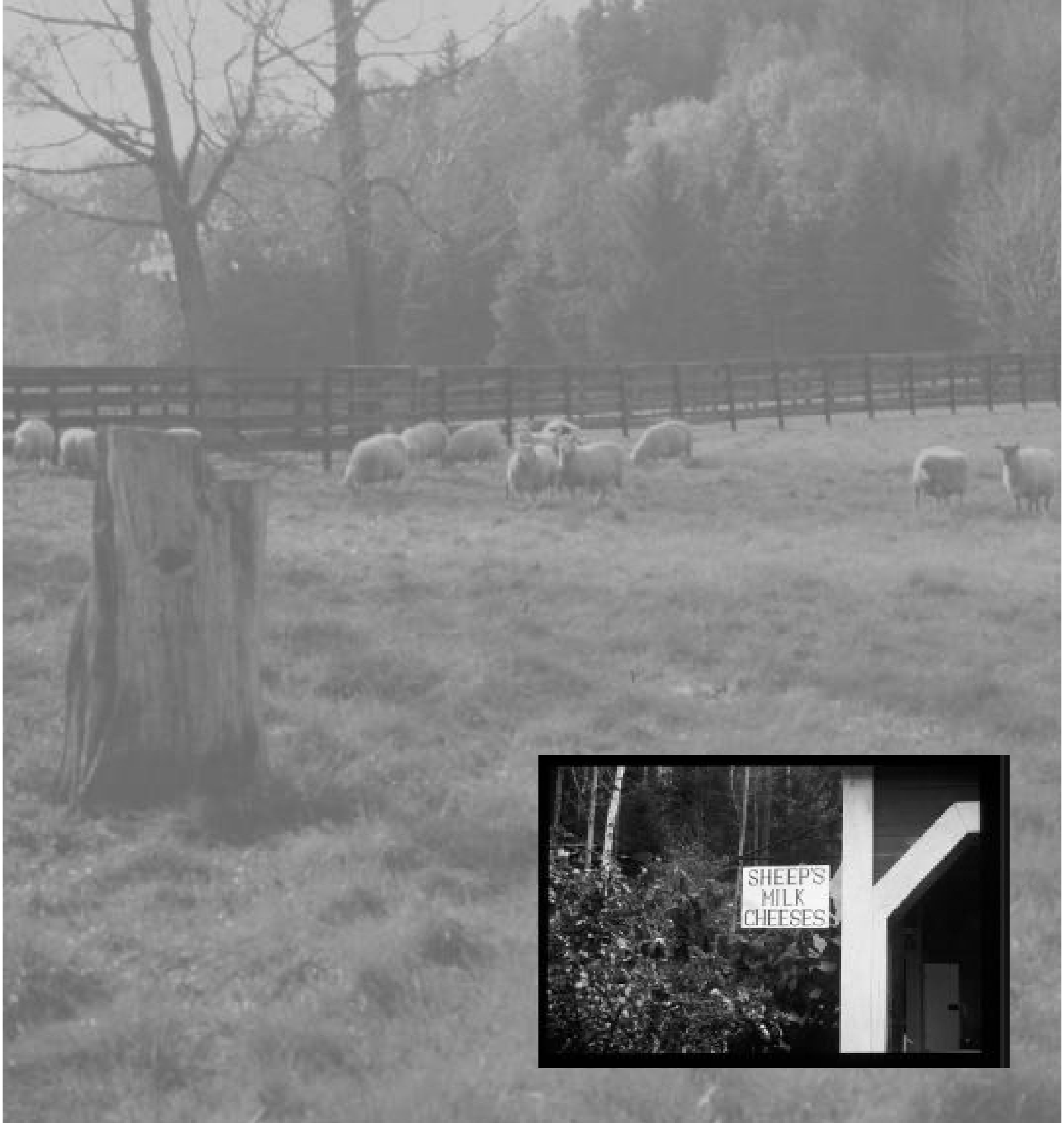
Proceedings of the 5th Great Lakes

Dairy Sheep Symposium

November 4-6, 1999

Brattleboro, Vermont, USA



PROCEEDINGS OF THE 5TH GREAT LAKES

DAIRY SHEEP SYMPOSIUM

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BRATTLEBORO, VERMONT, USA

Sponsored By:

University of Vermont, Burlington
    Small Ruminant Dairy Project
    Center for Sustainable Agriculture
    Animal Sciences Department
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University of Wisconsin-Madison
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        Department of Animal Sciences
        The Babcock Institute for International Dairy Research and Development

Vermont Shepherd, Putney, Vermont

Old Chatham Sheepherding Company, Old Chatham, New York

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Background:
Ewes on fall pasture at Old Chatham Sheepherding Company sheep dairy, Old Chatham, New York; owners - Tom and Nancy Clark, manager - Ken Kleinpeter

Inset:
Sign at the on-farm sheep milk cheese processing facility, Major Farm, Putney, Vermont; owners - David and Cindy Major.

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, W4628, Rio, WI 53960-9547, USA
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Copies of the 1998 and 1999 Proceedings of the 4th and 5th, respectively, Great Lakes Dairy Sheep Symposia can be purchased from Yves Berger, Spooner Agricultural Research Station, W6646 Highway 70, Spooner, WI 54801-2335, USA
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Program

5th Great Lakes Dairy Sheep Symposium

Brattleboro, Vermont

Thursday, Friday, and Saturday
November 4, 5, and 6, 1999

November 4

10:30 a.m. – 4:00 p.m.	**Tour Old Chatham Sheepherding Company,** Ken Kleinpeter, Manager, Old Chatham, New York

November 5

8:00 a.m.	**Registration –** Quality Inn, Brattleboro, Vermont
8:30 a.m.	**Welcome –** Carol Delaney, University of Vermont and Yves M. Berger, University of Wisconsin-Madison
8:45 a.m.	**Effects of Nutrition on Ewes' Milk Quality -** François Bocquier, UFR Production Animales, INRA, Montpellier, France
9:45 a.m.	**The Effect of Three Weaning Systems on Commercial Milk Yield and Lamb Production of Dairy Sheep –** Yves M. Berger, University of Wisconsin-Madison
10:45 a.m.	**Break**
11:00 a.m.	**Farming to Love the Children: The Unfair Advantage of Small Ruminant Dairying. Lessons Learned at Northland Sheep Dairy –** Karl North, Northland Sheep Dairy, Marathon, New York
Noon	**Lunch**
1:00 p.m.	**Herd Health Management and Record Keeping for Dairy Sheep –** Josef G. Regli, Canreg Farm, Finch, Ontario, Canada
2:00 p.m.	**Farm Adapted Breeds: A Panel Presentation of Flock Performance Records:** **East Friesian –** Frankie Whitten, Skunk Hollow Farm, Greensboro, VT **Crossbreds –** Mike Ghia, Ewetopia Sheep Dairy, Westminster West, VT **Lacaune –** Josef Regli, Canreg Farm, Finch, Ontario, Canada
3:15 – 4:30 p.m.	**Updates on Research –** François Bocquier, UFR Production Animales, INRA, Montpellier, France Bruce Clement, University of New Hampshire, Cooperative Extension, Cheshire County Chantal Deojay, Sterling College, Craftsbury Common, Vermont David L. Thomas, Department of Animal Sciences, University of Wisconsin-Madison
6:00 p.m.	**Social Time** – Putney Inn, Putney, Vermont
6:30 p.m.	**Symposium Banquet** – Putney Inn

November 6

9:00 a.m. – Noon	**Tour of Vermont Shepherd's Cheese Room and Aging Cave,** David and Cindy Major, Putney, Vermont and **Optional Tour of Local Sheep Dairies Aging Cheese at Vermont Shepherd**

Speakers

Ken Kleinpeter is the manager of Old Chatham Sheepherding Company sheep dairy at Old Chatham, New York; the largest sheep dairy in the U.S.

Carol Delaney is the Small Ruminant Dairy Specialist for the University of Vermont, Cooperative Extension, Burlington, Vermont.

Yves Berger is Researcher and Assistant Superintendent of the Spooner Agricultural Research Station of the University of Wisconsin-Madison, Spooner, Wisconsin.

François Boçquier is a small ruminant nutritionist for INRA (National Institute of Agricultural Research), Montpellier, France

Karl North is a writer and activist who promotes sustainable agriculture through his work with local, national, and international organizations. He and his wife, Jane, operate Northland Sheep Dairy in Marathon, New York.

Frankie Whitten and his wife, Mary Beth, operate Skunk Hollow Farm, an East Friesian dairy in Greensboro, Vermont, where they produce Northeast Kingdom Sheep Milk Cheese.

Josef Regli, DVM, and his wife, Barbara, operate Canreg Farm sheep dairy in Finch, Ontario, producing fluid milk from 300 Lacaune, East Friesian, and crossbred Rideau Arcott ewes.

David Thomas is Professor of Sheep Genetics and Management and Extension Sheep Specialist in the Department of Animal Sciences at the University of Wisconsin-Madison.

Bruce Clement is a University of New Hampshire Extension Educator for Cheshire County. He also operates Highland Sheep Dairy with his wife, Ellen, at Keene, New Hampshire producing green cheese for aging at Vermont Shepherd.

Chantal Deojay is a student at Sterling College in Craftsbury Common, Vermont who worked as a research intern for five months at Major Farm in Putney, Vermont.

David and Cindy Major are owners of Major Farm sheep dairy at Putney, Vermont and operators of Vermont Shepherd for aging and marketing of sheep milk cheeses.

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EFFECTS OF NUTRITION ON EWES' MILK QUALITY

François Bocquier[1] and Gerardo Caja[2]

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Summary

Control of milk composition is of importance in dairy ewes because milk is mostly used for cheese making. Besides numerous factors that alter milk composition, knowledge on the effects of nutrition is useful for it concerns both yield and milk content. Furthermore, modification of nutrition is a powerful and short-term means of altering milk composition. Global effects of nutrition are to be separated from specific effects of some nutrients, for they may be combined in order to finely control milk composition. Level of nutrition is a main factor affecting milk yield and milk composition in dairy ruminants : *i.e.* milk yield increases with level of nutrition and vice versa, but effects on milk composition are less clear. Milk fat content is in general negatively correlated to energy balance, whereas with protein content the correlation is positive. In consequence, in most cases, a high level of nutrition in dairy sheep will depress fat content and slightly increase milk protein content. On the other hand, an increase in dietary protein supply will increase milk protein yield, if the ewe has not reached its potential yield, but this response is not associated to changes in milk protein content. An easy means of increasing energy supply is to use high quantities of concentrate. As a result of rumen acidosis, this may directly depress milk fat and protein content and secondarily change energy partitioning from milk to body fat depots. The use of specific nutrients such as protected fat, or amino acids appears to be of interest as a mean of improving milk fat and/or protein content in dairy ewes. Limited experience is, however available, nowadays and advantages or drawbacks are not fully known.

In the practical conditions of dairy flock management the effects of nutrition are often hidden in the complexity of numerous factors that are also known to alter milk composition. Therefore, as a within-group individual nutritional status is unknown, the global response in term of bulk milk composition is difficult to predict. This leads to the notion of group-feeding strategies that include the variety of animal response to feeding treatments.

Introduction

Like for other dairy ruminants, dairy ewe lactation curves, both in terms of milk yield and milk composition, are conditioned by main factors including breed, stage of lactation, milking system and feeding (Flamant and Morand-Fehr, 1982; Treacher 1983, 1989; Bocquier and Caja, 1993; Caja and Bocquier, 1998). In addition it must be remembered that milk yield and milk composition (fat, protein, casein and serum proteins, but not lactose) are negatively correlated (Barillet and Boichard, 1987; Molina and Gallego, 1994; Fuertes et al., 1998). This phenomenon generally appears as a result of improved management practices. As a consequence it requires to find a balance between practices that will increase milk yield and those which increase the milk content ; the financial income being the result of a combination of prices related to both the volume and its quality.

As ewe's milk is mainly used for cheese making, it is of importance to pay attention to fat and protein contents because these parameters, which are routinely measured, can precisely predict cheese yield (Pellegrini et al., 1997). In fact, the main dairy sheep breeder's objectives are: 1) increase of the total milk dry matter output (cheese quantity), 2) a year round stabilization of the milk content, and 3) control of a high fat:protein ratio in order to ensure an adequate fatness of cheese for manufacturing processes and ripening properties. Hence, the primary and long-term objective of the breeder is to improve its ewes' dairy merit both in milk yield and milk composition. Like in the Lacaune breed the objective on maintaining milk composition only came after a successful improvement of milk yield (Barillet et al., 1993). Other objectives can also include criterions such as milkability and mammary morphology (Marie et al., 1999). Ewe dairy merits are widely differing between breeds. Large differences in both milk yield, milk composition and in kinetics during the whole lactation have been reported. They are however confounded with the large variety of production system (Casu et al., 1983; Fernández et al., 1983; Gallego et al., 1983, 1994; Labussière et al., 1983; Caja, 1994; Bocquier and Caja, 1993; Fuertes et al., 1998). In particular, most dairy sheep production systems include a short lamb-suckling period (3-5 weeks length) and, after weaning, a long milking period (4-8 months), but 'suckling-and-milking' can occur simultaneously during the first 2 months of lactation in some breeds (Caja and Such, 1991; Sheath et al., 1995). In regard with ewe milk composition, the lowest values in fat, protein and casein are observed during this 'suckling-and-milking' period (Gargouri et al., 1993 ; Bocquier et al., 1999 ; McKusick et al., 1999) or immediately after weaning, raising afterwards with lactation stage. Slopes of the increasing curves of milk content are mainly conditioned by the breed and level of production (Bocquier and Caja, 1993). Whatever the influence of the above factors, feeding of the ewe modulates both the volume and the composition of milk.

The aim of the present paper is to focus on the known effects of nutrition on milk composition of the dairy ewe (see review of Bocquier and Caja 1993, Bencini and Pulina 1997; Caja and Bocquier, 1998), because results obtained in dairy cattle and goat may not be successfully extrapolated to the dairy ewe. In addition, as dairy ewes are mostly fed in large flocks, it is necessary to briefly analyze the effect the flock structure (including days in milk and parity) on the bulk milk composition (Fraysse et al. 1996) and its consequences for feeding strategies of dairy ewes. We artificially separated the global effects of nutrition from the effects of specific nutrients that may be effective for the manipulation of milk composition of ewe.

Effects of level of nutrition

Energy supply and milk composition : Level of nutrition, mainly referred as level of energy or of feed intake, is a main positive factor affecting milk yield and milk composition in dairy ruminants. Hence, a steeped curve with an early and high peak milk is observed with a high nutrient supply during the early lactation period. Conversely, nutrient shortage during pregnancy and early lactation lead to a low and late peak milk yield. Effects of nutrition on milk composition are less clear because of interactions with the natural evolution of milk composition and through indirect effects of nutrition on milk volume (called dilution effect). Furthermore, in the middle and at the end of lactation, changes in nutrition mainly affect the persistency and/or the body reserves reconstitution, this is why limited effects are generally observed on milk yield or composition (Bocquier and Caja, 1993). Due to the respective variability of milk fat and protein content, the possibilities of altering milk composition by feeding are higher for fat than for protein and/or casein contents (Sutton and Morant 1989).

The specific effects of the level of nutrition on milk composition in dairy ewes are only partially known as recently reviewed by Caja and Bocquier (1998). In this sense, only few experiments are based in individual feeding of dairy ewes during the milking period and results obtained in suckling ewes are also taken into account to obtain reliable conclusions. Available references on the effects of different levels of nutrition in lactating ewes are summarized in Table 1.

Table 1. Ranges of variation on milk yield and composition induced by the level of nutrition in lactating ewes.

		Diet		Milk		
Lactation period and reference	Breed	Energy (UFL/d)[1]	Protein (gPDI/d)[2]	Yield (l/d)	Fat (g/l)	Protein (g/l)
Suckling:						
Robinson et al. (1974)	Cheviot	2.14-2.27	188-265	2.4-3.1	76-74	54-50
Cowan et al. (1981)	FxD	1.78-2.77	214-317	2.2-3.3	83-74	55-52
Cowan et al. (1981)	FxD	2.28-2.33	241-277	3.3-3.5	84-92	53-56
González et al. (1984)	FxD	1.66-2.36	183-260	2.3-2.6	90	50-52
" "	"	"	212-302	2.3-2.7	90	52-54
" "	"	"	239-339	2.5-3.1	90	53-54
Geenty & Sykes (1986)	Dorset	1.99-2.00	146	2.4-2.5	76	40-39
" "	"	1.51-2.42	138-170	2.0-2.7	79-69	40-39
Pérez-Oguez et al. (1994)	Manch.	1.36-1.49	143-162	1.4-1.5	88-84	49
Milking:						
Treacher (1971)	Dorset	1.06-2.18	107-221	1.2-1.5	83-68	46-52
Bocquier et al. (1985)	FxSxL	0.87-0.95	113-122	1.0	35-52	32
Geenty & Sykes (1986)	Dorset	1.83	124	1.7	71	47
" "	"	1.69-2.10	132-158	1.5-2.0	71-65	53
Pérez-Oguez et al. (1994)	Manch.	1.41-1.50	147-164	0.6	92-99	57-58

FxD= Finnish landrace x Dorset horn; FxSxL= Finnish x Sardinian x Lacaune; Manch.= Manchega.
[1]UFL : 1.7 NEL ; total requirements : 0.033 UFL/BW$^{0.75}$ + 0.7 UFL/l of milk : [2]PDI : Protein Digestible at the level of Intestine ; Total requirements : 2.5 g /BW$^{0.75}$ + 80 g/l (Bocquier et al, 1987b).

Existence of significant correlation between same milk components in successive controls (fat: r= +0.5; protein: r= +0.7 ; Barillet and Boichard, 1987) suggest that effects of nutrition at early stage of lactation may have carry-over effects on milk composition during the milking period. Direct evidence of such effects are however lacking (Fraysse et al., 1996), even if it is obvious that it is of interest to optimize nutrition during early lactation because milk yield regularly declines.

In most dairy sheep breeds fed *ad libitum* good quality forages, the energy balance reaches the equilibrium within few weeks after weaning (Caja, 1994 ; Bocquier et al., 1995) as a consequence of the evolution of voluntary intake (Bocquier et al., 1987a, 1997; Pérez-Oguez et al., 1994, 1995; Caja et al., 1997) and milk yield. This may not be the case when using large amounts of concentrate that induce a decline in forage consumption (Bocquier et al., 1983) or with too poor quality forages. Milk fat content is negatively correlated (r=-0.87; P<0.05) to energy balance (-1 UFL/d=+12.2 g/l milk fat), this relationship being established (Bocquier and Caja, 1993) from available references of suckling and milking ewes in a wide range of net energy balance (-1.5 to +1.5 UFL/d) and milk yield (0.6 to 3.5 l/d). Consequently, in most cases, a high level of nutrition of dairy ewes will reduce milk fat percentage. In comparison with fat content, and in agreement with cow and goat conclusions, the response of ewe milk protein content follows a positive relationship (r=+0.64; P<0.05 ; Bocquier and Caja, 1993) with a lower and flatter slope. As a consequence a high level of nutrition of dairy ewes generally produce moderate increase in milk protein and casein percentages. This was also demonstrated in both dairy goats (Flamant and Morand-Fehr, 1982) and cows (DePeters and Cant, 1992).

Effects of undernutrition : Grazing dairy ewes in typical extensive or semi-intensive systems of the Mediterranean area are periodically subjected to undernutrition, in relation to seasonal changes in forages or by-products availability (Caballero et al., 1992; Sheath et al., 1995). Moreover, in intensive large flocks of dairy ewes, even when food supply is theoretically sufficient, stage of lactation and competition for food between ewes often lead to some individual underfeeding situations, specially in the case of most productive ewes in early lactation (or rearing twins or triplets) which have higher nutrient requirements (Bocquier et al., 1995). Negative energy balance produced by undernutrition will result in a decrease in milk yield and protein content and in an increase in milk fat, in agreement with values shown in Table 1. Slope of regression between milk yield and fat percentage (-6.3 g/l) estimated by Bocquier and Caja (1993) from available data is higher than observed in the Lacaune population (-4.9 g/l ; Barillet and Boichard, 1987) indicating that not only dilution-concentration effects are involved in this increase of fat percentage. Increase of blood free fatty acids, as a consequence of body fat mobilization, is an important reason for observed high milk fat percentage.

While undernutrition is mostly physiological at the onset of lactation, its effects during middle- or late-lactation are not well documented, neither in dairy ewes (Bocquier and Caja, 1993) nor in cattle (Coulon and Rémond, 1991). During this period, a severe and chronic undernutrition of dairy ewes reduced strongly the milk yield (-31%) and increased milk fat content in +9.6g/l (+16%), while protein content of milk was unchanged (Agus and Bocquier, 1995).

Effects of over-feeding : Over-nutrition is also consequence of group feeding and its is considered as a normal way to restore body reserves in the middle or late lactation. High levels of intake during lactation are achieved when ensuring that ewes can have high quality diets during early lactation i.e. before weaning (Pérez-Oguez et al., 1994, 1995). As a general trend, when the energy supply is increased, milk protein content tends to increase slightly and fat content tends to decrease, as described before. The expected increment in milk protein content by increasing the level of nutrition during the milking period are very low as indicated in Table 1 and (Bocquier and Caja, 1993). Variations of milk content are lower than during the suckling period as a consequence of differences in amplitudes of energy balance.

It should be stressed that, in practical conditions of dairy flock management and as a consequence of group feeding practices, the observed global effects of level of nutrition (over or undernutrition) are normally hidden inside the feeding treatments and are mainly due to high yielding ewes. Individual intake of forage and concentrate can differ according to feed intake capacity. In these conditions a careful interpretation of data is recommended.

Effects of the level of dietary protein supply : Analysis of ewes' references (Bocquier et al., 1987b) indicate a quadratic relationship (r^2=0.97) between protein supply (in g PDI) over maintenance requirements and milk protein yield. Mean estimation of PDI efficiency was of 0.56, which is close to the value (0.59) observed by protein balances (Bocquier et al., 1987). Marginal increase of protein yield as a result of protein increment is almost null above 300 gPDI/d. There is, however, no significant effect of protein (PDI) balance on milk content neither on fat nor on protein in the compiled data by Bocquier and Caja (1993). Effects of dietary protein level on milk production of early lactating ewes are mainly attributed to energy savings as a consequence of an increase in body fat mobilization (Robinson et al., 1974, 1979; Cowan et al., 1981) and utilization (Geenty and Sykes, 1986).

Effects of the interaction between dietary protein and energy were studied by Cannas et al. (1998) in Sarda ewes during mid-milking period and related to milk urea nitrogen. Ewes were fed in pens with whole pelleted diets varying in two energy and four protein levels. Results are summarized in Table 3.

Table 3. Effects of energy and protein content in the diet on milk yield and milk composition in dairy ewes (Cannas et al., 1998).

	Energy[1] level	Crude protein (% DM)				Mean
		14	16	19	21	
Milk yield (l/d)	L	1.26	1.43	1.50	1.48	1.42
	H	1.16	1.20	1.34	1.34	1.26
Milk fat (g/l)	L	60	57	57	59	58
	H	57	57	54	56	56
Milk true protein (g/l)	L	55	54	53	52	54
	H	57	54	53	54	55
Milk urea N (mg/dl)	L	12.9	17.7	23.4	26.7	19.9
	H	12.2	17.0	22.3	25.8	19.3

[1] : L= 1.55 Mcal EN_L/kgDM (i.e. 0.91 UFL/kgDM), H=1.65 Mcal EN_L/kgDM (i.e. 0.97 UFL/kgDM).

Milk yield tended to increase and milk true protein to decrease with dietary protein level, in agreement with previous conclusions. Milk yield seems to reach a plateau above 19% of crude protein in the diet. Furthermore, energy level reduced significantly both milk yield and milk fat. Milk fat values were low and close to those observed in low fat syndrome, probably as a consequence of pelleted diets and of high content in non structural carbohydrates. True milk protein decreased with dietary protein level but was higher with the high, compared to the low energy diet. Milk urea nitrogen, which is positively correlated with protein in the diet, is better related to protein concentration of the diet (r^2=0.82) than with protein intake (r^2=0.56) giving an effective indicator of N utilization. Milk urea of these ewes varied between 12-27 mg/dl according to protein level, which was lower than measured in cow, and in general agreement whith measures on Lacaune ewes.

Effects of the level or proportion of concentrate in the diet : Effect of concentrate is positively associated with the energy level of the diet as a result of its energy density, and as a consequence milk fat may be depressed and milk protein increased. Furthermore, the use of high proportion of concentrates (>60% of dry matter) in diets may depress, by itself, both the milk fat and protein contents during the first months of lactation (Eyal and Folman, 1978). These effects might be different according to ewe's breed : higher for Awassi (fat: -28 g/l; protein: -2 g/l) than for Assaf ewes (fat: -6 g/l; protein: +1 g/l). Negative effects of concentrates on milk production are attributed to a quick and phasic degradation of non-structural carbohydrates in the rumen, reducing dramatically the rumen pH and altering the amount and composition of microbial protein synthesis and limiting the degradation of structural carbohydrates. These adverse effects of excess concentrate may be partially reversed by use of pH buffers (Hadjipanayiotou, 1988). During full lactation, it is also observed in group-fed ewes that the level of concentrate, if moderately increased, mainly affects the weight and body condition in lactating ewes, whereas bulk milk yield and composition are small or not significantly affected.

