SCC) and linear score (LS).
- The report on single test days lists the individual results for a specified date. It includes the measured milk, fat, protein, SCC and LS for the test day and calculates the production to date in this lactation. The results can be sorted by any of the measured or calculated parameters to allow the identification of problem animals or superior producers.
- The test day summary report summarizes the results of a single test day and displays these results for the specified time period. This is most useful for the detection of flock trends and for the comparison of production years.

A summary report for individual animals is still under construction, but will be added in the near future. This report will allow comparisons between lactations and years for specified groups of animals or the entire flock.

The program is currently tested by a number of participating dairy producers and will be released with the next version of EweByte.

AN UPDATE ON COOPÉRATIVE LAITIÉRE OVINE DU QUÉBEC (Co.L.O.Q.)

Jean-Guy Fillion, Secretary/Tresurer, Co. L.O.Q., St. Remi de Tingwick, Quebec, Canada and Daniel Vasseur, Manager, Co.L.O.Q., Bécancour, Quebec, Canada

Coopérative Laitière Ovine du Québec is a cooperative that represents most of the dairy sheep producers in Quebec for the sales of their milk to different processors.

Some facts on how and why the cooperative was formed…

- The first delivery of milk started in 1997 with two producers and one buyer. The production was 4,500 liters.
- In 1998, one more producer and two new buyers were added. The production was 15,000 liters sold.
- In January 1999, 5 producers worked together and scheduled their deliveries to 3 different cheese factories. Everything was being done with verbal agreements. Things were going fine and looked pretty good. The quantities the buyers wanted were the same as what we were forecasting as producing.
- But come summer 1999, the situation changed drastically. One cheese factory shut down and the other two stopped buying milk for differents reasons. So then, the stockpile of frozen milk started.
- At that time, we decided to look for a different way of doing business with better solutions for the future.

<u>We agreed on our first priorities</u>:

1) Form an official organization
2) Find new buyers
3) Keep our price at $1.80 a liter
4) Produce the best quality milk possible

After many meetings, we finally made Co.L.O.Q. official on September 17, 1999. By the end of 1999, two different cheese factories agreed to start making tests with sheep milk. At the beginnig of year 2000, another producer joined the group. In May, we had 5 cheese processors that had decided to buy milk on a regular basis. To this date, they are still buying, so we are now faced with a different situation: A SHORTAGE OF MILK.

Some information on the CO-OP itself.

The members have an annual meeting where major decisions are taken and a board of directors is elected. The directors meet once a month. Everyone has some special responsibilities:

1) Control of milk quality
2) Taking inventory of all dairy sheep producers in the co-op and scheduling the deliveries to the processors
3) Looking at improving the genetics
4) Development and marketing, etc…

The members of the Coopérative Laitière Ovine du Québec , in cooperation with Goverment people, have written a working document that the producer must follow. It gives information on buildings, feeding, preventative medicine, milking, storage of frozen milk, etc…

The co-op meets with the processors each fall to determine the volume of milk that will be available the following year, how to share that volume, the regularity of deliveries, the selling price, and anything else that either side feels important to discuss.

When a producer wants to join the co-op, he has a few steps to follow:

1) Fill out an application form.
2) Prove to the co-op that he has had a visit from the inspector who approves his installation.
3) Give us a copy of the milk sample analysis that the inspector sent to the government laboratory.
4) Produce milk as per the working document.
5) Make milk deliveries to the cheese factory as instructed.

The co-op has a $0.10 / liter check-off. $0.05 is used for administration and making payments. The other $0.05 goes into a fund for promotion, penalty, and insurance.

We work hard at having the maximum number of new dairy sheep producers join the co-op. Even though it is on a voluntary basis, we should have over 90% of all sheep milk farmers, that sell milk, as members of the co-op in year 2001.

This year, we marketed approximate 60,000 liters. In 2001, we should be around 110,000 liters. Most of the cheese processors we do business with, pefer the approach of one big pool of high quality milk, with one phone number.

In the near future, we will try to form a working group where producers, processors and marketing people sit around the same table to keep the dairy sheep industry moving forward.

