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Sheep dairying: Building on tradition

Sheep's milk cheeses are becoming very popular with U.S. consumers.

Sheep dairying and cheese production from sheep's milk has a long tradition in many of the countries of southern and eastern Europe, the Middle East and North Africa. The top five countries for sheep milk production in 1996 were Turkey (922 million kg), Italy (700 million kg), Greece (630 million kg), Sudan (510 million kg) and Syria (499 million kg).

The top five countries for sheep milk cheese production in 1996 were Greece (113 million kg), Italy (81 million kg), France (41 million kg), Spain (41 million kg), and Syria (40 million kg) (FAO, 1998). Famous sheep milk cheeses produced in some of these countries are: Manchego (Spain), Roquefort and Ossau-Iraty (France), Pecorino Romano and Sardo (Italy), and Feta (Greece).

Once very much the domain of Mediterranean and Middle Eastern countries, sheep dairying now extends to many other parts of the world. The United Kingdom, Australia, New Zealand, Argentina, Uruguay, Iceland, Holland, Sweden, Norway and the United States are all countries without a sheep dairying heritage (or long forgotten tradition), but that support a budding sheep dairy industry with the potential to flourish.

What has sparked the renewed interest in sheep dairying? There is no single answer to this question. Common problems faced by sheep producers, a slow and subtle change in consumer preferences, the development of new technologies and communication are certainly important contributors.

Domestic market for sheep's milk cheeses

Sheep's milk cheeses are becoming very popular with U.S. consumers. Imports into the U.S. increased from 16.7 million kg for a value of 64 million dollars in 1987 to 30.1 million kg for a value of 139.7 million dollars in 1997 (FAO, 1998)—an 80% increase in just ten years. Of the 18 countries that report imports of sheep milk cheeses, the U.S. imports the most—approximately 2.5 times the amount imported by the second ranked country (FAO, 1998).

In 1989, under the guidance of William Boylan of the University of Minnesota, two or three Wisconsin sheep producers and a small cheese plant created the embryo of the sheep dairy industry in the U.S. In 1998 there were roughly 100 dairy sheep producers in the U.S., producing approximately 500,000 kg of sheep milk annually (representing 100,000 kg of cheese).

To all indications, there is a large domestic market for sheep's milk cheese that could support a domestic dairy sheep industry several times that of the current industry. But although growth in producer numbers has been constant, it has not been dramatic because of limitations on production and marketing. Production limitations have included low milk production of domestic breeds, lack of financing and lack of a knowledge base or pool of sheep dairy experience to serve as a source of information. Marketing limitations have included lack of an organized marketing system for sheep's milk and few processors.

Many of these problems are being addressed. Dairy sheep breeds with high levels of milk production are now available in the U.S. The University of Wisconsin–Madison has established the only dairy sheep production research unit in the country with the physical facilities located at the Spooner Agricultural Research Station. Considerable work on breed evaluation, milking techniques, management, physiology of lactation and processing properties of sheep's milk is being conducted by scientists in the UW–Madison College of Agricultural and Life Sciences, Department of Meat and Animal Science, Food Science and the Center for Dairy Research.

While large strides have been made toward developing an economically viable dairy sheep industry in the U.S. through generation of research results, applying those research results to production, and developing a milk marketing organization still needs substantial work. This publication is part of this continuous effort. By compiling the most recent knowledge on dairy sheep production, it provides existing and future dairy sheep producers (small or large) with a tool to help them increase their knowledge and make good management decisions.

References

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Metric conversions

Weight

Gram (g) x 0.04 = ounce
Kilogram (kg) x 2.2 = pound
Metric ton (t) x 1.1 = ton (Imp.)

Volume

Liter (L) x 0.035 = cubic foot
Hectoliter (hl) x 22 = gallon (Imp.)
Hectoliter (hl) x 2.5 = bushel

Length

Millimeter (mm) x 0.04 = inch
Centimeter (cm) x 0.39 = inch
Meter (m) x 3.28 = foot
Kilometer (km) x 0.62 = mile

Area

Hectare (ha) x 2.5 = acre

This book deals only with problems very specific to dairy sheep and is not intended to be a sheep production or "how to" handbook. Readers are advised to check another source for information on general sheep management, health (except for mastitis), pasture management, lambing management, reproduction and related topics.

Chapter 1

Sheep's milk and its uses

For the master cheesemaker, sheep's milk is a dream come true.

For thousand of years, sheep and goat's milk have been the staple of life in many areas of the world. Sheep were certainly the first animals to be domesticated by humans in their effort towards an agricultural way of life. Eventually, the conservation of milk by its transformation into cheese was discovered and the best cheeses of the world were developed.