Consequences of group-feeding on nutritional strategies : The dairy sheep allowances were established for an individual ewe or a group of ewes with similar performances and they do not take into account differences between animals, *i.e*. variability within the group of ewes to be fed (Bocquier and Caja, 1993; Bocquier et al., 1995). If possible, ewes should be allocated into homogeneous groups according to their characteristics (physiological status, prolificacy, stage of lactation, milk yield or suckling litter size and body condition score). When this allocation is, however, not possible and ewes performance are widely spread, it is an usual practice to supply more feed than the average recommended allowances of the group. In Lacaune dairy ewes for instance, the main aim of feeding strategies is to give a diet that is adequate for ewes that make the most important contribution to total milk production; these ewes are those which produce about 10% more milk than the group average. Therefore, the energy supply for such group of ewe is calculated for an individual milk production that is 10% above the actual mean milk yield. The protein supply is generally calculated for a milk production that is 30% over the mean milk yield. This is because of marginal responses both in milk yield and in protein content, although the excess of dietary protein induces waste of protein especially for the low producing ewes of the group. Few comparative trials of group-feeding strategies have been done in dairy ewes. In this aim, an experiment was conducted (Bocquier et al., 1995) to compare the effect of two strategies of group-feeding. In this aim two similar groups of Lacaune dairy sheep (96 ewes each) were either fed altogether (all levels of milk yield confounded) or after separation in two subgroups according to milk yield (high and low). Total milk yield and milk composition were identical in both groups, but 'low-milk yield' subgroup showed a higher increase in body weight and body condition score at the end of the experi ment. Most of the beneficial effects of group feeding are obtained on the saving of concentrates, with dairy performances generally maintained or slightly improved.

On the other hand, at a given time, the main factor of milk yield variability in a flock comes from lambing dispersion and direct effects of feeding on milk composition are hidden by the heterogeneity of performance. Studies that have been conducted in France (Roquefort and Pyrenees) to measure the impact of within flock lambing kinetics on annual milk production and its composition (Fraysse et al., 1996) allow to take this factor into account for indirect comparisons of flock performances.

Effects of specific nutrients on ewe's milk composition:

Effects of fat supplements : The interest of fat supplements in the diets of dairy sheep has increased in the past years as a result of the availability of new preparation of fat as food for ruminants and of favorable results obtained in dairy cows. Available information on dairy ewe is however limited and we specially focus on calcium soaps of long chain fatty acids (CSFA). The effect of protected fat on ewe milk production and composition has been reviewed by Casals and Caja (1993) and Chilliard and Bocquier (1993) and main results referred to milking period of dairy sheep are summarized in Table 4.

Table 4. Effects of calcium soap of long chain fatty acids on milk production of Manchega dairy sheep during milking.

Lactation period and reference	Basal diet	Lipid (g/d)	Yield (%)	Fat (g/l)	Protein (g/l)
Casals et al. (1989, 1992a, 1999)	Grazing	0	0.75	79	62
	"	160[1]	0.78	97	56
	Gr.+ Protein suppl.	0	0.73	85	64
	"	160[1]	0.69	100	59
Casals et al. (1991, 1992b)	Grazing	0	0.74	74	60
	"	40[1]	0.83	82	59
	"	80[1]	0.70	94	60
	"	120[1]	0.74	89	55
	"	160[1]	0.71	94	56
Font et al. (unpublished)	Grazing	0	0.51	99	65
	"	72[1]	0.53	105	61
Cuartero et al. (1992)	Grazing	0	0.45	92	-
	"	75[1]	0.46	104	-
Gargouri et al. (1995)	Grazing	0[2]	0.94	82	67
	"	72[1,2]	1.00	84	63
Gargouri (1997)	Grazing	0	0.92	74	63
	"	96[1]	0.83	83	61
Pérez Alba et al. (1997)	Oat-vetch hay	0	1.40	65	51
		166[3]	1.56	68	49

[1]: Calcium soaps of palm oil; [2]: Including 2% of animal fat and 3% of whole soybean seed in both concentrates; [3]: Calcium soaps of olive oil.

First references (Pérez Hernández et al., 1986) in suckling ewes tried to improve lamb growth with contradictory results, but most clear response was obtained in the improvement of milk fat content in dairy ewes. Lactational (suckling and milking periods) effects of CSFA included in the concentrate fed to Manchega dairy ewes grazing in semi-intensive conditions have been reported mainly by Casals et al. (1989, 1991, 1992ab, 1999), Cuartero et al. (1992), Gargouri et al. (1995), Pérez Alba et al. (1997) and Osuna et al. (1998). The last authors compared the use of oilseeds vs CSFA and Lacaune vs Manchega dairy ewes in indoors conditions. Although total milk yield was unaffected in all experiments, dietary CSFA significantly increased the milk contents of fat and solids, in most cases, and decreased slightly milk protein content in overall lactation. Responses varied according to CSFA dose and lactation stage. Apparent efficiency of CSFA transfer to milk was higher in suckling than in milking ewes, and optimum intakes to maximize milk fat production were close to 120 and 70 g CSFA/ewe/day, in suckling and milking respectively. The depressive effect of CSFA on milk protein increased with time after lambing, and optimum intake of CSFA that maximized milk protein production were the same as for milk fat. Milk casein also decreased with CSFA but casein content as percentage of milk protein was unchanged in all cases. Fatty acids profile in milk and cheese was changed with a strong increase in palmitic (C16:0) and oleic (C18:1) acids and a decrease in the C6 to C14 acids (Gargouri et al., 1995; Pérez Alba et al., 1997), but differences in fatty acids profile were non significant after the ripening of cheeses. Change in fatty acids profile of milk was dependent on CSFA profile (Gargouri et al., 1995; Pérez Alba et al., 1997). Special care must be taken in relation to changes in lipolysis rate or organoleptic characteristics after modification of fatty acid composition in cheese.

More recently Osuna et al. (1998) studied the effects of feeding whole oilseeds, to partially replace calcium soaps of fatty acids, on dairy ewes intake and milk production and composition. In this aim Manchega and Lacaune dairy ewes were used in mid-milking period to determine the lactational effects of supplementing diets with fat coming from palm oil CSFA (5.5%) or from a mixture of CSFA (2.5%) and whole cottonseed (11%) or CSFA (2.5%) and whole sunflower seeds (4%). Diets were isonitrogenous (16%CP) and were offered as a total mixed ration (71% forage: 29% concentrate) where fat supplements were included. Ether extract increased from 2.5% in control to 7% in fat supplemented. Results are summarized in Table 5.

Table 5. Effects of feeding whole oilseeds and Calcium soaps of fatty acids on milk production and composition of Manchega and Lacaune dairy ewes during mid milking.

Item	Breed[1]	Control	CSFA[2]	CSFA+WCS[3]	CSFA+SFS[4]
Milk yield (l/d)	M	0.8	0.8	1.0	0.8
	L	1.7	1.7	1.5	1.7
Milk fat (g/l)	M	74	95	95	90
	L	61	77	82	70
Milk protein (g/l)	M	63	60	64	62
	L	55	55	58	55

[1]: M= Manchega, L= Lacaune; [2]: CSFA= Calcium soaps of fatty acids; [3]: WCS= Whole cotton seed; [4]: SFS= Sunflower seed.

Due to the dietary fat, intake tended to decrease, milk fat percentage and yield were increased, and casein content was reduced. Milk yield was not affected by treatments and no interactions were found between breed and fat supplementation, in spite of the respective differences (P<0.01) between Manchega and Lacaune dairy ewes in milk yield (0.9 and 1.6 l/d), and fat (8.8 and 7.2%) and protein (6.2 and 5.6%) percentages, respectively in the control diet. A significant effect was detected on milk casein as percentage of total protein that decreased as response to lipid supplementation.

Effects of protein supplements: Studies on the use of low degradable protein supplements, protected proteins or protected amino acids in milk production of sheep are very limited and most of the references were obtained from suckling ewes, altering the practical significance of data of milk composition. In addition, in some cases the results are not significant or contradictory. In regard to low degradability protein supplements Robinson et al. (1979), Cowan et al. (1981), Penning and Treacher (1981), González et al. (1982), Hadjipanayiotou (1988, 1992) and Penning et al. (1988), and most recently Purroy and Jaime (1995), showed increases in milk yield during early lactation when included or substituted a degradable protein by fishmeal (60-140 g/d) as in lactating ewes. Milk composition was, however unchanged in most cases and only significantly improved in the trials of Penning et al. (1988) and Purroy and Jaime (1995), when compared to soybean and fishmeal in suckling ewes. These last authors reported significant increases in milk protein (+2.9 g/l, +6.2%) but not in milk yield, probably as a consequence of the reduction of undernutrition (70-80% of energy requirements) applied in the experiment. Robinson et al. (1979) also found a slight increase (P<0.10) in milk protein in ewes fed fishmeal, when compared with those fed soybean or peanuts protein supplements. Effects of fishmeal are attributed to an increase in the amount and profile of amino acids absorbed in the small intestine and that are available for milk synthesis.

Use of protected proteins also gave interesting results, but in some cases they are not significant or contradictory. Treatment of protein supplements with formaldehyde must be done at optimum doses (Caja et al., 1977). In this sense, compared the use of soybean, fishmeal and formaldehyde protected soybean in Chios dairy ewes were without significant effects on milk yield and milk composition (Hadjipanayiotou, 1992), even if milk fat and milk protein contents were slightly higher in ewes fed formaldehyde treated soybean. The use of formaldehyde protected soybean in Chios dairy ewes in negative energy balance also did not affect milk yield and composition (Hadjipanayiotou and Photiou, 1995). Industrially protected soybean by mean of lignosulphonate treatment is nowadays available for ruminants. Evaluation of treated vs untreated soybean was done in Manchega dairy ewes fed with poor quality forage at two levels of supplementation with concentrate (Pérez et al., 1994, 1995). Values of effective degradability measured in sacco for treated and untreated soybean used in the experiment were 0.30 and 0.56, respectively. Differences between treatments were not significant, but a significant interaction (P<0.05) was observed in the milk yield comparisons between the level of concentrate and degradability of protein. The highest values in milk yield were obtained with the high level of low degradability soybean supplements. Milk composition was unaffected by treatments.

More recently, protected amino acids have been used in lactating ewes to increase milk production during suckling (Lynch et al., 1991; Baldwin et al., 1993) or milking periods (Bocquier et al., 1994). Lynch et al. (1991) studied the supplementation of Methionine (0.11%) and Lysine (0.28%) in two concentrates for suckling ewes of varying levels of protein (10 and 16% crude protein). Obtained results indicated a higher milk yield (+11%) in the ewes fed with the high protein supplemented concentrate, but the difference was not significant. Milk protein was also unaffected by both experimental treatments. The inclusion of protected Methionine (0.2%) in the concentrate produced small (+2%) and non significant increases in milk yield and milk protein as observed by Baldwin et al. (1993) in suckling Dorset ewes. It has been also shown that the milk protein content of milk can be increased by addition of 3 or 6 g/d of protected Methionine at early stage of lactation of milking period in Lacaune ewes (Bocquier et al., 1994) with ewes in positive nutrient balance (117-120% and 120-140% of energy and protein requirements, respectively). The response to Methionine was higher when basal diet was based on silage than on hay, indicating that Methionine content could be the limiting amino acid in this last diet. Milk yield and milk fat content were unaffected by the supplementation.

Conclusions and prospects

Quality of milk can be defined in many different ways according to its final destination and/or to consumer's demands. In the next future, however, at a very limited scale, some dairy ewes may be bred for their milk properties, because it has been demonstrated the feasibility of producing pharmaceuticals in the milk of transgenic animals. For the majority of breeders, the problem is to produce milk at large scale. For them, the changes in the way to produce milk followed a stepped evolution which was allowed by scientific knowledge and technical progress either in the improvement of its production or on the control of the products. The major step was to increase productivity of dairy ewes and to control the health aspects. The second step was imposed by cheese manufacturers : milk is now generally paid on its ability to be transformed into cheese, *i.e.* fat and protein content. Nowadays, there is a wide variety of new objectives that are emerging as a demand of social groups. Among them, "natural" production, animal welfare, perennial land use and waste control are often cited. These objectives appear somewhat confusing because they may be contradictory or they may not be economically adapted to the present context. This is the reason why, breeders defend their products and their income by well-defined new production rules that are collectively chosen. Hence, in France, it is not allowed to treat dairy ewes with genetically engineered substances such as BST. In addition, decisions have been taken in the Roquefort region of France and nowadays the use of some constituents of concentrates are prohibited (ruminal-protected fat or amino-acids) or animal by-products. The use of some others feed are in discussion for they may contain parts of transgenic plants.

Sheep milk producers are mostly located in the Mediterranean area. Their breeding system relies on local sheep breeds that are well-adapted to such an environment with local feed resources together with traditions of cheese making and consumption. They perceive that this is not sufficient and this is why they decided to emphasize the use of local feed that may contribute to the milk quality in order to reinforce the notion of typical cheese.

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EFFECTS OF THREE WEANING AND REARING SYSTEMS ON COMMERCIAL MILK PRODUCTION AND LAMB GROWTH

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Abstract

A flock of 132 East Friesian (EF) crossbred ewes and their lambs were used to study the effects of three weaning and rearing systems on milk production and lamb growth. During the first 30 days of lactation, ewes were either weaned from their lambs at 24 hr post-partum and then machine milked twice daily (DY1), separated from their lambs for 15 hr from late afternoon through early morning and machine milked once daily in the morning (MIX), or not machine milked and allowed unlimited access to their lambs (DY30). After 30 days, MIX and DY30 ewes were weaned, and ewes in all three groups were machine milked twice daily. Commercial milk yield and milk composition were recorded weekly until mid-lactation and then twice monthly until dryoff. Average lactation length (suckling + milking periods) was 176 d and was similar between weaning systems. Total commercial milk production differed ($P < .001$) between weaning systems (240, 205, and 149 L/ewe for DY1, MIX, and DY30 systems, respectively). During the first 30 days of lactation, commercial milk production, percentage of milk fat and protein, and somatic cell count (SCC) were lower ($P < .05$) for MIX ewes than for DY1 ewes (42 and 70 L/ewe of milk; 3.24 and 4.88% milk fat; 5.36 and 5.52% milk protein; 44,700 and 81,300 SCC, respectively). Approximately 30 days after lambing, commercial milk production, percentage of milk fat, and SCC were not different between weaning system groups, however percentage of milk protein was higher ($P < .05$) for DY30 ewes (5.30%) compared to DY1 and MIX ewes (5.07 and 5.11%, respectively). Litter size was a significant source of variation for most lactation traits, however parity and proportion of EF breeding tended not to be significant. Ewes put on a legume-grass pasture in mid-lactation had greater ($P < .005$) milk production and lactated for more (P < .005) days than ewes fed in drylot. Growth traits of 272 twin-or-greater-born lambs sired by EF or Texel rams were estimated for three rearing systems. Lambs were either raised artificially (ART), allowed access to their dams for nine hours per day (LMIX), or allowed unlimited access to their dams (TRAD) for approximately their first 30 days of age. Lamb weights at 30 days were similar, however at 120 d, TRAD lambs were heaviest ($P < .01$) compared to ART and LMIX lambs (47.8, 43.6, and 45.5 kg, respectively). From a simplified economic analysis, the MIX/LMIX system produced the greatest financial returns from milk and lamb production.

Introduction

Approximately 25% of the total lactational commercial milk yield of a dairy ewe is produced during the first 30 days of lactation (Ricordeau and Denamur, 1962; Folman et al., 1966), a time when, traditionally, lambs are allowed to suckle their dams. For a dairy sheep enterprise, waiting until after 30 days post-partum to begin machine milking significantly affects economic returns as a result of reduced marketable milk (Geenty and Davison, 1982; Gargouri et al., 1993b) yet lamb growth may benefit from later weaning (Peters and Heaney, 1974; Gargouri et al., 1993a).

In an effort to maximize commercial milk yield and (or) lamb growth, a variety of weaning and rearing systems for dairy ewes and their lambs have been previously described. In northern Europe, particularly for the East Friesian breed (Flamant and Ricordeau, 1969), the ewe is removed from her lambs within 24 h of birth and then machine milked twice daily until the end of lactation while the lambs are raised artificially. In the middle-East, e.g. in Israel with the Awassi breed (Folman et al., 1966a), shepherds with limited means to raise lambs artificially have developed a partial-weaning system that allows for once daily milking of the ewes until complete weaning, between 30 and 60 d post-partum, and then twice daily milking until the end of lactation. Typically lambs suckle ewes between 8 and 12 h per day until complete weaning. Finally a third scenario exists in New Zealand (Geenty and Davison, 1982) and the United States (Wolf and Tondra, 1994; McNalley, 1995; Thomas, 1996a); areas of the world where the production of lamb has traditionally been emphasized.

In the U.S., lambs are removed from their dams at approximately four weeks of age, and then the ewes are machine milked twice daily for the remainder of lactation. The American sheep dairy industry is young and as a consequence, effective weaning and rearing strategies specific to dairy-crossbred sheep have not yet been determined. The objectives of this study were to compare commercial milk yield, milk composition and quality, and lamb growth for three weaning and rearing systems in an experimental flock of East Friesian-cross sheep and to estimate their relative impact on economic returns.

Materials and Methods

Since 1993, East Friesian (EF) crossbred ewes have been produced from the matings of EF-crossbred rams and Dorset-cross ewes. In the autumn breeding season of 1997, these ewes were mated to full-blood EF or Texel rams. Prior to the 1998 lactation, 132 of these EF-cross second and third parity ewes were assigned to one of three weaning-system treatments. Treatment one ewes (DY1, n = 42) were weaned from their lambs between 24 and 36 hr post-partum, and then machine milked twice daily for the remainder of lactation. Treatment two ewes (MIX, n = 48), beginning 24 hr post-partum, were separated from their lambs at 1700 each day and milked once daily every morning at 0600. After the morning milking, ewes were returned to their lambs. MIX ewes were milked twice daily following permanent weaning of their lambs at approximately 28 days of age. Treatment three ewes (DY30, n = 42) were initially not milked and allowed constant access to rear their lambs. After approximately 32 days post-partum, the ewes were weaned from their lambs and milked twice daily.

The experimental ewes gave birth to 289 lambs. Because there were relatively few single-born lambs, they were excluded from the lamb analyses. Fourteen lambs were born dead or died at birth, providing 258 live lambs for allocation to three rearing system treatments which generally corresponded to their dams' weaning system treatment. All lambs from DY1 ewes and some lambs from MIX and DY30 ewes were raised artificially on milk replacer dispensed from a lamb-bar (lamb treatment = ART, n = 93). Lambs raised artificially were weaned from milk replacer at an average age of 24 days. Lambs reared naturally by MIX ewes (lamb treatment = LMIX, n = 78) and by DY30 ewes (lamb treatment = TRAD, n = 87) were weaned at average ages of 28 and 32 days, respectively.

Machine milking of ewes took place in a 12 x 2 milking parlor with indexing stanchions and a high-line pipeline system. Milk production was recorded weekly during early lactation and thereafter, twice a month using a Waikato milk meter jar. Individual milk production was recorded on Monday evening and Tuesday morning, and samples for composition analysis were taken on Tuesday morning. Milk composition analysis for percentage of fat, percentage of protein, and Fossomatic® somatic cell count was performed by a State of Wisconsin certified laboratory. The terms pre-, peri, and post-weaning were used to describe the stages of lactation: days 1 to 30, 31 to 45, and 46 post-partum to the end of lactation, respectively. Total days in lactation was defined as the number of days from parturition to dryoff. Milk production for each stage of lactation was calculated based on the weekly testings. Milk fat and protein percentages for each stage were calculated as weighted averages. Somatic cell counts were transformed to base-10 logarithms and then averaged over each stage of lactation. Lambs were weighed at birth, at weaning from their dams (LMIX and TRAD lambs) or from milk replacer (ART lambs), and prior to slaughter, and adjusted 30-day and 120-day weights were calculated. Least squares means analysis of variance was conducted with the GLM procedure of SAS (1999). Sources of variation accounted for in the ewe models were: weaning system (DY1, MIX, or DY30), parity (second or third), ewe breed (≤ 1/4 EF or > 1/4 EF), litter size (one, two, and three or greater), mid- to late-lactation nutrition (pasture or drylot), and 1997 adjusted milk production (< 150 L, 150 to 200 L, or > 200 L). Sources of variation included in the lamb models were: rearing system (ART, LMIX, or TRAD), sex (female or intact-male), birth type (twin, or triplet and greater), breed of sire (Texel or EF), breed of dam (≤ 1/4 EF or > 1/4 EF), and age of dam (two or three years). Lamb birth weight was modeled as a covariate in the analyses of 30-day and 120-day weights. This report presents the results of data collected during the 1998 lactation.

For economic comparisons of the three weaning and rearing systems, calculations were based on the production of one ewe and her 2.19 lambs (the average number of lambs born [n = 289] to ewes lambing that were allocated to experimental treatments [n = 132]). The price received for commercial milk and for live lamb marketed at 120 d of age was $.1.32/kg and $1.87/kg, respectively. The increased expenses for the DY1 and MIX ewes over DY30 ewes included the labor to milk the DY1 and MIX ewes during the first 30 d of lactation ($.27/ewe/milking) during which time the DY30 ewes nursed their lambs and were not milked. An additional expense for the MIX ewes was the extra labor to separate the lambs from the ewes once per day for 30 days (15 min/day/two people at $8.00/hr/person) which totaled $2.50/ewe. The increased expenses for the ART lambs over the TRAD and LMIX lambs included milk replacer (8.4 kg/lamb at $2.51/kg), labor to feed the lambs (1.2 hr/lamb at $8.00/hr), and supplies ($.34/lamb) which totaled $31.03/lamb.

Results

Milk yield and lactation length. Lactation curves for commercial milk production of the three weaning systems are displayed in Figure 1. Liters of commercial milk per ewe produced over the entire lactation by DY1 and MIX systems was 61 and 38% greater ($P < .001$) than for the DY30 system, the system traditionally used by most U.S. sheep dairies (Table 1). Milk production was similar between systems during the post-weaning period, however large differences ($P < .0001$) were observed during the pre-weaning period (70, 42, and 0 L/ewe for DY1, MIX, and DY30 systems, respectively). During the peri-weaning period, DY1 and MIX ewes produced similar amounts of commercial milk, but both produced more ($P < .05$) than DY30 ewes (32, 34, and 28 L, respectively). Length of lactation was similar between weaning systems, however inherent to the DY30 system was a loss ($P < .0001$) of 38 or 31 d of machine milking during early lactation when 20 to 30% of total commercial milk yield is obtained relative to the DY1 and MIX systems, respectively (Table 1). Average daily commercial milk yield was greatest ($P < .005$) for DY1 ewes and greater ($P < .005$) for MIX ewes than for DY30 ewes.

Weaning system by nutrition interaction was significant for total commercial milk yield and average daily commercial milk yield traits (Table 2). DY1 and DY30 ewes produced similar amounts of milk regardless of nutrition. MIX ewes, however produced 32% more milk ($P < .05$) on pasture than in the drylot.

Milk composition and quality. Milk fat percentage tended ($P < .05$) to rise as lactation progressed (Figure 2). Averaged over the entire lactation, MIX ewes' milk fat content (4.65%) was lower ($P < .05$) than that of the DY1 and DY30 systems (5.05 and 4.98 %, respectively, Table 3). The differences between systems were greatest during the pre-weaning period where DY1 ewes (4.88%) had 1.5 times higher ($P < .0001$) percentage of milk fat than MIX ewes (3.24%) and during the peri-weaning period when DY30 ewes (4.21%) had lower ($P < .01$) percentage of milk fat compared to DY1 and MIX ewes (4.90 and 4.78%, respectively). Post-weaning percentage of milk fat was not different among weaning systems. Kilograms of fat was highest for DY1 ewes, intermediate for MIX ewes, and lowest for DY30 ewes ($P < .0001$).

Milk protein percentage was highest during the pre-weaning stage, decreased through mid-lactation, and then increased for the remainder of lactation (Figure 3). Average protein percentage over the entire lactation was similar between weaning systems (Table 2), however differences ($P < .05$) were present during the pre-weaning and post-weaning periods. Kilograms of protein was highest for DY1 ewes, intermediate for MIX ewes, and lowest for DY30 ewes ($P < .0001$). SCC did not differ significantly from beginning to the end of lactation (Figure 4). During the pre- and post-weaning stages, SCC was lowest ($P < .01$) for MIX ewes compared to the other two weaning systems; post-weaning SCC was not different (Table 2).