SHEEP CHEESE-MAKING AND MARKETING

Hani Gasser

Mountain Meadow Sheep Dairy, Inc.
Chase, British Columbia, Canada

You probably have the totally wrong person standing in front of you. If everything would have gone the way I promised Theres (the better looking half of our farm cheese-making operation) back in ’92 when we started out, we would be laying on a beach somewhere in the south right now.

But nevertheless, since I am standing here, I will start bragging now. I have to admit that there are probably much better cheese makers, much closer to Guelph, than me. But I would like to show you where my wife, Theres, and I came from and what we have experienced on our cheese-making journey since 1983. In 1983 I took a cheese-making course in Switzerland where I went high up in the Alps to make cows’ milk cheese. Since then we have made cheese, and we have become masters at improvising on what is now called artisan cheese-making. I would like to show you a few slides of the traditional way of cheese-making in the Alps and the translation of that to North America.

If you have two million dollars to spend on your cheesery, there are people with much more expertise than Theres or me, but I believe we know how to make a decent cheese as simply as possible.

I actually think the equipment we use now is really too complicated, and I would not mind going back to the good old copper vat and the open fire. When I took that mountain cheese-making course in 1983, one of the first questions the instructor asked was on which Alp we were going to spend the summer. When I told him where we were heading, he informed me that our Alp was one of the most primitive places still operating, and he was right. We had to carry every drop of water 100 feet uphill to the cheesery from a well that produced the same amount of water at the same temperature all year round. The water had to be heated on the same fire as we heated the 250 liter copper vat with the milk. We also cooked our meals on this fire. To get to the corner of the shack where we made the cheese, you had to walk through the barn where we milked the cows twice a day. That part of the building had a wooden floor; the cheesery had a dirt floor. A hole in the roof replaced the chimney. The drain-table was a wooden board. We nailed a piece of wood above the cheese mould on the log wall behind the press and stuck a branch over the cheese mould and under that wood. On the branch that stuck out over the press table, we hung a rock to press the cheese. Parts of the cheese knife and the tool to stir the curd in the whey were made out of wood. To pull the curd out of the whey, you used a soft flat steel that you wrapped into one side of the cheese cloth. The opposite two corners of the cloth, you held with your teeth. With the bendable flat steel, you then followed the curve of the vat and pulled out as much cheese as needed to fill the mould. The moulds were made out of wood too, of course. To test if the brine of the salt bath was strong enough, you put a raw potato in it. If it sinks, you add more salt. If it starts to swim, you knew the salt content was right. You know, there are some real good cheeses coming from places like that, some not so good as well.

Here in British Columbia, Canada, we turned an old unfinished horse box stall into our cheesery where we now process about 50,000 liters of sheep milk annually into 5 different cheeses, yogurt and butter. Right from the start, we worked together with the dairy and dairy plant inspector, so that now everything is tiled, stainless steel, and even the hot water comes out of a tap. We never showed the Alp pictures to any of the inspectors and never told them that up there sometimes we would have a bath in the whey in the vat after pulling the curd out of it. Well, we did clean the vat afterwards. Even up there, we cleaned all milking and cheese-making equipment very thoroughly, the milking equipment twice daily, sanitizing it with boiling water. Cleanliness is the most important thing when you work with milk. Some cheeses can handle a little more than others, but you can only make a good end product with good milk and clean equipment. The smaller the surface that the milk touches on its way from the udder to the vat, the easier it is to keep the quality up. To me, as a cheese maker, hand milking would be the best because all you have to clean is one bucket - no pumps, seals, elbows or 30' milklines. But I am also a farmer, so I do like our milking machine and low line system.

With that background, we started up our cheese-making here, and that is where the marketing ties in with the cheese-making. I think that we, with our industry, have a big advantage over other specialty livestock producers. As soon as you have dairy sheep, you have sheep milk which will turn sour if you do not process it, and if you turn it into cheese, it has to be sold fairly soon or it will rot in the curing room. The marketing of the end product goes hand in hand with the breeding of the livestock - something many ostrich breeders did not look into enough. Well, it did not always go hand in hand at Mountain Meadows, and our dogs got pretty fat eating front end loaders full of sheep milk Brie in our first year of production.

We started out making Brie as our first type of cheese. I love white mould cheeses. We looked at the prices of Brie in the stores, and we figured "Man, we've got it made. Two or three years making that stuff and we will retire." We are still making Brie. There is a reason why Brie is expensive and why very few cheese makers make it. We found out Brie is a tough one to make. You not only deal with bacteria and enzymes, but you also have to fight with mold, or even worse, with molds. Brie also prefers a more neutral pH, but so do E. coli and all its friends. From a marketing point of view, Brie may be a good cheese to start out with, because the return is o.k. and it does not take a long time to cure, but if you are lambing, milking, and cheese-making all at the same time, try to find time to go to the city and sell your Brie, that will turn into an ammonia smelling goo in another 10 days, to some city boy that runs a yuppie health food store. Maybe you better start out with Feta. The return is lousy, but it is a lot easier to produce with its low pH. You can stick it into the brine and sell it a week or a year later. Go back to the lambing barn, the parlor, or the symposium.

If you cannot stand behind a batch of cheese that you made, dump it. Your Border Collies will love you. The worst thing that can happen to us as a young industry, is to have "would like to be cheese makers" give away their strange looking and smelling samples to people that then will say for the rest of their lives "I have tried sheep cheese, man it's disgusting". You also know that word of mouth is our best advertising. The public education that it will take to boost our industry is way out of my budget. Sheep milk is such a smooth, sweet, silky product that we like to keep these features in the end product. We found it sells well because of the delicate taste, and once a customer is hooked, it is quite easy to convince him or her of the health benefits.

The price of the raw milk that we purchase depends on the time of the year and bacteria count. 3M has nice petri plates that we use for raw milk testing. After 24h of incubation, you know what kind of raw milk you are dealing with. But it does not tell you what change of feed the sheep had or in what stage of lactation the ewes are. That is when artisan cheese-making becomes an art, because you have to be able to read your milk and react to it. Some old cheese makers in the Alps with years of experience notice weather changes in the milk. One challenge in small-scale sheep cheese-making is that you most often have milk from ewes in the same stage of lactation. Milk from sheep early in lactation will coagulate much faster than milk from ewes in late lactation. As you know, the composition of the milk changes throughout lactation, so to have a fairly consistent product, you have to react to all of that during the processing of the milk.

We used to go to all kinds of health food shows and agricultural fairs and give away tons of samples. We do not do that anymore. We found that people get too many impressions at a single show, so your product can get lost in the jungle of products. Most shows are very expensive. The samples you give out to people, that will not remember your product afterwards, can cost you an arm and a leg. In the first two years, we also delivered our products to the stores in Vancouver by ourselves. That would be the best, because you can keep an eye on the store shelf, and you can inform the dairy guy in the store about the benefits of sheep milk. Well, it got to the point where when driving to Vancouver, I could hardly step on the brakes anymore because I was afraid of yogurt running down my neck. We went through all kinds of delivery systems until we now have two big wholesalers, one in Vancouver and one in Calgary. Sometimes along the road, we have hired and fired a broker. For the 5% commission he cashed, he did not increase the sales enough.

This last summer you could find us weekly at three to four different Farmers Markets and one Public Market throughout BC. These markets are gaining popularity. You can sell your product at the same time that you give out samples and educate consumers. People, that realize that local food production, animal welfare, and healthy food choices are concerns that we as farmer’s share with them, soon became a growing and regular customer base. Sometimes I am shocked by some city folk. Since we have been at these markets, we have had at least three adults asking us “what kind of sheep do you kill to make this cheese”. I have to say that I am happy when fall comes and the markets slow down. But every spring, I ask Campell Jones, who sells honey beside us, if he did not learn anything either over winter because he is back again. I have to say that by about February, I start to miss the Market atmosphere and socializing (or gossip?).

Anyhow, we are very proud to be part of this unique industry, and we know that there is a huge potential for all of us to keep growing.

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