Lamb growth. The significant differences in birth weight (Table 4) between lamb rearing groups were unexpected since ewes, and therefore lambs, were assigned to treatment groups prior to lambing. Therefore, lamb birth weight was included as a covariate in the analyses of the other lamb growth traits. Growth and weight of lambs up to 30 d were not different between rearing groups. At 120 d, TRAD lambs had grown 13% faster and weighed 10% more ($P < .01$) than ART lambs. LMIX lambs were intermediate in 120-d weight to the other two groups, however, growth of LMIX lambs from 30 to 120 d was similar to that of TRAD lambs.

Discussion

Milk yield and lactation length. MIX ewes during the pre-weaning period were machine milked once per day and produced only 40% less commercial milk compared to DY1 ewes that were milked twice per day (Table 1). These results imply that physiological and hormonal maintenance of lactation for MIX ewes may have been superior to the other two groups, at least during early lactation. Other authors who have studied partial weaning systems have determined that the oxytocin-mediated-milk-ejection is impaired compared with ewes that were exclusively machine milked (Marnet et al., 1999b; *Negrão and Marnet, 1998*). However, more frequent and complete udder evacuations prevent overdistention and physical crushing of the alveoli (Labussière et al., 1978), and quite possibly reduce local concentrations of a feedback inhibitor of lactation (Wilde et al., 1987, 1995). These factors could compensate for the deleterious effects of poor oxytocin release on commercial milk yield for the MIX ewes (Marnet, 1997; Marnet et al., 1999b). Furthermore, MIX ewes produced 7 and 20% more commercial milk during the peri-weaning period than DY1 and DY30 ewes, respectively (Table 1), and therefore appeared to be least affected by the negative effects of weaning on milk production that have been previously reported (Ricordeau and Denamur, 1962; Gargouri et al., 1993b; Bocquier et al., 1999). DY1 and MIX ewes produced 13 and 6%, respectively, more milk than DY30 ewes during the post-weaning period (Table 1), however the differences between systems were not significant. The relatively poor performance of the DY30 ewes could be due to a stronger maternal bond as a result of spending longer and uninterrupted periods of time with their lambs (Marnet et al., 1998a,b). The early effects of weaning system are large enough to account for most of the differences in commercial milk yield between groups over the entire lactation (Louca, 1972; Geenty and Davison, 1982; Knight et al., 1993), yet do not significantly affect lactation length (Lawlor et al., 1974; Geenty, 1980; Knight et al., 1993).

The weaning system by nutrition interaction is difficult to explain. It is possible that MIX ewes had a greater udder secretory capacity than either the DY1 or DY30 ewes as a result of both nursing lambs and being machine milked. This may have physiologically prepared them to better respond to the increased nutritive value of pasture with increased milk production.

Milk composition and quality. Percentage of fat and protein during the pre- and peri-weaning stages of lactation were suppressed in the two groups of ewes that were allowed partial or full access to their lambs during the first 30 d of lactation which is consistent with other reports (Ricordeau and Denamur, 1962; Papachristofourou, 1990; Gargouri et al., 1993a; Kremer et al., 1996; Fuertes et al., 1998). Following complete weaning of these ewes from their lambs, milk composition eventually returned to the levels of the DY1 ewes. The most likely explanation for this phenomenon is impairment to the milk-ejection reflex which occurs when ewes are allowed to bond with their lambs (Labussière 1993; Marnet 1997; Marnet et al., 1999a,b). Milk fat droplets in the ewe are large (Muir et al., 1993) and exceed the diameter of the intralobular secondary ducts therefore requiring adequate myoepithelial contraction for their expulsion into the cistern. Without optimum milk-ejection reflex, milk fat (and to some degree, milk protein) is trapped in the udder, and the milk extracted by the machine has a low fat content. Besides the obvious economic consequences of residual fat retention, it has been hypothesized that certain fatty acids present in alveolar milk might inhibit further fat synthesis of neighboring cells during moments of stagnation (Labussière et al., 1978). The MIX and DY1 systems yielded approximately 38 and 65% respectively, more kilograms of fat and protein than the DY30 system ($P < .0001$), which was largely due to the strong differences in overall commercial milk yield. Milk quality as judged by SCC was superior for MIX ewes compared to the other two weaning systems. This would imply that perhaps more frequent and (or) complete udder evacuations associated with a partial weaning/milking system are more desirable with respect to udder health (Barillet, 1989). Furthermore, machine milking beginning within 24 hr post-partum is perhaps more traumatic on ewes' udders and may allow greater entry of pathogens into the udder than would the suckling of a lamb during the first 30 d of lactation (Bergonier et al., 1996). During the peri-weaning period, SCC was significantly elevated for the DY30 system, the time when ewes were being weaned of multiple, fast-growing lambs and were also making the transition to twice-daily machine milking. Although SCC in the present experiment were extremely low compared to other reports in the literature for ewes (Ranucci and Morgante, 1996), it would appear that at least during early lactation, SCC are influenced by weaning system. However, after complete weaning, differences between systems were no longer significant.

Lamb growth. Adjusted 30 d weight and adjusted daily gain from birth to 30 d were similar between lamb groups which is in contrast to previous studies that have concluded that lambs reared naturally by their dams have superior growth and weight by 30 d compared to partial weaning systems (Hadjipanayiotou and Louca, 1976) or artificial rearing systems (Peters and Heaney, 1974; Knight et al., 1993). Furthermore, the results of the present experiment also differ with previous reports which concluded that rearing system had no effect on final lamb weight (Louca, 1972; Peters and Heaney, 1974; Gargouri et al., 1993a,b) or growth rate (Peters and Heaney, 1974; Knight et al., 1993). The ART system was detrimental to both lamb growth and weight from 30 to 120 d. Lamb growth rate was somewhat lower than what has been observed for lambs artificially raised at the Spooner Agricultural Research Station in previous years under similar management conditions (320 to 360 g/d; Berger and Schlapper, 1993). LMIX lambs seemed to have compensatory weight gain during this period which has been previously confirmed in growing animals with prior nutrition limitations (Peters and Heaney, 1974; Black, 1983).

Rearing System × Birth Type Interactions. A significant interaction between rearing system and birth type was found for 30-d weight and average daily gain from birth to 30 d (Table 5). Twin-born lambs reared by the LMIX system had significantly inferior 30-d weights and grew slower from birth to 30 d than twin-born lambs reared by either the ART or TRAD systems (14.4, 15.3, and 16.1 kg, respectively; 322, 352, and 378 g/d, respectively, Table 5). Rearing system was not a significant source of variation for lamb growth traits of triplet-or-greater-born lambs and were similar to growth traits for the twin-born lambs raised by the LMIX system. These findings imply that lambs raised by the LMIX system are no more disadvantaged with respect to growth than triplet-or-greater-born lambs raised under any of the three rearing systems.

Relative economic returns. Table 6 summarizes the returns associated with combined commercial milk and lamb production for the DY1 and MIX system relative to the DY30 system. The MIX/LMIX and DY1/ART systems offer 15.6 and 6.6%, respectively, more returns than the DY30/TRAD system. More days of machine milking for the DY1 and MIX systems enabled returns in ewe milk value ($108.27 and $67.15, respectively) to overcome their decreases in net lamb value, relative to the DY30 system (-$83.27 and -$8.38, respectively). Overall lamb mortality in the present study was 11%, and was not significantly different between rearing system treatment groups. Other authors have reported lamb mortality of artificially raised lambs to be between 15 and 35% (Peters and Heaney, 1974; Knight et al., 1993). Mortality rate would have to be 25% or greater for the DY1 system to offer returns equal or less than that of the DY30 system. In this experiment, milk purchase price was constant ($1.32/kg), regardless of milk composition or quality. It is reasonable to assume that in the future, producers will receive lower prices for milk of poorer fat and protein content or higher somatic cell count. Because of the milk fat suppression observed during the pre-weaning period for the MIX ewes, milk purchase price during early lactation may be affected. Milk from MIX ewes would have to be worth only $1.17/kg and $1.06/kg to equal the returns of the DY1 and DY30 systems, respectively.

Implications

Weaning and rearing systems for dairy sheep producers attempt to maximize commercial milk yields without seriously disadvantaging lamb growth, and are thus markedly different from the systems used in traditional lamb and wool operations. Thus far, weaning at 30 d has been the most common system used by American dairy shepherds. The results of this experiment demonstrate that two other weaning systems, a partial suckling/milking system and a 24 hr weaning system, offer significant increases in commercial milk production and greater economic returns than a 30-day weaning system.

Table 1. Least squares means (±SE) for milk yield lactation traits of the three weaning systems

Trait		Weaning System	
	DY1	MIX	DY30
Number of ewes	42	48	42
Commercial milk yield, L/ewe			
pre-weaning	69.6 ± 2.3[a]	42.4 ± 2.3[b]	-
peri-weaning	31.5 ± 1.1[a]	33.8 ± 1.1[a]	28.1 ± 1.2[b]
post-weaning	138.1 ± 6.1	129.9 ± 6.0	122.1 ± 6.5
total	239.6 ± 7.6[a]	205.4 ± 7.51[b]	148.6 ± 8.2[c]
Lactation length, d	177.7 ± 5.3	171.0 ± 5.0	169.4 ± 5.9
Machine milking period, d	176.7 ± 5.3[a]	170.0 ± 5.0[a]	138.9 ± 6.0[b]
Average daily commercial milk yield, L/d	1.33 ± .03[a]	1.20 ± .03[b]	1.05 ± .04[c]

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

Table 2. Least squares means (±SE) for total commercial milk yield and average daily milk yield by weaning system - nutrition combinations

Trait	Nutrition	Weaning System		
		DY1 (42)[§]	MIX (48)	DY30 (42)
Commercial milk yield, L				
	pasture	243.6 ± 11.4[a]	234.2 ± 9.83[a]	156.9 ± 10.4[bc]
	drylot	235.6 ± 10.4[a]	176.5 ± 10.4[b]	140.4 ± 11.8[c]
Average daily milk yield, L/d				
	pasture	1.33 ± .05[a]	1.31 ± .04[a]	1.06 ± .05[b]
	drylot	1.33 ± .04[a]	1.10 ± .05[b]	1.04 ± .06[b]

[§] Number of ewes.
[a,b,c] Within an independent trait, means lacking a common superscript letter are different (*P* < .05).

Table 3. Weighted[†] least squares means (±SE) for milk composition and quality traits of the three weaning systems

Trait	Weaning System		
	DY1	MIX	DY30
Number of ewes	42	48	42
Milk fat, %			
pre-weaning	4.88 ± .16[a]	3.24 ± .18[b]	-
peri-weaning	4.90 ± .14[a]	4.78 ± .15[a]	4.21 ± .17[b]
post-weaning	5.14 ± .10	5.25 ± .11	5.30 ± .12
total	5.05 ± .10[a]	4.65 ± .10[b]	4.98 ± .12[a]
Total milk fat, kg	12.3 ± .52[a]	10.2 ± .58[b]	7.45 ± .64[c]
Milk protein, %			
pre-weaning	5.52 ± .06[a]	5.36 ± .06[b]	-
peri-weaning	5.12 ± .07	5.04 ± .06	5.07 ± .07
post-weaning	5.07 ± .07[a]	5.11 ± .06[a]	5.30 ± .07[b]
total	5.23 ± .06	5.14 ± .06	5.23 ± .06
Total milk protein, kg	13.0 ± .47[a]	10.9 ± .46[b]	7.86 ± .49[c]
Somatic cell count, log units			
pre-weaning	4.91 ± .06[a]	4.65 ± .06[b]	-
peri-weaning	5.02 ± .07[ab]	4.86 ± .07[a]	5.18 ± .08[b]
post-weaning	4.88 ± .06	4.81 ± .06	4.95 ± .06

[†] For percentages of milk fat and protein.
[a,b,c] Within a row, means lacking a common superscript letter are different (*P* < .05).

Table 4. Least squares means (±SE) for lamb growth traits of the three rearing systems

Trait	Rearing System		
	ART	LMIX	TRAD
Number of lambs reared	93	78	87
Birth weight, kg	4.58 ± .11[a]	4.37 ± .27[a]	5.00 ± .15[b]
Weaning age, d	24.2 ± .60[a]	27.9 ± 1.0[b]	31.5 ± .90[c]
Adjusted 30-d weight, kg	14.9 ± .27	14.3 ± .39	15.2 ± .38
Adjusted daily gain from birth to 30 d, g/d	338.7 ± 8.92	319.4 ± 13.1	348.6 ± 12.5
Adjusted 120-d weight, kg	43.6 ± .84[a]	45.5 ± 1.2[ab]	47.8 ± 1.2[b]
Adjusted daily gain from 30 to 120 d, g/d	319.1 ± 8.60[a]	346.4 ± 12.8[b]	361.9 ± 12.3[b]

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

Table 5. Least squares means (±SE) for lamb growth traits by rearing system - birth type combination

Trait	Rearing system	Birth Type: twin	Birth Type: ≥ triplet
Adjusted 30-d weight, kg			
	ART	15.3 ± .32[a]	14.5 ± .37[b]
	LMIX	14.4 ± .42[b]	14.3 ± .49[b]
	TRAD	16.1 ± .46[a]	14.3 ± .40[b]
Weight gain from birth to 30 d, g/d			
	ART	352.1 ± 10.6[a]	325.4 ± 12.3[b]
	LMIX	322.1 ± 14.0[b]	316.8 ± 16.4[b]
	TRAD	377.8 ± 15.3[a]	319.4 ± 13.3[b]

[a,b] Within an independent trait, means lacking a common superscript letter are different (*P* < .05).

Table 6. Simplified relative economic comparison of the three weaning systems

	weight (kg)	price per kg ($/kg)	receipts ($)	expenses over DY30/TRAD system ($)	returns (receipts - expenses) ($)	returns relative to DY30/TRAD system ($)	returns relative to DY30/TRAD system (%)
Ewe, milk value							
DY1	248.2	$1.32	$327.62	($16.20)[¥]	$311.42	+$108.27	53.3%
MIX	212.8	$1.32	$280.90	($10.60)[‡]	$270.30	+$67.15	33.1%
DY30	153.9	$1.32	$203.15	$0.00	$203.15	$0.00	0.0%
Lamb value, 2.19 lambs/ewe							
ART	43.6[µ]/85.0[£]	$1.87	$158.99	($67.96)[◊]	$91.03	-$83.27	-47.8%
LMIX	45.5/88.7	$1.87	$165.92	$0.00	$165.92	-$8.38	-4.8%
TRAD	47.8/93.2	$1.87	$174.30	$0.00	$174.30	$0.00	0.0%
Total system[¶]							
DY1/ART			$486.61	($84.16)	$402.45	$25.00	**6.6%**
MIX/LMIX			$446.82	($10.60)	$436.22	$58.77	**15.6%**
DY30/TRAD			$377.45	$0.00	$377.45	$0.00	**0.0%**

[¥]Labor to milk one ewe twice daily for 30 days.
[‡]Labor to, once daily, separate the ewes from their lambs and milk one ewe for 30 days.
[◊]Cost of milk replacer, supplies and labor to raise 2.19 lambs artificially.
[µ]Weight (kg) of an individual lamb.
[£]Weight (kg) of 2.19 lambs x 11% mortality (1.95 lambs marketed per ewe).
[¶]For one lactating ewe and her 2.19 lambs.

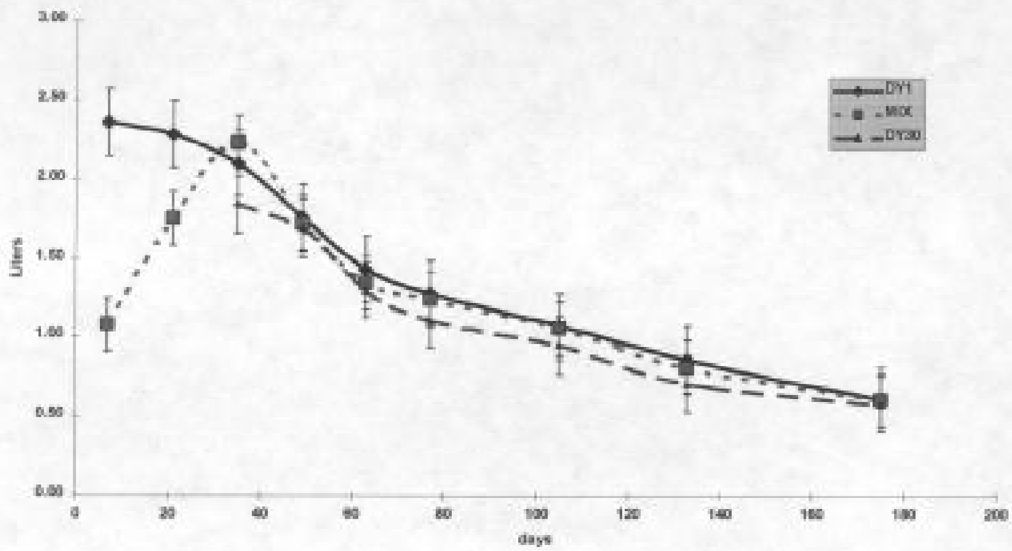

Figure 1. Average daily commercial milk yield for the three weaning systems.

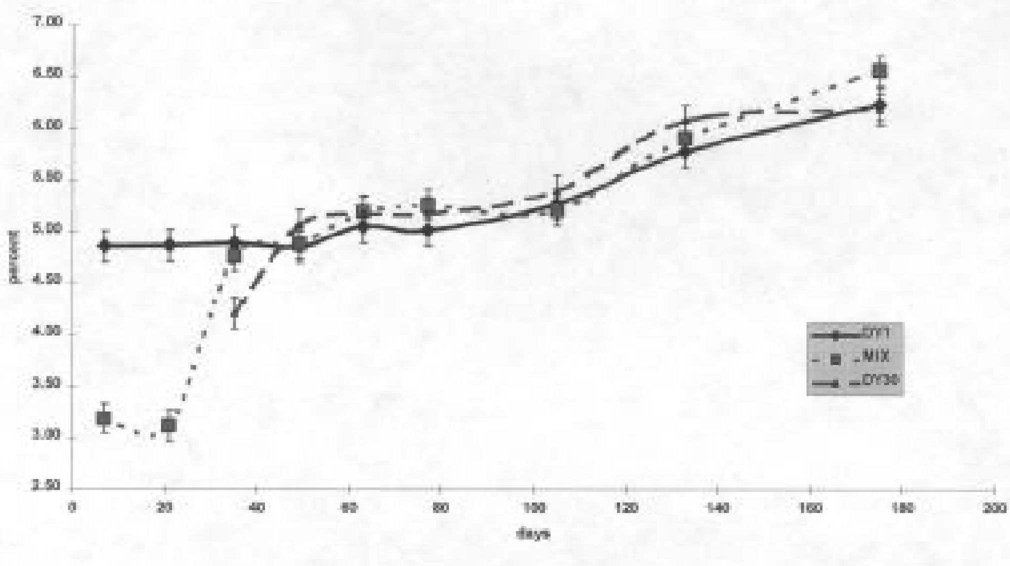

Figure 2. Percentage of milk fat for the three weaning systems.

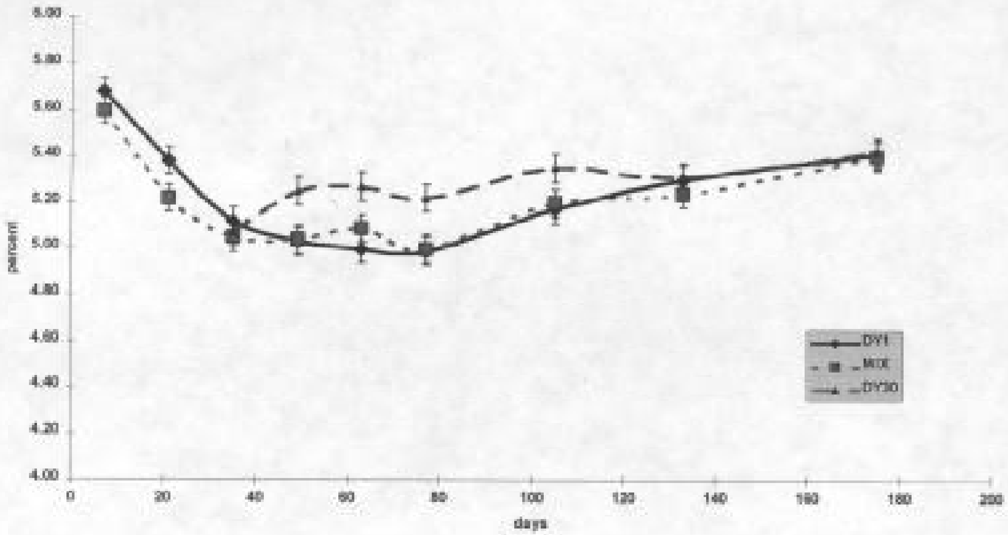

Figure 3. Percentage of milk protein for the three weaning systems.

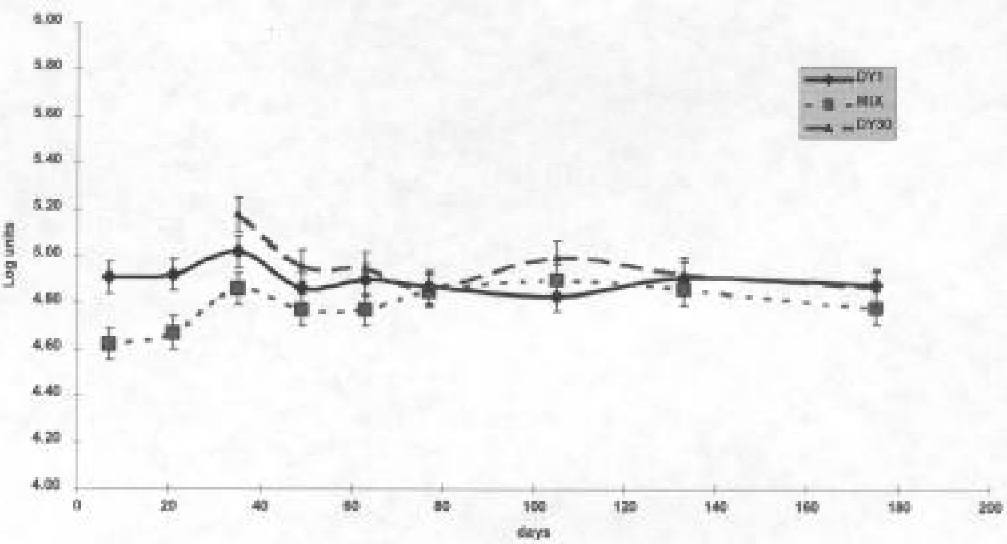

Figure 4. Log-transformed somatic cell count for the three weaning systems.

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FARMING TO LOVE THE CHILDREN: THE UNFAIR ADVANTAGE OF SMALL RUMINANT DAIRYING. LESSONS LEARNED AT NORTHLAND SHEEP DAIRY

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Evidence has accumulated rapidly in recent decades that much of our industrial way of food production cannot be sustained, for it destroys both the environment necessary to human health and quality of life, and the natural resource base food production is dependent upon. Our main agricultural export is not a commodity like grain, but topsoil. Modern farming practices produce short-run abundance but long-run damage to essential agroecosystem processes: to water and mineral cycles, to energy sources and flows, and to the eco-community dynamics that requires a critical mass of interacting species. As the adverse consequences of our economic and technological choices are often delayed, the brunt of them falls largely on future generations, on our children. Few of us would deny that we love the children, but the way we live and farm discredits our best intentions, and amounts to an intergenerational tyranny. In effect the ways we have chosen to maximize our present standard of living constitute a theft from future generations. The objective of this report is first to identify two main forces driving these choices, and then to explore opportunities in small ruminant dairy farming to counter these forces, and make progress toward a more sustainable agriculture: a way of farming to love the children.

Major Obstacles

In order to understand what has happened to food production in the modern industrial age, we need to look closely at two fundamental forces: classical science and the laissez-faire economy.

The holy grail of science up to now has been its predictive power; that is what has given science its virtually sacred status in modern times. But to achieve that predictive power scientists have had to follow a method that *reduces* their focus to a few variables: add genes A to Cow B and get higher milk yield C, or add heat A to raw milk B and get rid of tuberculosis C. This reductionist science works fine in a controlled laboratory, but when we practice A+B=C in the complex systems that make up the real world there are *always* many more outcomes than C, a lot of which, we are finding, eventually cause worse problems than the one the scientist solved.

Thanks to reductionist science, sheep farmers have the chemical technology to deliver a knockout blow to the intestinal parasites that plague lambs, but well apart from the largely unresearched effects of those chemicals on our food, a short term focus allows the scientist to disregard the fact that routine use eventually builds resistance and renders the technology useless. Similarly, the narrow focus on maximum milk yield in the modern Holstein has produced a now classic constellation of negative outcomes at, at least, three levels: animal health, ecosystem health, and food quality, and promises a repeat performance when applied to the dairy ewe. To the numerous known negative consequences of concentrate feeding of ruminants to boost milk and meat yields, recent research adds two more: it turns the animals into factories that are generating the dangerous acid-tolerant E coli strain turning up in our food supply. And feeding grain and even conserved forage degrades the quality of milk and meat by removing substances inherent in milk from purely grass-fed dairy animals, components like CLA (conjugated linoleic acid) that help us defend against three of the degenerative illnesses that plague modern industrial societies: cancer, heart disease, and diabetes. Thus the reductionist nature of most of current science is partly responsible for the delayed but accumulating problems, often down-played as ‘side effects’, caused by powerful modern technologies.

Our world is a complex system of elements within wholes within wholes. Some of the components are inert, some alive, themselves whole complex systems, some communities of whole systems. It follows that what we must pay attention to, as we operate in this world, is less the seemingly discrete elements and more their interdependency, their relationships. In general, it has been the assumption of the classical scientific paradigm that if we manage the parts right, the whole will come right. Evidence that this is not the case is now coming from every quarter, yet our systems of knowledge and management are still structured around this assumption. In fact some of our best thinkers are saying that the most important scientific advance of the 20th century will be our grudging acceptance of the interdependency of our world, putting the pressure on science to change its very nature. In practice this means that problems can no longer be addressed only from a disciplinary viewpoint. The complex dynamics of strongly interacting processes will force scientists and decision-makers to think and act in a more holistic manner.

Probably even more important than the nature of our science has been the nature of the economic system we have allowed to develop, especially in the United States. When Monsanto developed the Terminator gene that can land it control over the bulk of the world seed market, critics called that diabolical; but to Monsanto, Terminator is just devilishly good business. Such predatory behavior is perfectly normal and in fact necessary for long term business survival in an economic system which the French long ago dubbed laissez-faire, or ‘anything goes’, perhaps because at the time it contrasted starkly with their catholic notions of social order. Early predictions that unrestrained market economies contain an inherent drive toward monopoly have come true, and in the agricultural sector this effectively reduces most farmers to serfs at the mercy of farm commodity markets dominated by huge corporations. Since the amoral nature of our chosen economic system is such that it mainly rewards short term gain, and considers only local, immediate costs, it allows us to pass on heavy ecological and social costs of our economic behavior to future generations and other remote peoples. It allows, eventually even forces farmers, if we are to remain profitable within this economic system, to practice intergenerational tyranny.

In sum, both the current scientific paradigm and our current economic system have a similar flaw in design: a tendency to ignore delayed or distant consequences, down the road in time, as on future generations, and down the road in space, as when the agritoxins in the creek running below my farm empty into Chesapeake bay several hundred miles away, where they destroy fisheries and endanger public health.

Compounding the problem, the concentrated power in our economic system constantly bends the scientific establishment into its service via skewed incentives and rewards:

Over 90% of weed scientists are dependent on funding from pesticide companies.
When an epidemiologist documented the damage North Carolina’s hog megafarms inflict on the health of nearby communities, the megafarms took him to court.

These are but two examples of common occurrences. Throughout the land grant agricultural education system, research in the corporate interest is rewarded, while research in the public interest, serving the original mandate of the land grants offers only risk and sacrifice.

An Alternative Agriculture?

Current fashion is to promote an ‘alternative agriculture’ focused on value-added, direct-marketing, and exotic products. This alternative fails to directly address core issues of ecological sustainability. Moreover, in as much as its goal is to exploit niches, this alternative promises little economic relief to the majority of farmers selling into commodity markets now increasingly subject to monopoly control, for niches are by definition but a small part of the system. Given the ever increasing concentration of market power in the economy, there appears little chance of major concern with issues of sustainability until accumulating negative social and environmental impacts generate the requisite political will to manage the economy according to different priorities. However, until such time as the political will for change emerges, the niche exploitation alternative *does* offer a breathing space, sheltered from the predatory market forces shaping commodity farming, to test, refine, and slowly propagate, sustainable practices. And sheep dairies are an obvious candidate for niche exploitation; that is their first ‘unfair advantage’.

Sustainable Sheep Dairy Systems

What can we do in this breathing space? The task is barely begun: commercial organic farming in this country does not yet practice anything close to its vision of sustainable agriculture. We organic farmers are far too dependent on fossil fueled technologies, monocultural agroecosystems, and distant supply lines and markets, just to name a few problems and challenges. Possibly the most effective first step in the restoration of sustainability is the re-integration of ruminant livestock with grain, vegetable, and fruit farming. Self-fed from permanent hay/pasture as they were originally designed, grazers like sheep and cattle are the fastest solar-powered soil building tool farmers have. Sheep dairies can model sustainable soil fertility and animal husbandry systems. That is our second unfair advantage. But only if the sheep are grass-fed. Grain feeding may be currently profitable for many farmers, but is not sustainable for many reasons. Those farms which attempt to model totally grass-fed systems cannot think piece-meal: they must redesign the whole, adapting sheep genetics, grazing design, pasture species mix, manure management, and pest control to one another. At Northland Sheep Dairy we have been moving gradually in this direction for fifteen years.

Sheep Genetics

In the rich, centuries-old, year-round pastures and mild climate of Friesland, the Friesian cow was an efficient milk producer on grass until it was exported and became the monster Holstein of today. In a comparable climate and soil quality, the Friesian sheep may, with some readaptation, do as well just on grass. In most locations in the United States the purebred Friesian sheep is a poor candidate for a sustainable system because of its long history of coddling with a high concentrate diet, and because so many of our pasture soils need decades of regeneration. Even in a high input system, dairy ewes that are over 75% Friesian appear uneconomical.

Several sheep dairies, in both the Midwest and the Northeast, at various levels of grass reliance, are finding lower levels of Friesian cross-breeding most economic. To genetically select toward a no-grain dairy sheep that will do well in a low external input sustainable system, Northland Sheep Dairy has reduced grain feeding over ten years mainly to a month on each side of lambing, peaking at 0.5#/ewe at lambing. To the resultant hardy, Dorset/Texel base, we have added 25-35% Friesian with no significant loss of hardiness in the sheep or solids in the milk. Unlike several 50-75% Friesian control ewes in the flock, these sheep have maintained body condition over the lactation, while giving as much milk as the controls. These results are tentative and the experiment continues. The ultimate genetic goal is a sheep that:

Lambs well on pasture in May, timed so that milk and meat production falls as much as possible within the grass season;
Maximizes not quantity, but economy of milk production and lamb growth;
Minimizes the need for farm inputs detrimental to the ecology of the farm or other environments.

This will require genetic selection for parasite resistance, as detailed below in a discussion of pest control.

An Intensive Grazing System

In keeping with the goal of making fullest use of the soil regenerative function of the sheep flock, we have developed an intensive grazing system where the flock, the farmer and the plants closely watch and adapt to one another. A careful reading of André Voisin's classic, *Grass Productivity*, reveals that permanent pasture, developed over time to its maximum potential, outyields temporary forage fields. Moreover, maximum production of manure, as well as milk, depends on high pasture consumption per acre, which in turn depends on a grazing rotation where both the grazeoff and the rest period are timed to keep vegetative, highly palatable plants in front of dairy ewes and growing lambs. It also depends on overseeding and grazing management to develop the most effective mix of legumes, grasses, and broad-leaf plants. Broad-leaf plants are ignored in conventional research because of low relative yield. But broad-leaf plants that are high on the forage preference list of sheep, like dandelion, plaintain, chicory, and wild carrot, are essential to a sustainable pasture species mix. Their deep roots and unique character keep them growing during dry periods, and fill special nutritional needs.

Research has demonstrated that sheep will make forage choices based on nutritional need. Accordingly, we are using pasture management and overseeding to develop the widest possible pasture smorgasbord consistent with flock preference and ability to thrive in our conditions. This includes some hedgerow forage, species with even deeper roots than pasture plants, which our flock craves from time to time. It includes overseeding of trefoil, our main legume, better adapted than alfalfa to our poor, acid soils. We must reseed every 2-3 years, or give it time to self-seed, which it does successfully enough to be a permanent part of the roadside ecology in our region, where one pass per season by the road maintenance mower creates a niche to its advantage. Our other overseed to date, Puna chicory, chosen because of its superior lamb production ability, has been persistent, but will not reach an economical size until our soil fertility improves. Our first choice for future overseeding will be a late maturing, diploid perennial ryegrass, although the jury is still out on whether newer varieties have finally achieved the winter hardiness necessary in the Northeast and Northern Midwest.

A future project in the quest for a sustainable pasture system will integrate black locust rows, spaced to allow machine hay harvest and just enough shading to protect pasture and flock from the hot, drying sun of midsummer. This sylvopastoral arrangement will produce both lumber and nitrogen for the farm. Planted in the fence row as well, and coppiced to fence post height, the locust will replace dead posts with more permanent live ones, and yield a regular harvest of palatable, nutritious forage.

The black locust project typifies the design strategy farmers will have to use to build an agriculture that uses land and other natural resources both efficiently and sustainably. The strategy uses the biodiversity potential of a location to *capture synergistic relationships* between species. Sheep/orchard sylvopastoral systems on our farm and elsewhere have demonstrated the capacity of the synergy design principle to address orchard pest problems by:

Keeping undergrowth down to promote air flow to reduce disease;
Consuming windfalls to break an apple pest cycle;
Enriching orchard soil, increasing both yields and earthworm populations which break another apple pest cycle by consuming fallen leaves.

We believe these are only first steps in realizing the full synergistic potential of sheep/ orchard systems.

Manure Management

Just as proper sheep nutrition feeds the rumen bacterial community, not the sheep, sustainable fertility systems feed the soil community, not the plant. Direct chemical plant fertilization that boosts yields while destroying soil and plant health has been a telling example of the failure of reductionist science serving a profit-at-any-cost economy. The end of cheap oil, due to arrive in one generation, around 2020, should curtail the use of these petroleum-dependent chemicals, so what better alternative can we model for the next generation?

The soil community needs more than manure or green manure: it needs the stabilized nutrients, high carbon content, and bulk of manure that has been composted with a large quantity of high fiber plant material. So soil fertilization schemes built around grass/ruminant core will need to capture as much manure for composting as possible, especially in the colder months, when much of the value of pasture-dropped manure is lost. Before the chemical age, corralling animals at night provided not only protection against predators, but manure collection as well.

Our farm works toward ideal manure management by:

- Feeding hay in sufficient quantity to provide leftovers for deep litter bedding that will capture the nutrients in winter manure build-up;
- Designing a sheep barn for easy summer clean-out;
- Using a bucket loader hefty enough for fast turning of composting windrows to achieve a stable end product before the weather turns too cold;
- Scheduling compost spreading for the following summer when soil biological activity is again high, for the compost to be absorbed with the least loss of nutrients.

The functions of the deep litter winter manure pack are multiple: manure storage with minimal leaching and ammonia losses; warmth, cleanliness and sanitation for livestock; odorless barns, and proper carbon/nitrogen balance for making good compost. The manure pack is such an attractive manure storage solution in sustainable livestock systems, that even a few organic cow dairies are beginning to consider it seriously again. The unfair advantage of sheep and goat dairies is that sheep manure packs need less bedding, and pasture manure is well dispersed.

Combined with artful intensive grazing management, this type of careful manure management eventually generates a fertility surplus beyond the fertility needs of the livestock supporting fields, as Voisin demonstrated. The surplus then becomes the fertility source needed to integrate tillage crops sustainably. So the grass/ruminant complex becomes the fertility production core capable of driving a wide variety of crop farming in a self-contained system dependent largely on current, local solar gain. Once the core is in place, other animal-powered complements become economic: draft animal traction, pig and chicken composters, and poultry-based pest controls, for example.

Pest Control

Since heavy reliance on vermifuges, be they chemical or herbal, breeds resistance, the burden of sustainable parasite control in small ruminants falls on genetics and management, especially grazing management. Genetic selection for parasite resistance can take place only where reliance on parasiticides is low to non-existent and animals are allowed to sink or swim within a management-controlled farm parasite load. The most effective management tool is the provision of clean pasture every year by dividing the farm forage field space in half, and alternating the main production stock yearly between halves. Forage on the other half is harvested by machine or by another pasture species.

Northland Sheep Dairy is certified organic and we make no routine use of parasiticides, at some sacrifice in lamb production. However this allows us to select for parasite resistance in replacement ewes from the lamb crop, which we expect to pay off in the long run. Our main criteria for parasite resistance are weight and condition at six months or more of age, after the lambs have weathered the summer gauntlet of parasite attack.

Acreage shortage has limited full implementation of the management program, but for the last 3 years we have been able to put the weaned lambs on pasture reserved for hay the previous year. Lambs are still exposed to contaminated pasture until weaning, but lamb production seems to be slowly improving, and for years we have seen little sign of excess parasite load in adult ewes. Plans for the future are to add enough animal units of another hardy pasture species, like a few Highland cattle, along with our team of Haflinger draft horses, to balance the dairy ewe and lamb flocks, and provide the annual alternation of stock that we need for sustainable pest control in the sheep.

Unwanted plants invading hay/pasture are another pest control problem. Since permanent hay/pasture is our goal according to the sustainable model we have set for the farm, we need to find management solutions: changing the patterns of grazing, haying, clipping, or overseeding. Bedstraw, our main unwanted pasture invasion, gets worse in an intensive grazing rotation, even with some hay harvest and clipping, because the sheep graze it last. So far we have not had the resources to subject invaded fields to repeated haying or clipping alone.

Conclusion

Small scale sheep dairies doing processing and direct marketing are excellent candidates for modeling farming systems that can repair and rebuild our sorely depleted natural resource base: ways of farming to love the children. A number of principles of sustainable design emerge from our experience, and from other efforts around the world:

Use holistic, site-specific designs
Capture inter-species synergies
Use current solar gain
Respect nature’s cycles
Design to appropriate scale

HERD HEALTH MANAGEMENT AND RECORD KEEPING FOR DAIRY SHEEP

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Introduction

The sheep industry, especially larger commercial flocks, have been looking for more efficient ways to fight against health problems for a long time. Traditional veterinary medicine with healing, curing and treating of single animals or entire flocks has lost its importance and will more and more be replaced by preventive measures and health management.

Reasons that are limitting the use of traditional veterinary medicine:

- Quite a lot of infectious diseases in sheep have an epidemic course (e.g. Pasteurella pneumonia, cocccidiosis) and are spreading very fast and aggressively (e.g. chlamydiosis, pneumococcosis in lambs) within a flock. Also non-infectious problems (e.g. copper poisoning, white muscel disease) involve more often several animals or even the whole herd;
- Some diseases in small ruminats (e.g. enterotoxemia, sudden death) can't be treated or cured;
- Low income per animal unit and modest value of the animal itself ;
- High animal numbers per farm are making conventional medical practice too expensive (chlamydiosos) and too labour intensive (e.g. infectious footrot);
- Lack of registered drugs for use in sheep;
- It's well known that the percentage of bacteria and parasites (internal and external) with single or multiple restistance against regular drugs is steadily growing. The more often and uncontrolled these drugs are used, the greater is the chance that resistance will grow.

Good herd health management helps to prevent the development and/or uncontrolled spread of diseasis and reduces economical losses. It is even more important in a dairy sheep operation than it already is in a common meat sheep flock.

Key reasons for the importance of herd health management in dairy sheep operations:

- **Health risks for humans**

Milk and milk products are an extremely volatile food. Several infectious diseases (e.g. listeriosis, staphylococcosis) can be spread easily via milk or milk products to consumers. Health risk can occur even when the milk was pasteurized (e.g. Staphylococcus aureus toxines). Sheep's milk with its high protein and fat content is especially prone to hazardous problems.

- **Inefficient milk performance and economy of enterprise**

Herd health problems have a direct (e.g. mastitis) or often an indirect (e.g. footrot, enzootic pneumonia, OPP) impact on the milk performance and are, besides primary feeding failures, the most common reasons for reduced milk performance and economical losses.

- **Increased suscebtibility to health problems**

Dairy sheep are more susceptible to a variety of health problems than meat sheep (e.g. Pasteurella pneumonia in East Friesian sheep). Additional stress factors (such as early weaning of lambs, milking procedure, performance stress, a.s.o.) have a negative effect on the immunity system.

In dairy flocks infectious diseases (e.g. OPP) often spread faster, evoke more severe clinical signs and result in more excessive economical losses.

- **Milk withdrawal time**

Most of the drugs that exist to cure and heal lactating dairy cows are not registered for use in dairy sheep. This means that they either can't be used or they have a very long milk withdrawal time, which results sometimes in big financial losses and additional labour, because treated animals have to be milked seperately.

Health problems

This paper will not include a complete review of all herd health problems in dairy sheep. It represents a selection of problems from the prospective of a dairy sheep producer and veterinarian. The herd health depends on many different circumstances as geography, type of management system (extensive, intensive), herd size, farm size, housing, feeding, a.s.o.

General problems

<u>Problem Biosecurity</u>

A really big threat to the health of every sheep flock is the [uncontrolled] traffic (e.g. purchase, breeding, pasture contacts, shows, exhibitions) of sheep or related ruminants (especially goats) and humans (e.g. farmer himself [sales barn visits], custom workers, visitors).

<u>Problem management & animal environment</u>

Many diseases and health problems that can occur in a flock are based on a faulty or incorrect:

- Sheep *environment* (*space, climate, bedding, light*: keeping conditions)
- *Feeding*
- *Handling*
- *Care*

Let us call these four subjects 'basic needs' of sheep. When any defects in the accomplishment of these basic needs exist over a long time period, then health problems will develop and worsen the longer these defects will exist.

Table 1: 'Basic needs' of sheep, which have to be satisfied by the management:

'Basic needs'	**Common failures**	**Normal**
Environmental conditions		
–**Space**	Too tight, crowding	Comply with codes
–**Climate**:		
. Air quality & movement	– Draft or sticky, with accummulation of noxious gases	⇒ better cold and dry, than warm and too humid
. Humidity	– Over 80 % for a longer time	
. Temperature	– Too cold or too warm	
–**Bedding** & walk ways	None, wet, dirty, foul, muddy	Dry, clean, sufficient
–**Light**	Too dark (often in old barns)	'News-paper'-test

Table 1: ‘Basic needs’ of sheep (continued)

‘Basic needs’	Common failures	Normal
Feeding	• Not balanced and not according to performance: - Energy ↑↑ and protein ↑↑ - Energy ↑↑ and protein ↓↓ - Protein ↑↑ and energy ↓↓	• Well-balanced and according to performance (3 phases: **starting** phase, **producing** phase, **high pregnancy & preparation** phase**)**
	• Not enough fiber in ration	• Always supply roughage, even during summer
	• Too monotonous	• Variety of feed
	• Feeding time too short	• Long feeding times (over 6 hours)
	• Spoiled feed	• Clean, without mold, dust-free
	• Not enough minerals, trace minerals, vitamins	• Well balanced mineral salts <u>and</u> NaCl-salt-[blocks], check intake, keep clean!
	• Not enough feed trough width for all	• Provide enough feed trough space
	• No or not enough water, bad quality	• Free accss to clean water, check & clean waterers regularly
Handling	No handling facilities: stress, injuries	Well considered handling: no need of fancy equipement and facilities
Care	Neglecting foot trimming, shearing	Foot trimming 1-2 x per year, shearing in minimum once per year (East Friesian: 1-2 x)

↑↑ = too much ↓↓ = not enough

Specific health problems

- **Infectious diseases**:

  a) *Contagious diseases:*

Of major interest are diseases which can be easily spread from flock to flock. A special concern for every sheep enterprise are those contagious diseases that can’t be cured (or rarely) and where no sanitation is possible:

Table 2: Listing of some important contagious diseases:

Disease	**Treatment**	**Sanitation**	**Preventive Measuress**
Footrot	Possible	Labour intensive, improved management	Closed flock, vaccination
OPP (Maedi-Visna)	Impossible	Complex, artificial rearing of lambs	Closed flock, test
Adenomatosis	Impossible	Unknown	Closed flock
Scrapie (*)	Impossible	Culling	Closed flock, test
Paratuberculosis	Impossible	Impossible or unknown	Closed flock, test
Pseudotuberculosis *	Impossible	Complex, artificial rearing of lambs	Closed flock, test, vaccination
‘Chronic mastitis’ *	Possible	Sometimes complex, improved management	Closed flock, CMT
Chlamydiosis *	(+-) possible	Complex, vaccination	Closed flock, test, vaccination
Ecthymia *	Possible	Labour intensive, vaccination	Closed flock, vaccination
Pasteurella pneumonia	Possible	Improved management	Closed flock

* Zoonoses (Diseases with a potential to affect both man and animals)

b)Low (or not) contagious diseases:

Some infectious diseases can occur within a flock without having contact with other herds. These diseases can have a great negative impact on the herd health, especially when there is no treatment or cure possible, but in general they are easier to prevent.

Table 3: Listing of some unimportant or low contagious diseases:

Disease	**Treatment**	**Sanitation**	**Preventive Measuress**
Enterotoxemia	Impossible	Improved management, vaccination	Vaccination
Listeriosis*	Impossible	Improved management, ‘vaccination’	Improved management
Tetanus	Impossible	Improved management, vaccination	Vaccination, desinfection

* Zoonoses (Diseases with a potential to affect both man and animals)

- **Parasitic diseases**

External and internal parasites can be administerd into a flock with the purchase or introducing of other sheep into the flock. Under certain conditions wild animals can be involved. Some internal parasites are very difficult to prevent, because they have hosts, where the parasite can pass the winter (e.g. Moniezia expansa [sheep tape worm]).

- **Other diseases**

Nutritional and Metabolic diseases (See Table 1 [feeding]):

Feeding disorders are quite common in dairy sheep. The lactation length (up to 300 days) and performance stress are much longer and more intensive than in meat sheep, therefore, feeding failures become especially problematic.

Table 4: Most common feeding disorders and their prevention:

Disease	**Cause**	**Prevention**
Pregnancy toxemia, ketosis	–Direct: Undernutrition (energy ↓↓), or overnutrition (energy ↑↑) –Indirect: Multiple fetuses, indigestion, rumen acidosis	Body scoring in early gestation, feeding balanced and according to performance, grain regularly, good quality roughage, (fetus counting)
Milk fever	–Direct: Too much calcium during late pregnancy, (wrong mineral salt, sugar beets, hay with lots of legumes, alfalfa?) –Indirect: Stress (handling), crowding	–Balanced mineral salt (specific for sheep, not dairy cow salts), grassy hay –Avoid stress in late pregnancy: enough space, optimal handling, enough trough width
Indigestion & Rumen acidosis	Lack of fiber (roughage in ration), too much grain, too fast increasing of grain amount in late gestation	Balanced rations (enough fiber), gradually increasing of quanities of grain (2-4 weeks), roughage feeding before grain, grain and corn silage distribution 3 or more times per day
Milk fat depression	Supplementing of poor quality roughage with concentrate (to boost milk performance)	Balanced rations, good hay quality, feeding of roughage always before grain
Enterotoxemia	Sudden changes in diet (e.g. new pasture, excessive grain feeding)	Avoiding of rapid diet changes: Feeding of hay when grazing ‘rich’ pastures (spring, seedings), regular feeding of grain (better often in small quantities)

Management Practices

General Measures

A good herd health management should be based on two main principles:

I. **Biosecurity**
II. Fulfillment of **basic needs** of sheep

These two principles must always to be met without compromise.

I. Care about biosecurity !

There are at least three possible levels of biosecurity:

A) Minimal preventive measures:

Animal traffic is restricted: Replacement ewes, rams a.s.o. can be brought into the herd after a quarantine of a minimum of 4 weeks. Only 'healthy' animals will be accepted. Attending of shows is possible.

This type of biosecurity is very controversial, because there is no guaranty that these measures can protect a good health standard.

B) Closed flock management

The herd is periodically controlled by clinical check and/or laboratory testing (serology a.s.o). Any animal traffic is strictly forbidden. No showing of sheep. A.I., E.T. Under certain circumstances animals out of herds with the same sanitary status may enter the flock after an obligatory quarantine. Traffic of humans is also restricted: Access to farm only after changing of boots and clothing (overall). The same precautions are necessary after visits of sales-barns, livestock exhibitions and slaughter houses!

Dairy sheep operations should be managed as closed herds. With a modest amount of labour a high level of security can be achieved.

C) Specific pathogen free flock (Hysterectomy, nucleus flock)

This is the most rigorous level of biosecurity. Theoretically all infectious diseases, (also in the moment not known or detectable infectious agens) can be barred from a flock. Needs a very good managment to keep and to control the sanitary status. The role of wildlife, birds, rodents and insects in spreading certain diseases is at the moment not always known. In the hog industry quite good experiences could be achieved, but hogs leave the barn environment just for the slaughter house!?

II. Care about the 'basic needs' each creature needs:

Enough space to move
Good climate
Dry and clean bedding & walk ways
Lots of natural illumination
Balanced feeding
Stress free handling
Good care

In herd health management it is of tremendous importance that the basic needs of each sheep can be fulfilled as well as possible. Without the fulfillment of these basic needs any further management measures will be futile. (See also Table 1)

Feeding:

The most common feeding disorders with their preventive measures are listed in Table 4.

Some general remarks regarding feeding management: (See also Table 1)

- Ruminants need over 18 hours for eating, ruminating, chewing!!!: Allow a minimum of 6 hours for eating;
- Sheep are selective eaters, if they have the choice to do so. Grazing of a modest quality pasture or feeding of an average quality hay can result in astonishingly good milk performance;
- Feeding of a variety of food boosts dry matter intake and results in higher performance;
- Sheep feeding should be done according to three performance phases:
  - **Starting** phase (Parturition to end of 2nd month of lactation);
  - **Producing** phase (3rd month of lactation to 3rd month of gestation);
  - **High gestation & preparation** phase (4th and 5th month of gestation).

Each phase is characterized by specific conditions, that have different requirements.

- Dairy sheep in lactation need free access to a water source of good quality.

III. <u>Cull sheep with (repeated) health problems:</u>

Not a main principle, but a quite important tool of herd health management is the culling of sheep which have had (several times) serious health problems. For some health problems it is adviseable not to use the offspring as replacement ewes or breeding rams, because susceptibility to many dieases is heritable.

Specific Measures

Measures as described under general should be able to control most of the infectious diseases normally. However some diseases need additional preventive measures:

(1) Infectious diseases:

For dairy sheep the following preventive measures sould be taken: (See also Table 2)

a) Birth, new born lambs:

- Dry and clean bedding;
- When help is needed: Only with clean, desinfected hands;
- Navel desinfection with Iodine;
- Check udder and make sure lambs get colostrom.

a) Vaccinations: Especially recommended for dairy sheep are:

- **Enterotoxemia;**
- Tetanus.

b) Mastitis: Mastitis problems are very frustrating and serious. Generally three types of mastitis are known (seeTable 5).

Table 5: Types of mastitis

Type	General	Clinical signs Udder	Milk	CMT	Treatment
Acute Mastitis	Fever, lameness, sick	–Swollen, hard –Hot or cold –Red or blue-black –Dolorous –(Assymetric)	–Dramatically reduced –Altered: water-like, bloody, pus, frazzels	+ + +	–Antibiotics in udder & systemic –(Dry treatment)
Chronic, clinical M.	No fever, no sick, ev. slight lameness	–Sensitive –(Assymetric)	–Reduced –Slightly altered: water-like, frazzels	+ + +	–Antibiotics in udder –Dry treatment
Chronic, sublinical M.	Absolutely normal	–Nodes and/or slightly assymetric	–Slightly reduced –Not altered	+ to + + +	–Antibiotics in udder –Dry treatment

Chronic, subclinical mastitis is a major concern for the milk processing industry, because the quality of the milk is reduced without being obviously altered, and affected sheep don't normally show any clinical signs. Some pathogen germs can even be a threat for human health (e.g. Listeria species). Chronic mastits does not seldom develop to a herd problem, with several sheep or nearly all affected. The only way to control chronic mastitis is an optimal udder health (preventive) management:

- Milking equipement: (Checks & maintainance)
  - Vacuum (level, fluctuations, leaks, drains)
  - Pulsation frequency
  - Pulsation rates (vacuum phase : rest phase)
  - Teat cup liners, hoses,valves
- Milking techniques & hygiene:
  - Strip into premilk cup, check milk
  - Clean just really dirty udders with paper towels
  - Remove all milk from the udder, but don't 'overmilk'
  - CMT a minimum of once per week
  - Teat dipping after (if necessary also before) milking
  - Tranquil handling
- Parlour & environment:
  - Avoid muddy walk ways and pastures
  - Pre-milking waiting area with good drain, better roofed
  - Access to parlour over grid, slotted floor or hard gravel
  - Dry, clean bedding
- Housing, feeding, handling a.s.o. (See under general preventive measures)

d) Listeriosis: Listeriosis needs some special remarks, because this disease can be quite dangerous for humans. The main concern are sheep that are affected, but don't show signs of sickness, but spread listeria bacteria in the milk and contamination of milk in dairies with an unsatisfactory hygiene.

Preventive measures are:

- Feeding of good fermented silage (corn and hay) only;
- Remove left-overs of the previous silage feeding from the feed trough. Don't throw these left-overs or other spoiled silage in the sheep pen (for bedding);
- For silage feeding use mainly concrete or steel feeders;
- No milking in the housing barn itself;
- Good parlour hgygiene.

d) Disease Monitoring: For some accreditation programs it is necessary to montior certain diseases (e.g. **OPP**, [Scrapie, Pseudotuberculosis, Paratuberculosis) with different laboratory test (e.g. blood serology)].

(2) Non-infectious diseases: Some remarks:

- Selenium/Vitamin-E deficiency: White-muscle disease in lambs and preventive measures are mostly well known. Selenium/Vitamin-E deficiency might be even more common in a 'chronic', latent form in adult dairy sheep. Possible problems could be: Reduced fertility, negative influence on immunity system and milk performance.
- Copper poisoning: Beware of commercial dairy concentrates! Check mineral salts on copper contents.

(1) Parasitic diseases:

a) Ectoparasites

General preventive measures to control infestation with ectoparasites as **mites**, lice, keds, ticks are:

- Closed-flock management;
- Periodic shearing (East Friesian sheep: if problems 2x);
- Optimal keeping conditions. (See under general measures)

a) Endoparasites

- ***General***:

Some of the many different types of endoparasites (e.g. Haemonchus) are a real threat to the herd health. Preventive management is the only reasonable way to control these parasites, but is very complex and depends on the individual existing circumstances of each farm (e.g. pasture or confinement, numbers of pastures, a.s.o.). In dairy sheep there is the additional problem of the availability of registered dewormers. Some dewormers are forbidden for lactating animals and others have a prolonged withdrawal time.

General preventive measures:

- All sheep (also goats) entering the herd (purchase, breeding) should be set under quarantine for three weeks and dewormed at least two times;
- Divide herd into age groups for grazing (adult ewes, weaned lambs): The older the sheep are the less problems they will have with worms (certain immunity). Lambs and sheep in the first grazing season are the most vulnerable. Therefore don't graze weaned lambs with adult ewes;

- Deworm ewes before beginning milking: e.g. directly after lambing, when milk can't be used for human consumption (colostrum) or as long as lambs suckle. Additional dewormings if necessary could be done with 'organic dewormer' (e.g. Diotomaceus Earth, herbal dewormer), that have no milk withdrawal time;
- Use the exact dosage of dewormer (or better too much than not enough: resistance), check accuracy of used equipement, keep newly dewormed sheep inside or in yard for at least a day;
- After grazing a field let the grass regrow and cut it as hay or silage (hay - pasture rotation) or graze this pasture with horses, cows, calves (not goats);
- Fence off manure piles (also run-off areas) and muddy yards;
- If possible monitor parasite infestation with faeces samples;

Record keeping

Record keeping is an important tool of the herd health management because it allows you to monitor the health status. Data analysis helps to track for problems, to show up solutions and to make necessary management decisions.

Besides regular milk performance and prolific data the following health records are essential to observe the herd health status:

Table 6: Recorded data for dairy sheep enterprises:

Data	**Kind of data**	**Reason**
Health	Kind of health problem, date	Decision for culling, offspring, preventive measures
Lambing	Date, problems, lambs born	Decision for culling, offspring, preventive measures
Breeding	Date(s)	Information for feeding, management
Vaccinations	Date, drug used, milk/meat withdrawal duration	Information for booster, animal sales, decision for milk/meat use
Foot trimmings	Date	Control
Culling	Date, reason	Decision for offspring, preventive measures
Deworming	Date, drug, doses, milk/ meat withdrawal time	Information for pasture management, decision for milk/ meat use

Table 6: Recorded data for dairy sheep enterprises (continued):

Data	**Kind of data**	**Reason**
Other treatments	Date, drug, doses, milk/ meat withdrawal time	Information for management decisions, decision for milk/meat use
Udder health •SSC (CMT and others) •Bacterial analysis •Mastitis treatments	 Date, results dito dito	Information for milk quality, decision for milk use, dry-treat-ment
Milk: (besides performance data) •Butter fat •Protein •Ammonia	 Date dito dito	Information for feeding and health
Blood testing (serology) (e.g. OPP)	Date, test reason, kind of test	Health monitoring, accredition programs, information for animal sale
Other monitoring tests (e.g. Scrapie)	Date, test reason, kind of test	Health monitoring, accredition programs information for animal sale
Hay & silage quality: •Analysis •Self-estimation	 Standard feed data Stage, weather conditions estimated value	Information for feeding
Pasture	Rotation date, quality estimation	Information for feeding

Computer programs:

Larger operations should do record keeping with a computer based program on a regular schedule to avoid the loss of important data.

Two possible sources for programs are available:

- **Individually adapted** or designed standard **programs**: e.g. Excel, MS-Acces
- Available **commercial programs**:
  - Different programs for goat dairies (e.g. Goat management software)
  - Specific sheep management programs (e.g. Ewe Byte: Ontario)

Conclusion

Good herd health management is an essential factor for economical and profitable operat-ing of a dairy sheep enterprise. Commercial sheep dairies should be managed as closed herds to minimize disease problems. The fulfillment of all basic needs of the sheep (keeping conditions: space, climate, bedding, light; feeding; handling; care) is very important for the general health and the response of the immune system to diseases.

Record keeping is a significant tool of herd health management. Data analysis of these records helps to track for problems, to show up solutions and to make necessary management decisions.

FARM ADAPTED BREEDS-CROSSBREEDS

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Background

My partner, Margo Tucker, and I began our farm, Ewetopia Sheep Dairy, in the Fall of 1997 with sheep that we purchased from Major Farm as well as an additional ram from Diane Kauffman at Sundance Hill Farm in Wisconsin. Since I had worked for the Majors in 1996, I was familiar with many of the sheep or their dams and sires. With only 2 years experience with these animals being milked as our own flock, I am drawing heavily on the 11 years of experience of the Majors for this talk. Further, I have also been in contact with Diane Kauffman, Yves Berger, and Ken Kleinpeter from Old Chatham seeking their input.

In the Spring of 1997, not being certain that the Major Farm animals would be available to us, or even our best option, we began looking for sheep predominantly in the United States, though we also looked into a few of the main breeders in Canada. This included a cross-country trip that with stops in New York, Ontario, and Wisconsin. We were predominantly looking at Friesian-crosses rather than pure-breds since, the pure-breds were not, and are not, readily available at prices that we felt comfortable paying. We also were concerned about our experience level, and all the unknowns that come with starting a new business in a relatively new industry. We felt that there were too many risks to warrant spending potentially a lot of money on animals with so much uncertainty. However, if we could afford it, we are not at all adverse to buying pure Friesian genetics provided that they had the records to back up a reasonable price.

Issues of Concern

In general, we continue to be concerned with certain aspects of dairy sheep breeding stock sales here in North America. First, we find a tendency for breeders to treat all Friesian genetics alike. We are supposed to expect that since they are Friesian, they are automatically worth more than any other dairy sheep, even if they don't have the records to back this up. Looking at DHIA reports on cow dairies in Vermont, one can see that there are Holstein herds with 28,000 pound averages, and there are also Holstein herds with under 16,000 pound averages. This means that there are Holstein cows producing 40,000 pounds and others producing only 10,000 pounds. No cow dairy farmer is going to pay high amounts of money for grade Holstein cows, just because they are Holsteins. Likewise, I can not accept that I should pay high amounts for Friesian genetics, without the milk records to back up the price. Talking with people who have pure Friesian in their flock, their production ranges from 200 to 1500 pounds. Some people selling genetics aren't even milking them at all, and don't really know what they have. Ideally, we would be able to buy sires that have been proven milk improvers, rather than ram lambs from proven milk improvers, or that we could affordably get AI done with semen from superior sires with reliable results. Both of these options are still not truly available now in my opinion, though hopefully coming soon down the road.

Our second concern is that milk records are not yet standardized in North America. Farms are calculating their flock averages and production records for individuals with different methods, and are reporting them differently. Lactation periods can be quite variable in length, especially depending on which weaning techniques are used. If we want to truly improve milk production for dairy sheep on this continent, then this needs to change.

Our last concern is that we frequently see people basing production potential on the percentage Friesian, and further basing animal pricing around this concept. We see no basis for this. Once cross-breeding starts, it adds a great deal of variability to the flock. Especially if the Friesian sire is not even a proven milk improver, it is impossible to say what the potential is for the progeny without reliable dam milk records. Even with these milk records, there still is potential for a great deal of variation. We have ewes with low percentage Friesian and no Friesian in them, that are better producers than some of our higher percentage Friesians. This is partly because the production of our higher percentage animals is all over the board. Even some of the ewes that have come from some of our top dams are not producing consistently higher than their mothers, though overall milk production has dramatically increased since Friesian genetics were added to the parent flock in 1994. This great deal of variability means that selection pressure needs to be great in order to get consistent milk improvement. It has been suggested to me on more than one occasion that, particularly without proven sires, our flock of 120 is too small for us to expect the type of milk improvement increase at the rate that we feel we need to be economically viable. We hope this is not the case.

Production at Ewetopia and Major Farm

At Ewetopia, we lamb in April, and the ewes and lambs head out to pasture as soon as lambing is complete in mid-April. Like Major Farm, we leave the lambs on the ewes for 29-36 days before weaning, and do not start milking until after they are weaned. At Ewetopia, milkers are given new grass every 12 hours, and supplemented with 1/2 pound of whole corn each milking, as well as a little hay for fiber. We meter the milk one morning each week and dry-off any ewe that produces less than .5 pound at metering. The top milkers (about 64 out of 115 ewes) will be in the parlor for 137-151 days. A significant number of ewes are milked for between 90-137 days (about 30 ewes), and the remainder dry off at various points during the summer. We calculate our flock average by dividing the total amount of milk produced during the season by the number of ewes milked for two weeks or longer. Ewes that come into the parlor and immediately dry off (within 2 weeks), or come in with mastitis, which usually results in them drying off, are not counted in the flock average, but instead are tracked as "flock shrinkage". Individual production is calculated by taking the individual ewe meter index total and dividing it by the average index total and multiplying it by the flock average.
When the Major Farm started milking in 1988, their Tunis-Dorset-Rambouillet crosses only produced 60 pounds each for the entire lactation. Through selection, milk production climbed slowly, but steadily. In 1994, the flock average was 139 pounds. In 1993, the Majors purchased a 57% Friesian (Swiss genetics)/43% Rideau Arcott ram from Hani Gasser in British Columbia. His first progeny were first milked in 1995 when the flock average climbed to 148 pounds. By then, another ram (a 50-50 cross) had been purchased from Hani Gasser, and his

progeny began to be milked in 1996. From 1995-1997, almost no selection pressure was placed on the flock, since the Majors were doubling the size of the flock in order to start a sheep dairy for the short-lived Vermont Sheep Dairy Education Center at the Patch Farm. This flock would eventually become the basis for our operation. The flock averages for Major Farm in 1996 and 1997 were 186 pounds and 201 pounds, respectively. During these years, the highest producing ewe was a non-Friesian that produced 700 pounds. We have used two of her sons by the 50-50 ram in our breeding program, though have yet to milk their progeny. During 1996 and 1997, the Patch Farm flock average was 217 and 183 pounds respectively. The drop in 1997 was undoubtedly due to lack of selection pressure as the flock climbed from 80 to 140 milkers.

We began milking the Patch Farm flock in 1998. With the exception of the one ram from Diane Kauffman, we have used the same rams as Major farm, and have not milked any ewes yet from the Wisconsin genetics. We chose to buy a ram from Diane Kauffman because she had good flock records and her pasture-based management style was similar to our own, something that we feel is an important consideration.The flock average from the 105 milked in 1998 was only 183 pounds. Factors that influenced this average included the lack of selection pressure and also that an accident with a grain bin lead to 36 sheep out of 145 being ill or dying from acidosis, including some of our best milkers. In addition, during June, it was cold and rainy with high parasite loads in the fields coming out of a warm winter. This undoubtedly affected milk production, since the Major Farm flock average also dropped to 193. In 1999, a dry, warm year, milk production on both farms increased by over 30%. The Major Farm flock of 129 sheep averaged 267 pounds, with one ewe at over 700 pounds, 1 >600, 5 between 500-600 pounds, 16 between 400-500 pounds and 23 greater than 300 pounds. The longest producing ewes at Major Farm were milked for 180 days. Our flock average increased to 248 pounds for the 107 ewes milked, with 1 ewe >500 pounds, 3 between 400-500 pounds, and 20 greater than 300 pounds. At least 2 dozen could have probably been milked for another month. On both farms, most all of the top producers are now Friesian crosses, though not exclusively. Much of the milk improvement has also come from the maturing of the flock as most of the ewes are now in their second, third, and fourth lactations. In 2000, we will milk ewes that we actually selected out of our top milkers and hope to see equally impressive production improvements as 1999, though we recognize that the genetic variability in our cross-breeds prevents us from making any concrete predictions.

We are watching very closely the experiences of other sheep dairies in order to see if there are any consistent trends, and to monitor our own progress. We hope to see the sheep dairy industry build a genetic improvement strategy that leads to producer cooperation and honest data collection rather than competition for breeding stock sales. We see this as necessary for the long-term sustainability of sheep dairying in North America.

FARM ADAPTED BREEDS: A PANEL PRESENTATION OF FLOCK PERFORMANCE RECORDS - LACAUNE DAIRY SHEEP

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Introduction

The Lacaune dairy sheep had its origin in an area of southern France, where the world-famous Roquefort cheese is produced. It is therefore nick-named 'Roquefort sheep' and is very well adapted to the harsh conditions of this rocky terrain. When you consult literature you will find performance data of 130-200 kg. in 100-200 days, well behind other dairy sheep breeds as East Friesian, Awassi, Chios and Sarda.

Why could somebody want to bring this sheep breed to a continent with a completely different climate and vegetation? Why exactely the Lacaune sheep, which is only ranking in position 5 for milk performance? To answer this question, I have to write a little bit about the dairy sheep industry in Switzerland.

History of Lacaune dairy sheep in Switzerland

Sheep dairying has a long tradition in Switzerland. Especially in the mountain areas, where beef and dairy cows can hardly graze the steep pastures, the dairy sheep had always a certain importance. The most popular dairy sheep in these often small alpine farms was for many decades the East Friesian dairy sheep.

In the early 80's agricultural structures began to change. Bigger farms in the lower lands started with sheep dairies. Larger herds were established and some of these farmers were not satisfied with the East Friesian sheep, because of health problems and unsatisfactory milk performance, especially in flocks over 50 sheep.

Several farmers gathered together and started to visit sheep dairies in different countries. Most impressive for them were the sheep dairies in southern France, which are milking Lacaune dairy sheep mainly. They saw healthy herds with 300 to 500 lactating sheep, well managed with a good, active breeding industry. The only problem seemed to be that southern France had a totally different climate, and the management of the Lacaune dairies was absolutely not the same as the Swiss farmers were used to.

In France the main lambing season is from December to January. The lambs suckle about 4 to 5 weeks, after that they are weaned and the ewes were milked for about 145 to 174 days. In July the ewes were brought onto pasture, which are at that time completely dry, so the sheep will dry off instantly.

Swiss dairy shepherds instead were accustomed to lamb in late winter to early spring and to milk until late fall or beginning winter for up to 300 days. Despite these differences, the farmers decided to import some Lacaune sheep.

Years later Swiss authorities allowed the importation of several hundered Lacaune ewes and rams. Nobody knew up to then, if the Lacaunes would adapt to the situation in Switzerland and how they would perform.

Experiences with Lacaune dairy sheep in Switzerland

Most of the imported ewes were kept under the same management conditions, the same environment and in the same climate as the other dairy sheep (East Friesian) on these farms. Therefore this project was a perfect way to compare, to see advantages and disadvantages of the two different breeds. The results were astonishing:

- Milk performance and lactation length were roughly equal to the East Friesian sheep, but with higher milk fat and protein;
- Productivity was also comparable to the East Friesian, but best fertility rates were mainly achieved in fall, winter breeding;
- Advantages:
  - Especially well adapted for large commercial dairy sheep operations;
  - Well shaped and suspendend udders: Systematically selected for machine milking;
  - Good graziers;
  - High daily gains in lambs with a good carcass quality;
  - Healthy, robust sheep: No major health problems.

These experiences led in Switzerland to the situation where larger commercial sheep dairies are keeping mainly Lacaunes and Lacaune crosses, whereas in smaller purebred operations, East Friesian sheep are dominating.

Table 1: Milk performance comparison of Lacaune sheep in France, Switzerland & Canada

	Av. performance in liters	Av. days in lactation	Av. days milked
France [1]	218-271 [2]	175-204	145-174
Switzerland [3]	350-412	250-260	250-260
Canada [4]	330-392 [2]	262-283	220-241

[1] = Source: UPRA Lacaune
[2] = Only milked amount (without suckling)
[3] = Source: Swiss Dairy Sheep Association
[4] = Source: Personal data

Experiences in Canada

My family and I had been milking Lacaune and East Friesian ewes already in Switzerland for years and had been very pleased with the Lacaune breed. In 1996 we imported the first Lacaune embryos, that had been flushed from ewes in our flock in Switzerland, to Canada. We also brought with us East Friesian embryos, because we didn't know how the Lacaunes would adapt to the conditions in Canada.

Table 2: Milk performance of Lacaune and EastFriesian sheep on our farm (1999; self recorded))

Breed (Numbers)	Av. performance in kg.	Av. days in lactation	Av. days milked
East Friesian [1] (53)			
•1st lactation (21)	333 [2]	263	221
•2nd lactation & up (32)	385 [2]	285	243
Lacaune [1] (42)			
•1st lactation (17)	330 [2]	262	220
•2nd lactation & up (25)	392 [2]	283	241

[1] = Only purebred sheep   [2] = Only milked amount (without suckling)

So far the Lacaune ewes are producing under the same feeding and management as good or even better than the purebred East Friesian ewes, and the lactation period is more or less the same for both breeds (sometimes up to 300 days!). Our highest producing ewes are Lacaunes. They are milking on the average of 2 kilograms a day. We don't 'push' our milkers: All ewes are on pasture and receive medium-quality hay during the night. In the parlour we feed up to 0.9 kilogram of a whole barley/corn mixture per ewe each day. In late fall and winter we add grass silage to the ration. Lacaunes are more like meat sheep, but are easier to keep in large commercial dairy flocks, and they are on the average healthier (less mastitis and pneumonia) and have by far better udders than the East Friesian.

Table 3: Advantages and disadvantages in comparison between Lacaune and East Friesian sheep on our farm:

	East Friesian	Lacaune
•Milk performance	Equal	Equal
•Milk contents	Lower	Higher butter fat and milk protein
•Fleece	Lots of good quality wool, fast regrowth, 1-2 shearings per year	Wool mainly on back, 0-1 shearing per year
•Productivity		
–Breeding	Year around	[+-] Year around
–Litter size	2.2	2.0
–Fertility	96%	94%
•Daily gain in lambs	0.350 kg.	0.410 kg.
•Udder	Tendency to bag udders (some lines)	Nice shape and well suspended, small teats, easy to milk
•Health	Susceptibility to respiratory problems and mastitis	No major health problems
•Character	Like pets, easy to handle, need more attention, not so suitable for large flocks	More like meat sheep, better adapted for large flocks
•Grazing	'Picky eaters'	Excellent, steady grazers

Conclusion

The Lacaune dairy sheep breed represents an excellent and robust dual purpose breed, characterized by:

- Good milk performance with high butter fat & milk protein;
- High daily gains in lambs with a good carcass quality and a mild tasting and, to consumers, attractive looking and nicely coloured meat.

Other outstanding advantages:

- Especially well adapted for large commercial dairy sheep operations;
- Systematically selected for machine milking;
- Good graziers;
- Healthy and robust;
- Breed has a professional organized breeding program with well selected and monitored sheep genetics.

Experiences with Lacaune dairy sheep in North America are so far too little to give a really accurate sight of this breed. More sheep producers need to be involved with a lot more Lacaune sheep in production for detecting all advantages/disadvantages and to pass a final judgement.

BRIEF UPDATE ON RESEARCH IN NUTRITION OF DAIRY SHEEP

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Dairy sheep may take advantages from all aspects of research conducted in the field of animal science and biology. There are, however, laboratories that specifically work in that field and have a direct objective of improvement of dairy sheep breeding. In the field of nutrition, an important body of work has been done in a collaborative EEC project involving France (INRA ; Barillet and Bocquier, 1993), Spain (UA-Barcelona), and Italy (IZCS-Sardegna). Agricultural EEC policy is oriented toward research that may improve the sustainability of a Mediterranean dairy sheep population of more than 70 million ewes.

These teams worked mainly with western Mediterranean dairy sheep production systems, and systems in which controlled feeding phases are strategically important. Compared to other ruminant production systems there is a specific need for knowledge of the effects of nutrition and management practices on both milk yield and milk composition. We proved that lactating ewes use dietary energy with the same efficiency as dairy cows. This allows the use of the net energy system established for dairy ruminants in diet formulations for dairy ewes. Furthermore, in case of underfeeding, the mobilized body energy is used with an efficiency of transformation into milk which is close to 80 %. During full lactation, milk energy output is linearly related to dietary energy supply. In ewes in negative energy balance, the body energy mobilization, assessed by dilution technique (Bocquier et al., 1999), can account for almost 50 % of milk energy output (Agus and Bocquier, 1995). Voluntary food intake is negatively affected by body fatness at lambing, while ambient temperature doesn't seem to affect significantly the voluntary food intake of Manchega sheep in the range of 5 to 25 ºC (Prió et al., 1994, 1995). An important work has been done on main factors that affect voluntary food intake of both forage and concentrate at different physiological stages (dry, pregnant and lactating), evaluating its significance in dairy ewes (Ferret et al., 1998) and providing reliable equations for the maximization of forage intake (Caja et al., 1997bc; Bocquier et al., 1997). Effect of genetic merit of ewes by the comparison of two lines of Lacaune ewes obtained by divergent selection (Marie et al., 1996) or between breed comparisons Manchega vs Lacaune on the relationship between milk yield, food intake and variations of body energy has been studied. Effect of using protected fat for dairy ewes also has been analyzed, for it may increase milk fat content and modify fatty acid composition of milk and cheese (Pérez Alba et al., 1997; Osuna et al., 1998; Casals et al., 1999).

As ewe milk is processed into cheese, manipulation of its composition is of great interest (see Bocquier and Caja ibid). We also isolated strong positive influence of long photoperiod (16h/d), compared to short photoperiod (8h/d), on milk yield (+25%), food intake (+16 %) and negative effects on milk fat (-14 g/l) and protein (-11 g/l) content (Bocquier et al., 1997). More recently we showed that leptin, an hormone secreted by adipose tissue and involved in regulation of food intake, is increased (Figure 1) by long daylength in the sheep (Bocquier et al., 1998). These results, altogether, illustrate that the sheep which is a seasonal breeder may have conserved a mechanism that may operate and enhance its adaptation to seasonal fluctuations of food resource (Chilliard and Bocquier, 1999).

In on-farm situation, it is of importance to take into account individual variability of milk performance because it may limit feed efficiency of the flock. In these situations, we analyzed the interest of group-feeding of ewes (Bocquier et al., 1995).

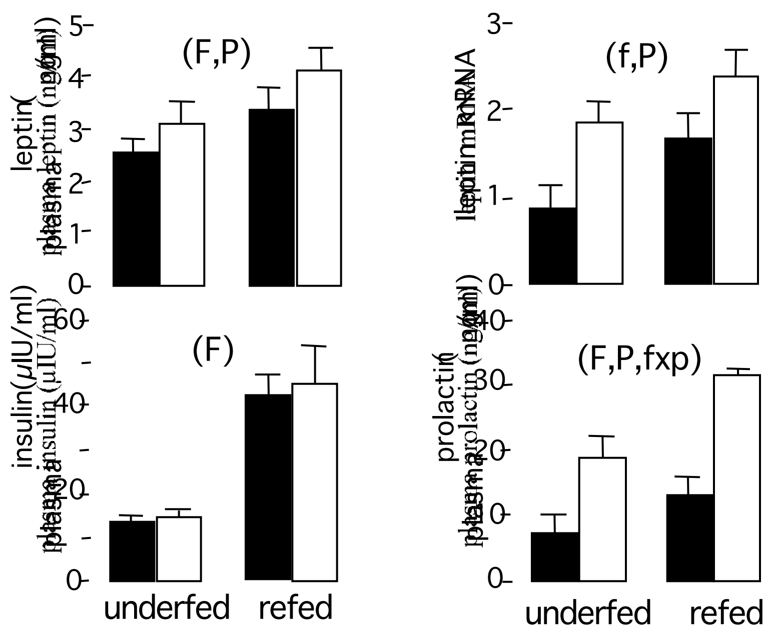

Figure 1. Effects of daylength (shaded bars: short days (8h/d) and open bars: long days (16h/d)) and nutritional status (underfed (22%) or refed (190% of energy requirements)) on (A) plasma leptin, (B) adipose tissue leptin mRNA (in arbitrary units), (C) plasma insulin and (D) overall mean plasma prolactin (5 ewes per group, mean + SEM). F, P or f, p: significant effect of feeding level and photoperiod ($P<0.05$ or $P<0.10$, respectively); f x p: significant interaction ($P<0.10$) (from Bocquier et al., 1998)

Although dairy sheep production is an important industry in the Mediterranean countries of EEC, only few flocks are under true feeding control. There is now a better knowledge on dairy sheep nutrition, even if specific research is still needed. Current need of knowledge on nutrition of dairy sheep is focused on milk composition, because of an industrial demand for cheese making from raw milk. Furthermore some important effects of nutrition on milk composition (composition of fatty acids) are still imperfectly known and should be studied. Feed intake capacity and substitution rates in lactating dairy ewes are now better known but they should be tested on a larger set of group feeding conditions. They should be adapted to different production systems encountered with the Mediterranean dairy breeds. There is no doubt that this will help to better adjust the concentrate supply to high producing ewes.

We showed that the flock structure affects the annual milk composition (Fraysse et al., 1995). These analyses of flock structure (dynamics of lambing and dry-off policy) and possibly the mean genetic level is a necessary step before analyzing the effect of feeding practices on milk composition. At the farm level, the perspective to use electronic devices (Caja et al., 1997a) will greatly help in a better adjustment of food to ewe requirements, thus insuring a higher milk quality.

ACKNOWLEDGEMENT

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SUPPLEMENTAL FEEDING OF DAIRY SHEEP AND GOATS ON INTENSIVELY MANAGED PASTURE

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1999 is the first year of a SARE funded on-farm research project to determine the optimal level of supplementation for dairy sheep and goats on intensively managed pasture.

For background, let me quote directly from our project proposal:

JUSTIFICATION and BACKGROUND

Over the past ten years, the number of dairy sheep and goat farms operated as commercial agricultural enterprises in Vermont and New Hampshire has been growing. In the past five years, there has been an increase in the demand and price for sheep and goat milk cheeses (Major - 1996, Nielsen - 1996). This, combined with the availability from Europe of East Friesien dairy sheep genetics and the utilization of high quality intensively managed pastures as the major roughage source, has made these enterprises economically feasible and sustainable.

It is a well established management practice to supplement the ration of lactating sheep and goats with concentrates. This is done to increase the level of saleable milk in early lactation or to increase the weight gain of nursing offspring. This practice is supported by a large amount of research, but this research was conducted using stored feeds as the forage source. (NRC, 1985)

Sound research-based data on supplementation of high producing dairy sheep and goats on high quality intensively managed pastures is not available.

In an attempt to gather this information, David Major of Westminster West, Vermont, in the summer of 1997, ran his own on-farm feeding experiment. He randomly divided his dairy sheep flock (160 ewes) into two groups. One group was fed approximately 1 lb of a corn/barley supplement, the other group was fed 2 lbs of the same supplement. His results showed that group 1 averaged 201 lbs milk per ewe for the lactation while group 2 averaged 186 lbs milk per ewe, just the opposite of what might be expected. But because there was no control group and no valid experimental design, the results were meaningless, and as David said, “It just goes to show how much in the dark we are.”

In mid October, David Major discussed these results with Bruce Clement, UNH Extension Livestock Program Coordinator. Bruce had also worked closely with Keith and Leslie Quarrier of Acworth, New Hampshire, dairy goat producers who have fed their herd on high quality intensively managed pastures since 1996. The Quarriers had also expressed frustration in getting sound data on which to base their pasture supplementation decisions.

Bruce convened a meeting in mid-November which included David Major and Mike Ghia, dairy sheep producers; Keith and Leslie Quarrier, dairy goat producers; Allison Hooper, Vermont Butter and Cheese Company; John Porter, UNH Extension Dairy Specialist; Chet Parsons, UVM Sheep Specialist; and Heidi Smith, NRCS Soil Conservationist. The need for this research project was confirmed and the decision to develop this proposal was made at that time.

Since then, Dr. Doug Hogue, Cornell University Sheep Specialist, Dr. Jim Welch, UVM Ruminant Nutritionist; and Dr. Nelson Escobar, Goat Specialist, E.de la Garza Institute for Goat Research, Langston, Oklahoma were contacted. All three have not only expressed support for this project but have provided substantial help in designing this experiment.

We feel this proposal is an especially timely one. It addresses a management question that producers, researchers, and Extension personnel have identified as having the highest priority for two economically and environmentally sound agricultural alternatives for small farmers not only in New Hampshire and Vermont but throughout the Northeast.

Approach and Methods

This project will use a team approach involving farmers, researchers, UVM and UNH Cooperative Extension, and NRCS personnel. The project will be conducted at two on-farm sites, Major Farm (dairy sheep), Westminster West, Vermont and Quarrier Farm (dairy goats), Acworth, New Hampshire.

The experimental design was developed by Dr. James Welch, UVM. In year one, we will conduct two experiments using a Randomized Complete Block design. All available animals will be identified according to previous milk production, genetic potential for milk production, number of offspring nursed, weight and age. Animals which are similar will be assigned to blocks of three according to the above criteria. Animals within blocks will be randomly assigned to treatments 1, 2, or 3.

In the first experiment we will look at the effect of different levels of supplementation on early lactation. The animals on each farm (150 ewes and 60 does respectively) will be divided at weaning into three treatment groups using the above described experimental design. Each animal will be identified by ear tag or tattoo and by a colored leg band for quick ID at milking.

The three groups will receive different levels of a nutritionally complete supplement designed by Dr. Hogue, Cornell University. This supplement will be designed utilizing the current information available on feeding high milk producing sheep and goats and will utilize readily available feedstuffs. The National Research Councils “Nutrient Requirements of Sheep,” 6^{th} edition, 1985 and “Nutrient Requirements of Goats,” 1981, will be used to determined the nutrient requirement baseline on which the level of supplementation will be determined.

Group 1 will be the control group. All animals in group 1 will receive pasture plus a minimal level of supplement (10-15% of their National Research Council (NRC) requirement). Group 2 will receive pasture plus a medium level of supplement (30-35% of their NRC requirement). Group 3 will receive pasture plus a high level of supplement (50-60% of their NRC requirement).

All three groups will be grazed together. They will be allowed unlimited consumption of the same high quality pasture. At milking each animal will receive the supplement according to which of the three groups it has been assigned. After milking the animals return to a single group. Animals will receive new pasture after every milking.

All animals will receive care at the best management level from the last trimester of pregnancy through to weaning. Animal care will be monitored weekly by Extension Specialists or a licensed veterinarian. Weaning will occur at day 1 or 2 postpartum for does and day 25-30 postpartum for ewes. As animals are weaned, the first experiment will begin and will continue until all animals have been on the experiment for a four-week period.

At the completion of the first experiment, the data will be immediately analyzed. The second four-week experiment will be conducted as soon as the data from the first experiment has been analyzed. The purpose of the second experiment is to look at the effect of different levels of supplementation on mid to late lactation. The same animals and the same experimental design will be used in the second experiment as was used in the first experiment.

The following measurements will be taken:

Weight - all animals will be weighed at the beginning of the last trimester of pregnancy, within 1-2 days postpartum and at the beginning and end of each experimental period.

Milk- milk will be weighed and analyzed weekly during each experiment for fat, protein, and somatic cell count. The milk will also be taste tested by an experienced milk grader. The milk will be analyzed at the New York DHIA lab.

Pasture- during each experiment pasture dry matter yield will be measured and recorded at each change of pasture (every 12 hrs). A rising plate pasture meter designed and made in New Zealand will be used for this measurement.

Soil- soil tests will be taken at the beginning and end of each experiment. Soil tests will be done at UNH Analytical Lab and will measure pH, P_2O_5, K_20, Ca and Mg.

Health- animal health and overall condition will be assessed by a licensed veterinarian at the beginning of the last trimester, and at the beginning and end of each experiment. Health treatments will be administered under the direction of the veterinarian.

An intern on each farm will assist in taking these measurements and recording and compiling the data. All data compiled will be statistically analyzed. In years 2 and 3, we will refine the feeding levels used in year one using a regression analysis design with several feeding levels. This will allow us to identify optimum feeding levels on which to base management decisions.

We are in the process of summarizing and statistically analyzing the data from the two trials done this summer. I will have a written report for distribution at the Great Lakes Symposium in November.

PRELIMINARY RESULTS:
SURVIVAL OF HIGH-PERCENTAGE EAST FRIESIAN LAMBS

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Introduction

East Friesian germplasm was imported into North America specifically for use by the dairy sheep industry in the early 1990's. Positive experiences of dairy sheep farmers with crosses between East Friesian and domestic breeds resulted in many sheep dairies entering into a breeding program of grading-up to high-percentage East Friesian or purchasing purebred East Friesian sheep.

The perceived superior value of East Friesian crosses by producers was supported by research. A study at the Spooner Agricultural Research Station of the University of Wisconsin-Madison found that East Friesian crossbred sheep (up to 50% East Friesian breeding) had 13% heavier lamb weights at 140 days of age, 16% greater number of lambs born per ewe lambing, 9% greater number of lambs weaned per ewe bred, and 92% more milk, 67% more milk fat, and 69% more milk protein produced per lactation than sheep of domestic breeding (50 to 75% Dorset breeding) (Thomas et al., 1998, 1999). The only traits in which East Friesian crosses were inferior to the Dorset crosses were in milk composition. East Friesian-cross ewes had percentage milk fat and percentage milk protein approximately .5 percentage units lower than Dorset-cross ewes.

Our study also showed good viability of lambs of East Friesian-cross breeding compared to lambs of Dorset-cross breeding. However, our East Friesian-cross lambs were all of 50% or less East Friesian breeding. Producers should not extrapolate these results to sheep of greater than 50% East Friesian breeding because there are reports in the literature of poor viability of pure East Friesian and East Friesian-cross sheep of over 50% East Friesian breeding (Katsaounis and Zygoyiannis, 1986; Ricordeau and Flamant, 1969). Therefore, there is a need to evaluate sheep of high-percentage East Friesian breeding for viability under U.S. production systems before such sheep are to be recommended without reservation.

European studies on survival

Katsaounis and Zygoyiannis (1986) reported especially poor viability of East Friesian sheep in Greece. They imported a total of 52 ewes, 10 rams and 18 lambs of East Friesian breeding in the three years of 1956, 1960, and 1965. They were run on their experimental farm along with sheep of two local dairy breeds. Of these imported animals, all the lambs died within two months, and all the adults had died by 1970. Of the purebred East Friesian lambs born in the flock in Greece, 38.3% were stillborn or not viable at birth, 29.6% died before the age of two months, and of those weaned, 69.2% died before one year of age. Ewes of 1/2 East Friesian breeding lived for a respectable 5.1 years (similar to the local breeds). However, ewes of higher percentages of East Friesian breeding had very short lifespans: 3/4 East Friesian = 2.6 years, 7/8 East Friesian = 2.7 years, 15/16 East Friesian = 2.5 years, 31/32 East Friesian = 2.5 years, and pure East Friesian = 2.0 years. The most common cause of death was pneumonia with a high incidence of Maedi (OPP-like disease) in adult ewes.

Ricordeau and Flamant (1969) 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.

Results and discussion

We have some early indications from the flock at the Spooner Agricultural Research Station that lambs of over 50% East Friesian breeding may have reduced survival rates. Table 1 presents the survival rates to July 1, 1999 of all lambs born alive in our flock in the winter/spring of 1999, grouped by breed of sire and expected proportion of East Friesian breeding in the dam. The survival rates varied from 100% to 70% among the groups with the lowest survival rates for lambs with East Friesian sires and East Friesian-cross dams.

Table 1. Arithemetic means for survival of lambs born alive by breed of sire and dam's percentage of East Friesian breeding (1999 lamb crop).

					Survival rate, %		
Breed of sire	Dam's % EF breeding	Dam age, yr	Lambing dates	No. lambs born alive	Birth to weaning	Weaning to 7/1/99	Birth to 7/1/99
East Friesian	0	1 - 9	3/4 - 5/28	60	95.0	93.0	88.4
East Friesian	>0 to <50	2 - 4	3/13 - 4/13	19	84.2	93.7	78.9
East Friesian	≥50	1 - 2	3/4 - 5/18	132	82.1	85.5	70.2
Lacaune	0	3 -5	4/7 - 5/1	45	95.5	100.0	95.5
Suffolk	0	2	2/26 - 3/20	10	100.0	100.0	100.0
Suffolk	>0 to <50	2 - 4	2/2 - 3/27	135	97.0	99.2	96.2
Suffolk	≥50	2 - 4	2/2 - 3/26	70	97.1	99.0	96.1
Texel	0	2	1/10	1	100.0	100.0	100.0
Texel	>0 to <50	2 - 4	3/25 - 4/5	11	90.9	100.0	90.9
Overall lamb survival rate of the flock				483	91.7	94.6	86.7
Percentage of dead lambs that died from pneumonia					45.9	91.3	63.3

As Table 1 indicates, the various groups also differ for age of dams and lambing dates which may also have had an effect on lamb survival. However, given these limitations of the data, the data have been regrouped by expected proportion of East Friesian breeding in the lamb and presented in Table 2. In all lamb growth intervals, lambs with over 50% East Friesian breeding had lower ($P < .05$) survival rates than lambs of lower percentage East Friesian breeding, and there was a tendency during the postweaning period for lambs of 50% East Friesian breeding to have lower ($P < .10$) survival rates than lambs of less than 50% East Friesian breeding.

Table 2. Least squares means for lamb survival by percentage of East Friesian breeding of the lamb (1999 lamb crop).

Lamb's % EF breeding	No. lambs born alive	Survival rate, % Birth to weaning	Weaning to 7/1/99	Birth to 7/1/99
0	56	96.4±3.5[a]	100.0±2.9[a]	96.4±4.2[a]
>0 to <25	146	96.6±2.2[a]	99.3±1.8[a]	95.9±2.6[a]
≥25 to <50	70	97.1±3.1[a]	98.5±2.6[a]	95.7±3.8[a]
50	60	95.0±3.4[a]	93.0±2.8[a,b]	88.3±4.1[a]
>50	151	83.4±2.1[b]	86.5±1.9[b]	72.2±2.6[b]

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

Conclusions

The survival rates of lambs of high-percentage East Friesian breeding need to be determined by better designed studies than the one presented here before definitive conclusions can be reached. However, this preliminary look under a U.S. production system combined with the results from other countries suggest that sheep producers that move to over 50% East Friesian breeding in their flocks should be prepared to deal with possible increased health problems in their lambs.

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TECHNICAL NOTE
ACCURACY OF THE WAIKATO MILK METER JAR

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The Waikato (Alfa-Laval Agri) meter jar is an apparatus to measure the milk production of a goat or sheep. It is a derivative system which means that only a fraction of the milk (7.5%) is collected in the flask. The jar is graduated in such a way that reading of the amount of milk in the jar gives the total amount of milk produced by the animal during the milking. A spigot at the bottom of the jar allows for the collection of milk samples.

The Waikato milk meter jar is a popular instrument and the Spooner Agricultural Research Station, University of Wisconsin-Madison uses it for the recording of milk yield of all its milking ewes. To be certain of the accuracy of the instrument and thus of the accuracy of the data being collected, a simple experiment was conducted to ascertain the effectiveness of the meter jar.

A Waikato milkmeter jar was placed as usual in the milk line. However, the milk, instead of going through the pipeline directly to the bulk tank, was collected in a plastic bucket known as "quarter saver" for the dairyman. After complete milking of the animal, the milk yield shown in the meter was recorded and a small sample of milk taken. The milk contained in the meter jar was flushed into the "quarter saver". The total amount of milk collected in the "quarter saver" was poured into a graduated cylinder. The total milk yield was recorded and compensated by .05 liter corresponding to the sample of milk taken from the meter. A milk sample of the total milk was taken.. The operation was repeated on 12 different ewes picked at random. The data collected were:

• Milk yield as read directly from the meter jar after completion of milking

• Milk sample from the meter jar (which represents a sample from a fraction of the total milk)

• Real milk yield + .05 liter

• Milk sample from the total milk.

Milk was analyzed for percentage butterfat, percentage protein and somatic cells. Results are shown in the following table. The milk meter jar appears to be extremely accurate in measuring the milk yield or the milk components. There is practically no difference between quantity read from the meter jar and quantity read from the whole production. Milk samples obtained from the meter jar or from the whole production have the same percentage of fat, protein and somatic cells. Therefore, producers can use the Waikato milk meter jar in all confidence as long as the reading of milk yield is performed carefully. Some milk foam will form at the surface and it is imperative to be able to see clearly the separation between actual milk and foam.

Quantity		Fat		Protein		SCC	
Meter	Real	Meter	Real	Meter	Real	Meter	Real
liter	liter	%	%	%	%	(000)	(000)
.6	.56	3.47	3.59	5.4	5.39	41	47
1.1	1.1	4.96	5.08	5.46	5.45	33	24
1.3	1.3	5.52	5.59	4.69	4.69	14	17
.35	.35	4.91	4.39	4.74	4.75	320	430
.7	.7	5.28	5.28	4.58	4.59	35	39
1.1	1.05	5.11	5.16	5.03	5.02	25	31
.35	.35	5.96	6.07	5.24	5.28	740	810
.75	.75	4.65	4.64	5.13	5.13	160	170
1	.9	4.04	4.1	4.83	4.82	43	43
.8	.83	5.48	5.45	4.47	4.5	29	28
1	1.01	6.62	6.82	4.84	4.83	13	6
.5	.55	6.29	6.3	4.83	4.86	26	24

RUMEN-PROTECTED BYPASS FAT FOR DAIRY EWE COMMERCIAL MILK PRODUCTION

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Summary

The effects of fat supplementation and weaning system on commercial milk yield and milk composition were determined on 129 East Friesian crossbred ewes. Prior to lambing, ewes were randomly assigned to one of two weaning systems. The DY1 system involved weaning of ewes from their lambs within 24 to 36 hr post-partum and then twice-daily machine milking. In the MIX system, ewes had access to their lambs during the day, were separated from their lambs overnight, and were machine milked once daily in the morning. After approximately 30 days in lactation, lambs were weaned from the MIX system ewes, and all ewes were machine milked twice daily. Additionally, calcium salts of fatty acids (CSFA) were premixed in a concentrate ration and fed to all ewes (100 grams/ewe/day) for 2 two-week periods during early lactation. Each CSFA feeding period was separated by two weeks of not feeding CSFA. Milk yield was measured weekly, and milk samples were analyzed for percentage of milk fat and protein and somatic cell count. During the first 30 days of lactation, DY1 ewes produced 38% more commercial milk, 73% more kilograms of fat, 42% more kilograms of protein, had significantly higher percentages of milk fat (5.90 vs 2.51%, respectively), and similar percentages of milk protein compared to MIX ewes. Following weaning, commercial milk, fat, and protein yields from MIX ewes were significantly more than those of DY1 ewes. CSFA supplementation did not influence commercial milk yield. Percentage and yield of milk fat was significantly higher for DY1 ewes that received CSFA supplementation compared to unsupplemented DY1 ewes. Conversely, for the MIX system, percentage and yield of milk fat was unchanged between CSFA-supplemented and unsupplemented ewes prior to complete weaning at 30 days post-partum. For both the DY1 and MIX systems, percentage and yield of milk protein tended to be suppressed in CSFA-supplemented vs unsupplemented ewes. Somatic cell count was not significantly affected by either weaning system or CSFA supplementation. As previously confirmed in this flock, weaning system significantly influences commercial milk production and composition during the first 30 days of lactation. CSFA supplementation did not increase percentage nor yield of milk fat in partially suckled ewes. CSFA supplementation of dairy ewes in early lactation induces a slight suppression in milk protein and increases milk fat yield provided that ewes have been completely weaned from their lambs. According to a proposed milk purchase price schedule from one sheep-milk processing facility where payments are based on milk fat percentage and other indicators of milk quality, CSFA-supplemented milk appears to offer greater financial returns compared to unsupplemented milk.

Introduction

Percentage of milk fat for East Friesian crossbred ewes at the Spooner Agricultural Research Station has been low in previous years (Thomas et al., 1999; McKusick et al., 1999). Additionally, when a mixed weaning system (partial suckling and once daily machine milking) is used for the first 30 days of lactation, percentage of commercial milk fat is suppressed, quite possibly due to retention of fat in the udder for as long as the ewe is in partial contact with her lambs (McKusick et al., 1999). Also, milk yield is inversely proportional to percentage of milk fat, and therefore in high-producing dairy-ewe breeds such as the East Friesian, reported average percentages of milk fat are low compared to other non-dairy or low producing dairy breeds (Casoli et al., 1989). However, owing to large commercial milk yields of dairy breeds, fat yield is ultimately superior to that of domestic breeds. Nonetheless, milk processing facilities are destined to favor milk with a higher percentage of milk fat and thus, milk produced with a low percentage of milk fat may potentially be at a serious economic disadvantage. In dairy ewes, protected fat supplementation has been shown to result in either similar (Hernandez et al., 1986; Casals et al., 1992; Caja and Bocquier, 1998) or increased (Sklan, 1992) commercial milk yield relative to controls; all authors report increases in both percentage and yield of milk fat. Therefore, it is hypothesized that feeding rumen-protected bypass fat to dairy ewes might increase overall fat percentage, fat yield, and furthermore, possibly reduce the negative effects of partial weaning systems on milk fat content. The objective of this experiment was to determine the effects of calcium salts of long-chain fatty acids (CSFA) supplementation on dairy ewe milk production and to evaluate concurrent effects with two weaning systems.

Materials and Methods

Megalac® Rumen Bypass Fat (Church and Dwight Co., Inc.) was pre-mixed in a concentrate ration of corn and a protein pellet (diet crude protein of 16%) to provide 100 grams CSFA per ewe per day. CSFA was fed twice daily to second, third, and fourth parity East Friesian crossbred ewes for 2 two-week periods beginning March 3, 1999, which were proceeded and separated by two weeks of no supplementation (Table 1). Throughout the experiment, all ewes received legume-grass hay (crude protein of 20%). During the two weeks of feeding CSFA, all ewes received the supplement. Likewise during the two weeks of not feeding CSFA, no ewes received the supplement. Ewes gave birth over a six-week period beginning February 10. Thus during all stages of lactation, ewes were receiving or not receiving CSFA in their diet, which was randomly determined by their lambing date.

Additionally, prior to lambing, ewes were assigned to one of two weaning system treatments. DY1 ewes were weaned from their lambs between 24 and 36 hr post-partum, and then machine milked twice daily for the remainder of lactation. MIX ewes, beginning 24 hr post-partum, were separated from their lambs at 1700 each day and milked once daily every morning at 0600. After the morning milking, ewes were returned to their lambs. MIX ewes were milked twice daily following permanent weaning of their lambs at approximately 28 days of age.

Machine milking of ewes took place in a 12 x 2 milking parlor with indexing stanchions and a high-line pipeline system (Alfa Laval-Agri®, Tomba, Sweden). Milking machine settings included a pulsation rate of 180/min, a ratio of 50:50, and a vacuum level of 38 kPa. Milk production was recorded weekly using a Waikato milk meter jar. Individual milk production was recorded on Tuesday evening and Wednesday morning, and samples for composition analysis were taken on Wednesday morning. Milk composition analysis for percentage of fat, percentage of protein, and Fossomatic® somatic cell count was performed by a State of Wisconsin certified laboratory. Milk production for each stage of lactation was calculated based on the weekly testings. Somatic cell counts were transformed to base-10 logarithms. Least squares means analysis of variance was conducted with the GLM procedure of SAS (SAS, 1999). In addition to the main treatment effects of CSFA supplementation and weaning system, other sources of variation included in the model were, parity (second, third, or fourth), litter size (one, two, or three-and-greater), and all two-way interactions. This report presents results obtained from the first 42 days of the 1999 lactation.

Results and Discussion

Milk composition of the weekly bulk-tank samplings is presented in Table 1. Corresponding to the presence or absence of CSFA supplementation, percentage of milk fat tended to be higher when CSFA was being fed, and low when CSFA was not fed. Percentage of milk protein and somatic cell count (SCC) did not seem to demonstrate this relationship, however percentage of milk protein did tend to decline with time.

CSFA supplementation tended not to affect commercial milk production for either the DY1 or MIX weaning systems (Table 2), which is consistent with other authors (Hernandez et al., 1986; Casals et al., 1992; Caja and Bocquier, 1998). As previously reported in this flock (McKusick et al., 1999), weaning system was a significant source of variation in commercial milk yield (Table 2). DY1 ewes produced 26% more ($P < .01$) commercial milk than MIX ewes during the first 42 days of lactation (94 and 84 L/ewe, respectively). This is to be expected as MIX ewes were being milked only once per day for at least the first 30 days, and in addition, MIX ewes were raising lambs. DY1 ewes had superior ($P < .0001$) commercial milk yield relative to MIX ewes for the first 28 d of lactation, after which MIX ewes were equal or superior ($P < .05$) in milk production to DY1 ewes. These results imply that MIX ewes' udders have higher overall milk secretory capacity than DY1 ewes, at least during early lactation. For commercial milk production, there were no significant interactions at any stage of lactation between CSFA and weaning system treatments.

The interaction between CSFA and weaning system treatments was significant for most stages of lactation with respect to milk fat (Tables 3 and 5). For the first 30 days of lactation, MIX ewes had markedly suppressed ($P < .0001$) milk fat content compared to DY1 ewes which confirms previous reports for this flock of ewes (McKusick et al., 1999). Within the DY1 ewes, CSFA supplementation resulted in higher ($P < .001$) percentage of milk fat and kilograms of milk fat at every stage of lactation compared to no supplementation (Table 3) which is in agreement with other authors (Hernandez et al., 1986; Casals et al., 1992). Conversely, within the MIX ewes, CSFA supplementation generally had no effect on percentage of milk fat nor kilograms of milk fat while the ewes remained in partial daily contact with their lambs. Despite exogenous fat supplementation, poor milk ejection during the first 30 days of lactation perhaps is continuing to inhibit the adequate release of milk fat during machine milking (Muir et al., 1993; Marnet et al., 1999). During the d 36 to 42 stage of lactation, MIX ewes that were supplemented with CSFA finally show an increase ($P < .01$) in percentage of milk fat compared to those not supplemented (Table 3). This perhaps indicates the gradual habituation of MIX ewes to having their lambs weaned and to machine milking and thus, more complete milk ejection and less retention of milk fat. Kilograms of milk fat produced by CSFA supplemented and non-supplemented MIX ewes were similar following weaning (Table 5), however it would be expected that as lactation progressed, milk fat yield would be significantly higher in the CSFA-supplemented MIX ewes.

Percentage of milk protein was almost always lower (occasionally significant) for ewes supplemented with CSFA compared to unsupplemented ewes (Tables 4 and 6). CSFA supplementation of dairy ewes has been previously shown to either have no effect (Horton et al., 1992; Espinoza et al., 1998), or to suppress percentage of milk protein (Casals et al., 1992; Sklan, 1992; Rotunno et al., 1998) probably due to decreased utilization of amino acids by the mammary gland (Cant et al., 1993). For the majority of the first 35 days of lactation, DY1 ewes produced commercial milk that was higher ($P < .01$) in protein content than MIX ewes. During the d 36 to 42 stage of lactation, which coincided with complete weaning of the MIX ewes, there were no longer any significant differences between weaning systems. This reconfirms the above observation concerning poor milk ejection during machine milking for the MIX ewes while suckling their lambs. The interaction between weaning system and CSFA treatments was not significant with respect to kilograms of milk protein, and tended to not be significant for percentage of milk protein.

The ratio of milk fat to protein percentage should be greater than 1.0 (higher fat than protein) for desirable cheese manufacturing. Of the bulk tank samples taken during this trial (Table 1), all four taken during CSFA supplementation had fat:protein ratios greater than 1.0 (range = 1.14 to 1.25), however, of the four taken during the nonsupplemented periods, only one sample had a ratio greater than 1.0 (range = .80 to 1.04). Furthermore, other authors have shown a significant increase in palmitic (16:0) and linoleic (18:1) fatty acids, and significant decreases in linoleic acid (18:2) and short chain fatty acids (C6 to C12) in milk from CSFA supplemented ewes (Sklan, 1992; Appeddu et al., 1996; Caja and Bocquier, 1998) that will merit further organoleptic and compositional evaluation of cheeses made from CSFA supplemented ewe milk.

Somatic cell count tended not to be significantly affected by either CSFA supplementation or weaning system treatments (Table 7) and there were no significant interactions between the treatments.

Implications

One of the major disadvantages of the MIX weaning system for dairy ewes is the markedly lower percentage and yield of milk fat while ewes remain in partial daily contact with their lambs during the first 30 days of lactation (McKusick et al., 1999). CSFA supplementation failed to increase milk fat content during this period which implies that milk fat synthesis is probably not impaired, but rather, milk fat is retained within the udder until its removal at the time of lamb suckling.

However, in the DY1 weaning system, milk fat content increased on average by 1.19 percentage units for CSFA-supplemented versus unsupplemented ewes (Table 3). Sheep milk processing facilities have already begun to implement milk purchase agreements with producers that are based on milk composition (percentage of fat) and quality (somatic cell count and bacterial plate count). One milk processing plant is considering a purchase agreement for sheep milk that would pay a base price of $.45/lb of milk between 5 and 6.5% milk fat, $.48/lb between 6.5 and 7% milk fat, and $.50/lb between 7 and 7.5% milk fat. Additionally, they have proposed a premium of $.0075 for each increase in .1% milk fat above 6%, provided that the milk has a somatic cell count below 400,000 cells/ml and a bacterial plate count below 40,000 plc. Within the present flock of ewes, milk from ewes not receiving the CSFA supplement would be worth only $.45/lb. Milk from the CSFA-supplemented ewes would be worth between $.46 and $.60/lb, depending on the number of days in lactation. On average, each ewe in the DY1 system produced 5.10 lb (2.25 L) of commercial milk per day. CSFA supplementation costs approximately $.10 per ewe per day, and therefore milk purchase price would have to average $.47/lb during the period when CSFA is being supplemented in order to cover the increased costs of the CSFA supplementation. Given the above purchase agreement, returns generated per ewe by milk sales from the DY1 CSFA-supplemented and non-supplemented ewes for the first 42 d of lactation were $104.82 and $95.46, respectively. The difference in returns is $9.36, in favor of the CSFA-supplemented milk, which is more than twice the break-even difference of $4.20.

In conclusion, with respect to a day-one weaning system for dairy ewes, CSFA supplementation increases milk fat percentage and yield, and generates an additional $5.16 per ewe (above expenses) for the first 42 d of lactation, according to one proposed milk-purchasing agreement which severely discounts milk of low fat content. Other purchase price schemes, which do not severely penalize milk for low fat content, may allow for even more increases in financial returns for CSFA-supplemented milk relative to non-supplemented milk. Further work is needed to evaluate the effects of CSFA supplementation on milk composition during mid to late lactation, as well as the effects of CSFA on milk processing characteristics.

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The authors wish to thank Dick Schlapper, Lori Brekenridge, and Ann Stellrecht. Without their invaluable assistance in the intensive management and data collection required by the experiment, this project would not have been possible.

Table 1. Milk composition of bulk-tank samples obtained during the CSFA supplementation trial

Sampling date	Number of ewes	CSFA[†]	Milk Composition		
			Milk fat, %	Milk protein, %	Somatic cell count, 1 x 10^3 cells/ml
2/17/99	27	no	4.39	5.10	300
2/24/99	39	no	5.70	5.48	400
3/3/99	51	yes	5.88	5.17	97
3/10/99	84	yes	6.52	5.25	600
3/17/99	116	no	5.06	5.25	700
3/24/99	123	no	4.20	5.20	420
3/31/99	135	yes	6.26	4.98	490
4/7/99	139	yes	5.98	4.84	230

[†]Calcium salts of long chain fatty acids (Megalac® Rumen Bypass Fat): 100 mg/ewe per day.

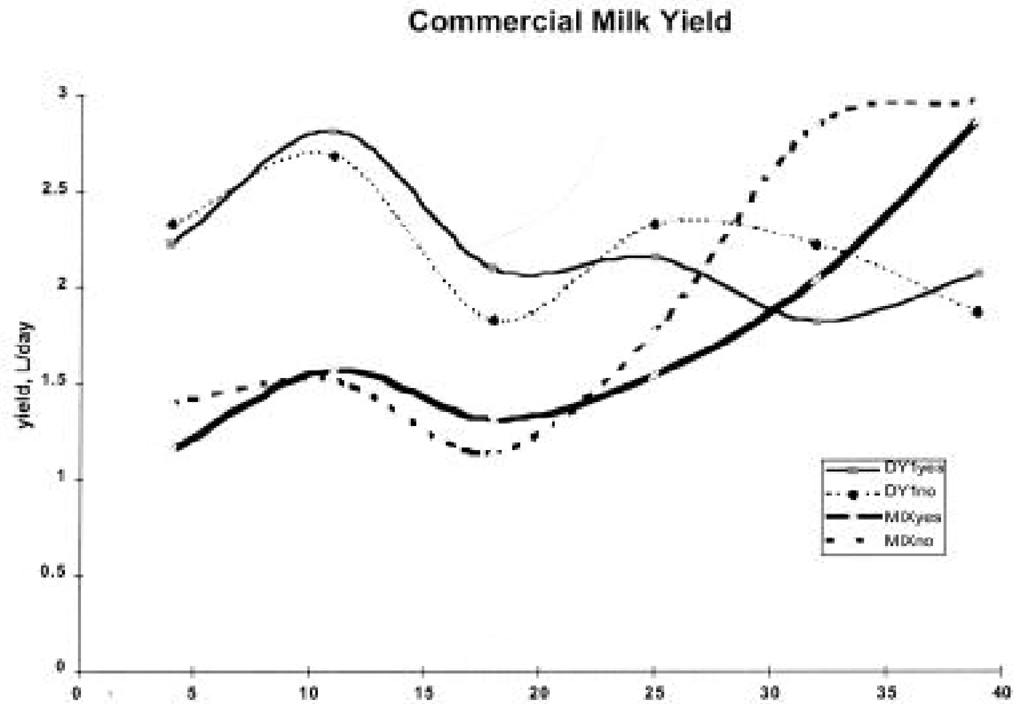

Table 2. Least squares means (±SE) for commercial milk yield (L/ewe) of the Weaning System and CSFA treatment groups

Stage of lactation	Number of ewes	CSFA	Weaning System DY1	MIX
Day 1 to 7	63	no	16.3±.85[a]	9.72±1.1[b]
	40	yes	15.6±.98[a]	8.06±1.4[b]
Day 8 to 14	76	no	18.8±.85[a]	10.6±1.3[b]
	53	yes	19.7±1.3[a]	11.0±1.6[b]
Day 15 to 21	48	no	12.8±.65[a]	7.95±1.1[c]
	70	yes	14.7±.64[b]	9.17±.87[c]
Day 22 to 28	34	no	16.3±1.1[a]	12.4±1.5[b]
	76	yes	15.1±.71[a]	10.8±1.1[b]
Day 29 to 35	37	no	15.6±1.3[b]	19.9±1.7[a]
	48	yes	12.8±.86[c]	14.3±1.5[bc]
Day 36 to 42	28	no	13.1±1.7[a]	20.8±4.1[b]
	34	yes	14.5±1.7[a]	20.1±2.5[b]
Day 1 to 42	62	N/A	94.4±5.2[a]	84.0±12[b]

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

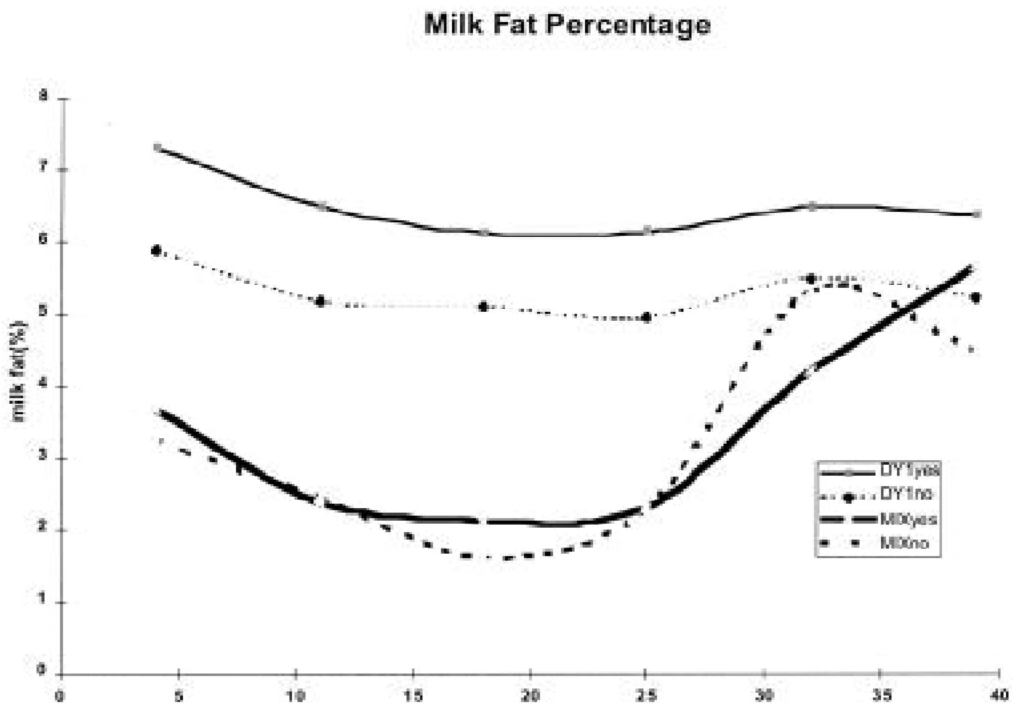

Table 3. Least squares means (±SE) for percentage of milk fat of the Weaning System × CSFA treatment combination

Stage of lactation	Number of ewes	CSFA	Weaning System DY1	Weaning System MIX
Day 1 to 7	63	no	5.88±.25[a]	3.25±.34[c]
	40	yes	7.30±.29[b]	3.68±.41[c]
Day 8 to 14	76	no	5.18±.15[a]	2.44±.23[c]
	53	yes	6.50±.18[b]	2.38±.26[c]
Day 15 to 21	48	no	5.10±.16[a]	1.60±.26[c]
	70	yes	6.13±.16[b]	2.12±.21[d]
Day 22 to 28	34	no	4.96±.27[a]	2.28±.38[c]
	76	yes	6.15±.18[b]	2.31±.28[c]
Day 29 to 35	37	no	5.50±.39[a]	5.31±.52[a]
	48	yes	6.50±.26[b]	4.21±.45[c]
Day 36 to 42	28	no	5.24±.22[ab]	4.49±.52[a]
	34	yes	6.39±.21[c]	5.66±.32[bc]

[a,b,c,d] Within a stage of lactation, means lacking a common superscript letter are different ($P < .05$).

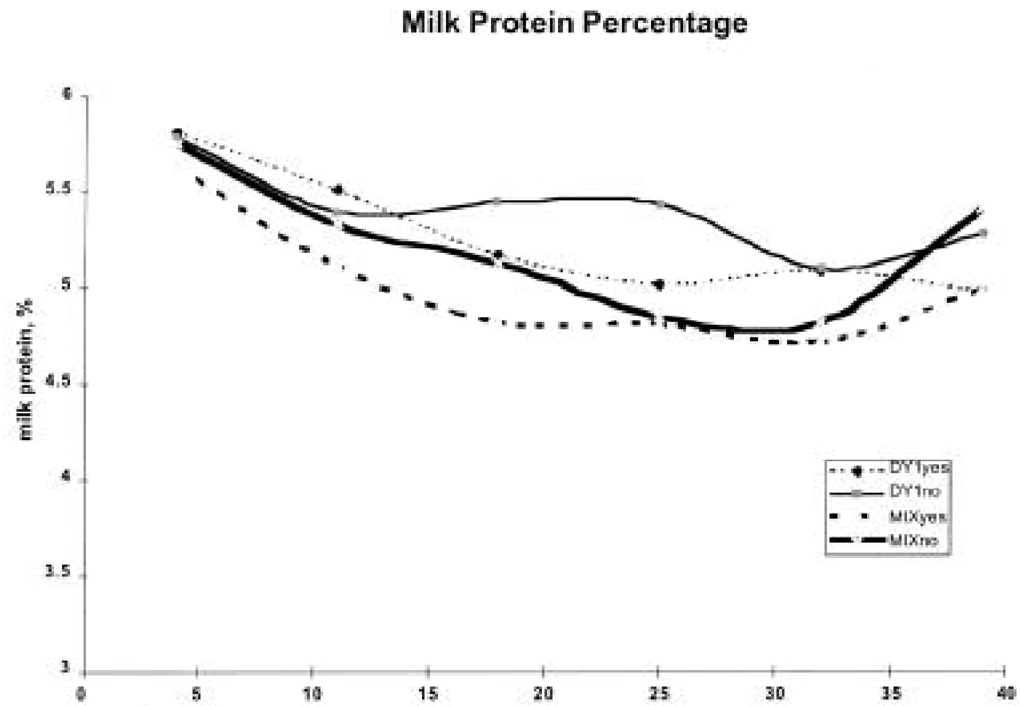

Table 4. Least squares means (±SE) for percentage of milk protein of the Weaning System and CSFA treatments

Stage of lactation	Number of ewes	CSFA	Weaning System DY1	Weaning System MIX
Day 1 to 7	63	no	5.78±.09	5.75±.12
	40	yes	5.81±.11	5.64±.15
Day 8 to 14	76	no	5.40±.07[a]	5.33±.10[a]
	53	yes	5.51±.08[a]	5.11±.11[b]
Day 15 to 21	48	no	5.45±.08[a]	5.13±.13[b]
	70	yes	5.17±.08[b]	4.82±.10[c]
Day 22 to 28	34	no	5.44±.09[a]	4.85±.13[bc]
	76	yes	5.02±.06[b]	4.81±.10[c]
Day 29 to 35	37	no	5.10±.12[a]	4.82±.16[ab]
	48	yes	5.09±.08[a]	4.72±.14[b]
Day 36 to 42	28	no	5.28±.11	5.42±.28
	34	yes	4.98±.11	4.99±.17

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

Table 5. Least squares means (±SE) for kilograms of milk fat of the Weaning System and CSFA treatments

Stage of lactation	Number of ewes	CSFA	Weaning System DY1	MIX
Day 1 to 7	63	no	1.00±.07[a]	.36±.08[c]
	40	yes	1.19±.08[b]	.27±.11[c]
Day 8 to 14	76	no	1.02±.05[a]	.27±.07[c]
	53	yes	1.33±.07[b]	.26±.09[c]
Day 15 to 21	48	no	.68±.04[a]	.14±.06[c]
	70	yes	.93±.04[b]	.23±.05[c]
Day 22 to 28	34	no	.82±.07[a]	.35±.09[c]
	76	yes	.98±.04[b]	.27±.07[c]
Day 29 to 35	37	no	.86±.09[ab]	1.03±.12[a]
	48	yes	.85±.06[ab]	.66±.10[b]
Day 36 to 42	28	no	.71±.10[a]	1.00±.24[b]
	34	yes	.97±.10[b]	1.14±.15[b]

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

Table 6. Least squares means (±SE) for kilograms of milk protein of the Weaning System and CSFA treatments

Stage of lactation	Number of ewes	CSFA	Weaning System DY1	MIX
Day 1 to 7	63	no	.97±.05[a]	.58±.06[b]
	40	yes	.95±.06[a]	.47±.08[b]
Day 8 to 14	76	no	1.05±.04[a]	.59±.06[b]
	53	yes	1.12±.07[a]	.57±.08[b]
Day 15 to 21	48	no	.72±.03[a]	.43±.05[b]
	70	yes	.79±.03[a]	.46±.04[b]
Day 22 to 28	34	no	.91±.05[a]	.61±.07[c]
	76	yes	.79±.03[b]	.54±.05[c]
Day 29 to 35	37	no	.82±.06[b]	1.00±.09[a]
	48	yes	.67±.04[c]	.70±.07[bc]
Day 36 to 42	28	no	.71±.08[a]	1.15±.19[b]
	34	yes	.73±.08[a]	1.02±.12[b]

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

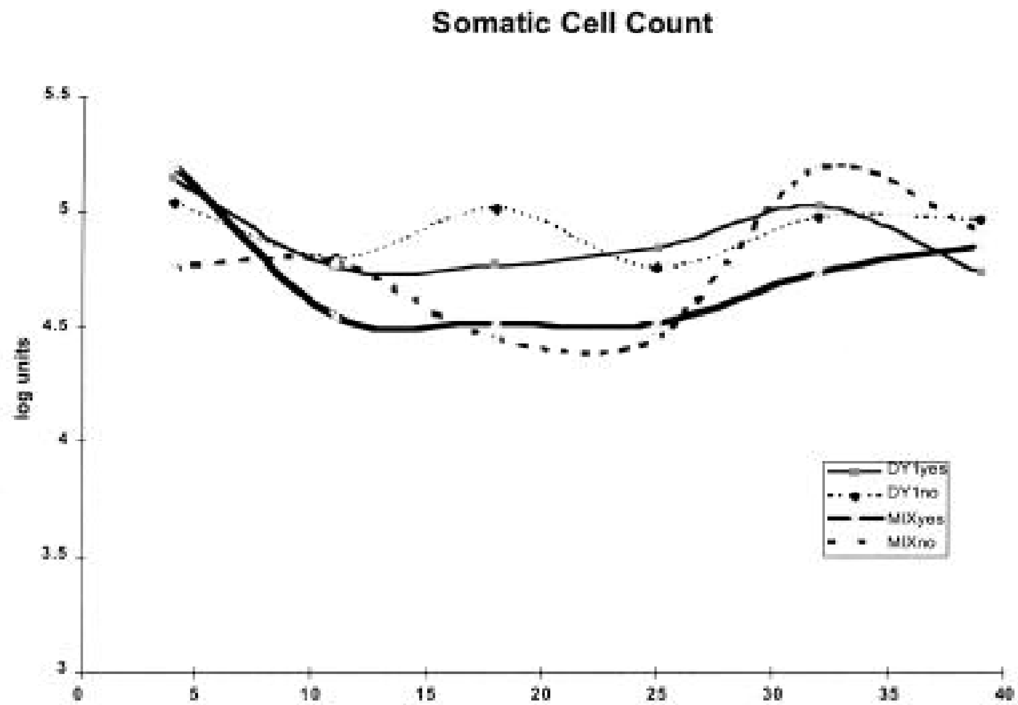

Table 7. Least squares means (±SE) for log-transformed somatic cell count (cells/ml) of the Weaning System and CSFA treatments

Stage of lactation	Number of ewes	CSFA	Weaning System: DY1	Weaning System: MIX
Day 1 to 7	63	no	5.04±.14	4.76±.18
	40	yes	5.14±.16	5.20±.23
Day 8 to 14	76	no	4.80±.10	4.78±.15
	53	yes	4.76±.12	4.55±.18
Day 15 to 21	48	no	5.02±.12[a]	4.45±.19[b]
	70	yes	4.77±.12[ab]	4.52±.16[b]
Day 22 to 28	34	no	4.76±.14[ab]	4.46±.20[b]
	76	yes	4.85±.09[a]	4.52±.15[b]
Day 29 to 35	37	no	4.98±.19	5.19±.26
	48	yes	5.03±.13	4.74±.22
Day 36 to 42	28	no	4.97±.18	4.92±.44
	34	yes	4.74±.18	4.85±.27

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

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PRELIMINARY RESULTS: EFFECTS OF UDDER MORPHOLOGY ON COMMERCIAL MILK PRODUCTION OF EAST FRIESIAN CROSSBRED EWES

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Abstract

Udder and teat morphology measurements were taken at approximately 7.5 hr after the a.m. milking for 131 East Friesian (EF) crossbred ewes at an average of 71 d in lactation. Additionally, milking time was recorded for each ewe during two evening and morning milkings. Average daily milk production, milking time, percentage of milk fat, percentage of milk protein, and somatic cell count were 2 L/ewe/day, 174 sec, 5.07%, 4.77%, and 56,250, respectively. When compared to reports in the literature on other dairy breeds of sheep, our EF crossbred ewes had larger udder width (14.6 cm), cistern height (2.97 cm), and teat angle (58.3°); similar udder circumference (45.2 cm) and teat width (1.64 cm); and smaller udder height (14.6 cm) and teat length (2.6 cm). Regression coefficients were calculated for these udder and teat measurements on various lactation traits. Ewes with greater udder circumference and udder height had greater commercial milk yield. Greater udder length, udder height, and cistern height were associated with increased milking time. Cistern height was positively associated with percentage of milk fat. In conclusion, ewes having larger udders with more cistern located below the teat canal exit are predicted to have higher milk yield, higher percentage of milk fat, and take longer to machine milk.

Introduction

Dairy sheep production in the United States is becoming an economically viable enterprise. Since the importation of the East Friesian (EF) breed in the early 1990's, relatively little genetic selection has been possible due to the limited amounts of dairy sheep germ plasm available. Therefore, many producers may have been milking ewes that are relatively unadapted to machine milking. High-percentage EF ewes and rams are now available to producers, and genetic selection programs need to be implemented to further adapt the EF dairy ewe to an American production setting. Producers who milk sheep are well aware of the individual variation in udder size, shape, and teat placement, and the ramifications that udder conformation may have on milk yield and machine milking time.

Sagi and Morag (1974), Jatsch and Sagi (1979), and Gootwine et al. (1980) with Awassi and Assaf ewes performed some of the earliest work with dairy ewe udder morphology in Isreal. Udder anatomy and morphologic parameters of Lacaune, Sarda, Manchega, Tsigaya, and Karagouniko dairy ewes have been studied in the Mediterranean basin, initially under a protocol issued by FAO, and have been reviewed by Labussière et al. (1981) and Labussière (1983, 1988). Further work has been done in France with the Rouge de l'Ouest (Malher and Vrayla-Anesti, 1994) and Lacaune (Marie et al., 1999); in Spain with the Churra (de la Fuente et al., 1996; Fernández et al., 1995, 1997), Laxta, Manchega, and Lacaune (de la Fuente et al., 1999; Rovai et al., 1999; Such et al., 1999); in Italy with the Sarda (Carta et al., 1999); in Greece with the Chios (Mavrogenis et al., 1988); and in Poland with the Zelazna (Charon, 1990). Tables 1 and 2 summarize the breed differences in udder and teat morphology measurements from some of the above references.

Morphology traits, such as udder circumference, udder shape, teat length, and teat width, are moderately heritable (Gootwine et al., 1980; Mavrogenis et al., 1988; Fernández et al., 1997; Carta et al., 1999) and are significantly correlated with milk yield (Labussière et al., 1981; Labussière, 1988; Fernández et al., 1995, 1997; Carta et al., 1999; Rovai et al., 1999). Moreover, it is plausible that these traits not only influence milk yield, but also milk composition and milking time. The objectives of this experiment were to quantitatively assess the variation in udder morphology in our EF crossbred dairy flock and to estimate the relationship between a variety of udder measurements and commercial milk production and milking time.

Table 1. Summary of breed differences cited in the literature with respect to udder morphology measurements

	Breed					
Measurement	Lacaune	Rouge de l'Ouest	Manchega	Churra	Sarda	Chios
Udder circumference, cm				46.5[6]		48.4[7a] 36.0[7b]
Udder width, cm	13.5[4]		11.9[4]	12.2[6]		
Udder length, cm	9.36[1] 7.01[2] 11.3[3] 11.0[4]	9.26[5]	8.38[2] 10.5[2] 11.4[3] 9.10[4]	8.13[2] 9.30[6]	10.7[2]	
Udder height, cm	17.8[3] 17.7[4]		17.2[3] 13.4[4]		23.4[7]	
Cistern height, cm	1.32[1] 1.93[2] 2.00[3] 2.09[4]	1.38[5]	.69[2] 1.60[2] 1.55[3] 1.10[4]	1.88[2] 1.48[6]	3.19[2]	

[1] Labussière et al. (1981) in France. 65 to 80 d in milk. Measured 8 hr after the a.m. milking.
[2] Reviewed by Labussière et al. (1988). 50 d in milk. Measured 8 hr after the a.m. milking.
[3] Rovai et al. (1989) in Spain. 10, 30, 60, and 120 d in milk. Measured 2 hr prior to p.m. milking.
[4] Such et al. (1999) in Spain. 110 d in milk. Measured 4 hr after a.m. milking
[5] Malher and Vrayla-Anesti (1994) in France. 22 to 110 d in milk. Measured immediately prior to milking.
[6] Fernandez et al. (1995) in Spain. 30, 60, 90, and 120 d in milk. Measured immediately prior to a.m. milking.
[7] Mavrogenis et al. (1988) in Cyprus. 50 d in milk. Measured immediately prior to[a] or after[b] milking.

Table 2. Summary of breed differences cited in the literature with respect to teat morphology measurements

Measurement	Breed					
	Lacaune	Rouge de l'Ouest	Manchega	Churra	Sarda	Chios
Teat angle, deg	41.8[1] 48.0[2] 44.1[3] 52.3[4]	26.5[5]	43.4[2] 46.1[2] 42.5[3] 45.6[4]	50.7[2] 50.4[6]	67.2[2]	
Teat length, cm	3.25[1] 3.06[2] 2.91[3] 3.08[4]	3.19[5]	3.07[2] 2.88[2] 3.36[3] 3.28[4]	2.61[2] 3.83[6]	2.72[2]	4.26[7]
Teat width, cm	1.53[1] 1.43[2] 1.32[3] 1.59[4]	1.53[5]	1.79[2] 1.53[2] 1.51[3] 1.66[4]	1.60[2] 1.93[6]	1.60[2]	2.30[7]
Teat position score, no	2.85[1] 3.20[2] 2.70[4]	3.10[5]	3.00[2] 2.50[4]	3.40[2] 3.64[6]	3.70[2]	

[1] Labussière et al. (1981) in France. 65 to 80 d in milk, measured 8 hr after the a.m. milking.
[2] Reviewed by Labussière et al. (1988). 50 d in milk, measured 8 hr after the a.m. milking.
[3] Rovai et al. (1989) in Spain. 10, 30, 60, and 120 d in milk, measured 2 hr prior to p.m. milking.
[4] Such et al. (1999) in Spain. 110 d in milk, measured 4 hr after a.m. milking
[5] Malher and Vrayla-Anesti (1994) in France. 22 to 110 d in milk, measured immediately prior to milking.
[6] Fernandez et al. (1995) in Spain. 30, 60, 90, and 120 d in milk, measured immediately prior to a.m. milking.
[7] Mavrogenis et al. (1988) in Cyprus. 50 d in milk, measured immediately prior[a] or after[b] milking.

Materials and Methods

Between May 12 and 14, 1999, 131 EF crossbred dairy ewes were evaluated for udder anatomy and machine milking time. Ewes were at an average of 71 d in lactation and were producing approximately 2 L/d of commercial milk. Udder measurements (Figure 1 and 2) were taken once on every ewe at approximately 7.5 hours after the morning milking (1230 to 1430) by one technician. A second technician photographed a caudal view of every ewe's udder. A third technician recorded the data. Ewes in the drylot (n = 59) were measured on May 12, and ewes grazing a kura-clover pasture during the day (n = 72) were measured on May 13. Udder anatomy and morphology data collected were:

1. *Udder circumference (ucirc):* a scrotal circumference tape was placed around the widest portion of the udder.
2. *Udder width (uwid):* a large caliper was used to measure the distance between the widest lateral points of the udder.

3. *Udder length (uleng):* a large caliper was used to measure the distance between the most cranial and caudal points of udder attachment at the intramammary groove.
4. *Udder height (uht):* a large caliper was used to measure the distance between the perineal attachment of the udder and the perpendicular of the site of teat attachment.
5. *Cistern height (cisht):* a T-square was used to measure the distance between the perpendicular of the site of teat attachment and the bottom of the right and left cisterns.
6. *Teat angle (tang):* with a plumb line hung behind the ewe, a photograph was taken of every ewe. From these photographs, right and left teat angles relative to the vertical were drawn, and then measured with a protractor.
7. *Teat length (tleng):* a small clear ruler was used to measure the distance between the tip of the teat and its attachment to the udder for both right and left teats.
8. *Teat width (twid):* a small clear ruler was used to measure the distance between the two lateral borders of the teat at the midpoint of the teat length measurement, for both right and left teats.
9. *Teat position score (tpos):* a subjective score from 1 to 5 was used to evaluate lateral teat placement for both right and left teats (1=caudal, 2=vertical, 3=slightly cranial, 4=cranial, 5=horizontal).

Ewes were machine-milked in a 12 x 2 milking parlor with indexing stanchions and a high-line pipeline system (Alfa Laval-Agri®, Tomba, Sweden) by two technicians. Machine-milking settings included a pulsation rate of 180/min, a ratio of 50:50, and a vacuum level of 38 kPa. Milking times were recorded for all ewes during the morning milkings (0600) of May 13 and 14, and for the evening milkings (1700) of May 12 and 13. Each ewe was individually timed with a separate stopwatch by a third technician. The stopwatch was started as the teat cups were being placed on the teats, the ewe was machine milked and machine stripped, and then the stopwatch stopped at the moment the teat cups were removed from the udder. Commercial milk yield (a.m. and p.m.) was measured weekly or bi-weekly with a Waikato® milk meter. Milk composition samples were taken weekly or bi-weekly and submitted to a State of Wisconsin certified dairy laboratory for analysis of percentage of milk fat, milk protein, and Fossomatic® somatic cell count. The last test day data included in this study was collected on May 11-12 to avoid any deleterious effects from the stress of measuring the ewes. Total commercial lactation milk yield to May 12 was calculated by using a previously reported formula (Thomas, 1996). Milk fat and protein yield for individual ewes were calculated weekly or bi-weekly by multiplying a ewe's test-day yield with her corresponding percentage of fat or protein by the number of days between test days .

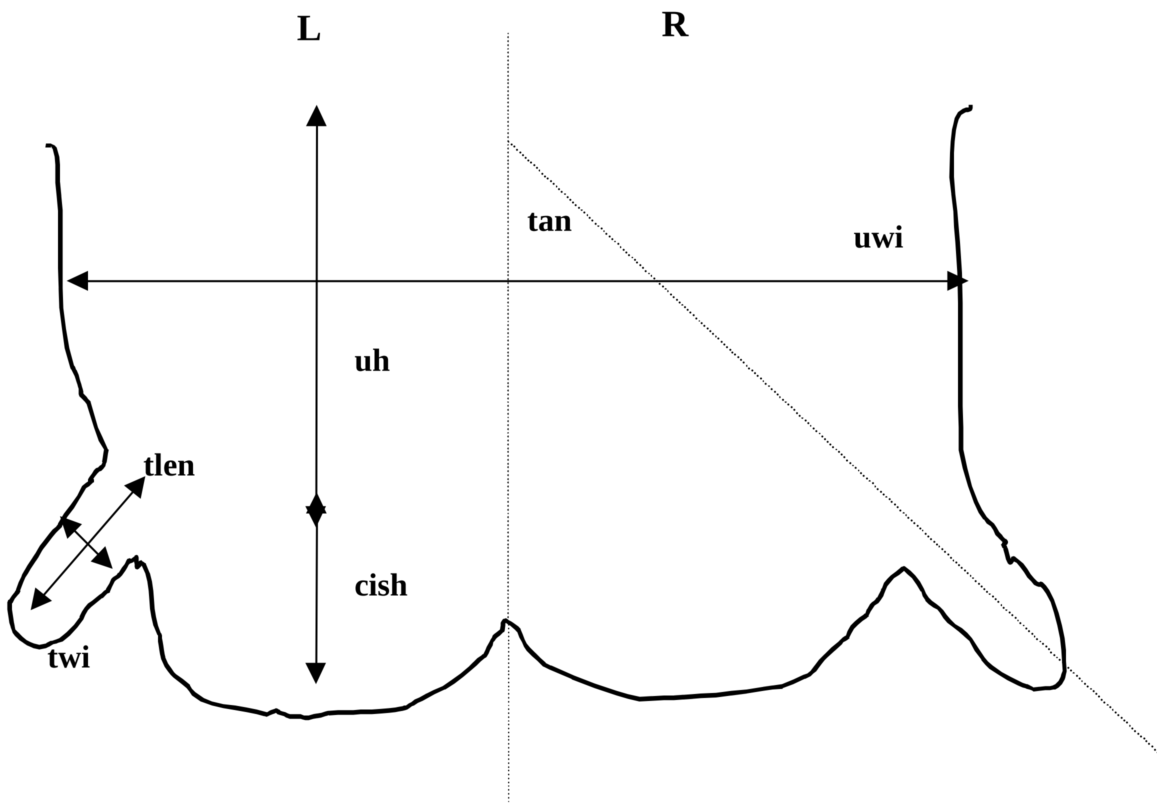

Figure 1. Caudal schematic view of a ewe udder demonstrating anatomical and morphologic measurements taken. Udder height (uht), udder width (uwid), cistern height (cisht), teat angle (tang), teat length (tleng), and teat width (twid).

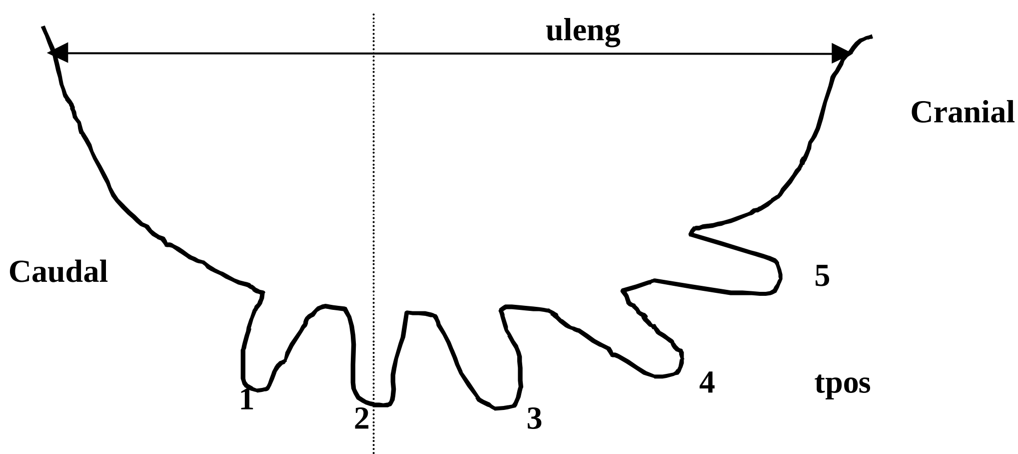

Figure 2. Lateral schematic view of a ewe udder demonstrating anatomical and morphologic measurements taken. Udder length (uleng) and teat position score (tpos).

The resulting values were summed to arrive at total fat and protein yields up to May 12. Average percentage of milk fat and protein was calculated by dividing total fat or protein yields by total commercial milk yield. Somatic cell counts were transformed to base-10 logarithms and averaged for each ewe. Days in milk were the number of days post-partum between May 12 and the lambing date. Average daily commercial milk yield for each ewe was calculated by dividing the total commercial milk yield by the number of days in milk.

Regression coefficients for the udder measurements were generated using the GLM procedure of SAS (1999) with the following model:

Y = par + ebrd + nutr + wg + ls + dim + ucirc + uwid + uleng + uht + cisht + tang + tleng + twid + tpos + error.

The dependent variables, Y, in the models were:

y512:	test-day commercial milk yield on May 12
time:	average of all milking times recorded for a ewe (a.m. and p.m.)
avgdyld:	average daily commercial milk yield
tyldkg:	total commercial milk yield
fatavg:	average percentage of milk fat
fatkg:	total fat yield
proavg:	average percentage of milk protein
prokg:	total protein yield
logavg:	average log somatic cell count

Main effects accounted for in the models included:

par:	parity (2^{nd}, 3^{rd}, or 4^{th})
ebrd:	breed of ewe (≤ 1/4 EF, >1/4 to ≤ 1/2 EF, or > 1/2 EF)
nutr:	nutrition (pasture or drylot)
wg:	weaning group (DY1 or MIX, see McKusick et al., 1999)
ls:	litter size (1, 2, or ≥ 3)

Regressors (covariates) in the models were:

dim:	number of days in milk
ucirc:	udder circumference
uwid:	udder width
uleng:	udder length
uht:	udder height
cisht:	cistern height
tang:	teat angle
tleng:	teat length
twid:	teat width
tpos:	teat position score

Results and Discussion

Unadjusted ewe means and ranges for various lactation traits are presented in Table 3 to familiarize the reader with milk production of our EF crossbred dairy ewe flock at the time of udder measuring. Ewes had been lactating for approximately 71 d, were producing about 2 L/d, and had already produced 141 kg of milk. Average milking time was 174 sec (almost 3 min per ewe), which included machine stripping. Average percentages of milk fat and protein were 5.07 and 4.77%, respectively. Average somatic cell count was 4.75 log units (56, 234 cells/ml of milk).

Unadjusted ewe means and ranges for udder teat morphology traits measured are presented in Table 4. Tables 1 and 2 summarize measurements made by other authors on Lacaune, Rouge de l'Ouest, Manchega, Churra, Sarda, and Chios dairy ewes. Although there are some inconsistencies with respect to stage of lactation and time of day when udders were measured, some general comparisons can be made between our EF crossbred flock and other dairy breeds. Udder circumference (46.2 cm) was similar to what has been reported for Churra and Chios dairy ewes. Udder width and height (14.6 cm) were similar for our EF crossbred ewes, and these both differ from what has been reported for other breeds. Our EF crossbred ewes had wider udders than Lacaune, Manchega, or Churra ewes (however the measurements for these later three breeds were either taken later in lactation or closer to the morning milking). When comparing udder height measurements of the present experiment with those in the literature, it must be noted that our measurements did not include the height of the cistern. However, when cistern height is subtracted from udder height for values reported in the literature, our EF crossbred ewes still have shorter udders than either Lacaune or Manchega ewes. Average udder length for our EF crossbred ewes was 11.2 cm, which is longer than what has been reported for other breeds. EF crossbred ewes in the present experiment had greater cistern height (2.97 cm) than all other breeds reported except the Sarda (3.19 cm). Average teat angle for our EF crossbred ewes was 58.3°, which is more horizontal than all other reports except the Sarda (67.2°). This is to be expected because teat angle increases as cistern height increases (Fernandez et al., 1995; Rovai et al., 1999). Compared to other breeds, teat length for our EF crossbred ewes (2.6 cm) tended to be shorter, but teat width (1.64 cm) was similar. EF crossbred ewes in the present experiment had cranially placed teats (score of 2.93), but were less cranial than other breeds.

Table 3. Unadjusted ewe means (±stdev) and range for lactation traits

Trait	Mean (±stdev)	Minimum	Maximum
Test-day yield, L	2.03±.72	.60	3.60
Milking time, sec	174±64	76	394
Days in milk, d	71.2±15	37.0	97.0
Total commercial milk yield , kg	141±55	32.3	281
Average daily commercial milk yield, L/d	2.03±.62	.69	3.42
Average milk fat, %	5.07±.86	3.10	7.05
Total fat yield, kg	7.29±3.2	1.50	14.4
Average milk protein, %	4.77±.32	3.98	5.76
Total protein yield, kg	6.72±2.6	1.59	13.4
Average somatic cell count, log units	4.75±.31	4.27	5.88

Table 4. Unadjusted ewe means (±stdev) and range for udder measurements

Measurement	Mean (±stdev)	Minimum	Maximum
Udder circumference, cm	46.2±5.3	35.0	61.0
Udder width, cm	14.6±2.0	9.50	19.0
Udder length, cm	11.2±2.0	6.50	16.0
Udder height, cm	14.6±2.2	8.00	21.0
Cistern height, cm	2.97±1.5	.30	8.50
Teat angle, deg	58.3±12	31.5	89.0
Teat length, cm	2.60±.49	1.50	4.25
Teat width, cm	1.64±.28	1.00	2.75
Teat position score, no	2.93±.64	1.50	5.00

Regression coefficients for udder and teat measurements on lactation traits are summarized in Table 5 and are bold-faced when significant (*P* < .10). Udder circumference and udder height (udder volume) have been previously shown to be significantly correlated with milk yield (Labussière et al., 1981; Labussière, 1988; Mavrogenis et al., 1988; Charon, 1990). In the present experiment, it is estimated that for each centimeter increase in udder circumference and udder height, there is a relative increase of .06 and .11, respectively, in liters of daily commercial milk yield. Milking procedure time is highly correlated with commercial milk yield, udder volume (Labussière et al., 1981), and quite possibly cistern height, as more time is needed for machine stripping. Our results support these relationships found in other studies, and predict that for each centimeter increase in udder length, udder height, and cistern height, there is a relative increase of 9.4, 4.8, and 15.1 seconds, respectively, in milking time. Correlations of udder and teat measurements with milk composition and quality traits are not readily available in the literature. Our work suggests that there is a significant relationship between cistern height and average percentage of milk fat. For each centimeter increase in cistern height there is a relative increase of .12 in percentage units of milk fat. This would imply that ewes with deeper cisterns are able to store milk and milk fat in the cistern between milkings, and avoid the deleterious effects of residual milk on the secretory alveoli of the udder (Labussière et al., 1978; Wilde et al., 1987, 1995). Although in the present experiment the regression coefficients for teat width on test-day yield and average daily yield were non-significant, it has been previously shown that teat width tends to increase with milk yield (Fernandez et al., 1995). Therefore, the significantly negative regression coefficients between teat width and percentage of milk fat and milk protein could be explained by the dilution effect: as milk yield increases, percentage of milk fat and protein decrease. The significant regression coefficients between average log somatic cell count and udder morphology traits are not easily explained. It would be expected for traits that are positively correlated with milk yield, that somatic cell count should increase accordingly. However, udder length is the only trait with a positive regression coefficient with somatic cell count.

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Table 5. Regression coefficients (±SE) for udder measurements on lactation traits

Measurement	Test-day yield	Milking time	Average daily yield	Average milk fat percentage	Average milk protein	Average log somatic cell
Udder circumference	**.06±.02*****	2.53±1.8	**.06±.01*****	.01±.02	-.02±.01	**-.02±.01***
Udder width	.01±.04	1.48±3.9	.01±.03	-.04±.05	-.03±.03	**-.06±.03****
Udder length	.05±.04	**9.35±4.5****	-.02±04	-.05±.06	.01±.03	**.10±.03*****
Udder height	**.11±.03*****	**4.84±2.7***	**.11±.02*****	-.03±.03	-.02±.02	-.02±.02
Cistern height	.04±.04	**15.1±4.3*****	.03±.04	**.12±.05****	.03±.03	**-.08±.03*****
Teat angle	.001±.01	-.66±.5	.01±.01	-.01±.01	-.004±.003	.005±.003
Teat length	-.07±.10	-10.4±11	-.02±.10	.10±.13	.06±.07	.09±.07
Teat width	.23±.20	16.4±20	.09±.18	**-.57±.25****	**-.25±.14***	-.07±.13
Teat position score	.04±.07	-.72±7	.02±.07	-.0002±.09	**-.11±.05****	-.04±.05

$^{***}P < .01$, $^{**}P < .05$, $^{*}P < .10$

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