Although cows have replaced sheep as dairy animals because of their higher production potential, sheep dairying remains a strong and viable enterprise. Nowadays, sheep dairy products (cheese, yogurt, ice cream) are particularly in demand because of their rich flavor and exceptional nutritive value. Anyone who has tasted the famous Roquefort, the hard Pecorino Romano, the softer Pecorino Sardo, the melting Manchego, the tender Ossau-Iraty or the salty Feta, wants to have more than just a taste. In addition, for the master cheesemaker, sheep's milk is a dream come true because of its composition and its cheese making properties.

Composition of sheep's milk

Sheep's milk contains almost twice the solids of cow's milk, as well as higher casein and fat content. Sheep's milk yields 18–25% cheese; that is, it takes only 4–5 kg of milk to produce 1 kg of cheese (it takes 10 kg of cow's milk to produce the same amount). Moreover, the higher casein content makes the rennet coagulation time for sheep's milk shorter and the curd firmer (Jandal, 1996). The gross composition of sheep's milk and milk of other species is shown in table 1.

Table 1. Composition of sheep's milk compared to other species.

	Human	Cow	Sheep	Goat	Yak
Dry matter (%)	11.5-13.9	10.5-14.3	17.4-18.9	11.9-14.0	16.8-19.6
Fat (%)	3.7-4.6	2.8-4.8	6.0-7.5	4.1-4.5	6.5-7.8
Alb. Glob. (%)	0.8-1.7	0.3-0.8	0.9-1.1	0.4-1.0	0.6-1.9
Casein (%)	0.4	2.5-3.6	4.3-4.6	2.5-3.3	5.0-5.8
Lactose (%)	6.4-7.0	4.2-5.0	4.3-4.8	4.1-4.4	4.6-5.3
Ash (%)	0.2	0.7-0.9	0.9	0.8	0.9
Calcium (mg/l)		1360	2030		
Sodium (mg/l)		460	360		
Vit. A (mg/l)		0.3	0.5		
Vit.E (mg/l)		7	15.8		
Vit. C (mg/l)		22	40.0		
Kcal/100g	73	73	113	77	114

Alfa-Laval (1981)

Fat

Jandal (1996) shows that the fat of sheep's milk forms globules with a size ranging from .5 to 25 microns with an average diameter of 3.3 microns (Assenat, 1985). This is smaller than fat globules of cow's milk (4.55 microns). The color of fat in sheep's milk is very white because of a total absence of b-caroten (Assenat, 1985). Twenty percent of the fatty acids of sheep and goat's milk are short-chain saturated fatty acids (C4:0 to C12:0) compared to 12% in cow's milk (table 2). Lipases attack the ester linkages of the short-chain fatty acids more rapidly, so these differences may contribute to more rapid digestion of goat and sheep's milk.

Moreover, Havel (1997) reports that short chain fatty acids have little effect on the atherogenic lipoprotein concentration in blood plasma (cholesterol) of humans. The amount of cholesterol in sheep's milk increases with the amount of fat and has been found to be between 150 and 300 mg/liter (Assenat, 1985). Sheep's milk has a higher proportion of short-chain fatty acids such as caproic, caprylic and capric than cow's milk (but less than in goat milk) and gives its special taste and aroma. Some other compounds such as phospholipids and phenols also have an important role (Kim Ha and Lindsay, 1991).

Smaller fat globule diameter and greater percentage of short chain fatty acids contribute to easier and more rapid digestion of sheep's milk.

Proteins

Quantitatively and qualitatively, proteins constitute the most important percentage of milk. Two types of proteins can be found in milk: the casein and the serum, or whey proteins. In sheep's milk, casein enters for 80% of the total proteins. Because of a higher casein content, sheep's milk has better coagulation properties and better cheese making potential than cow's milk.

Caseins are made of 5 major components: $\alpha\sigma_1$, $\alpha\sigma_2$, β, κ and γ, and the percentage of the 5 components varies from one species to the other as shown in table 4 (Assenat, 1985). The percentage of $\alpha\sigma_1$ and $\alpha\sigma_2$ is higher in sheep than in goat's milk but significantly lower than in cow's milk. Casein b, however, represents 50% of the total casein in sheep's milk compared to 2/3

Table 2. Fatty acid composition of goat, cow and sheep's milk (% per weight)

Fatty acid	goat	cow	sheep
C4:0 (Butyric)	2.6	3.3	4.0
C6:0 (Caproic)	2.9	1.6	2.6
C8:0 (Caprylic)	2.7	1.3	2.5
C10:0 (Capric)	8.4	3.0	7.5
C12:0 (Lauric)	3.3	3.1	3.7
C14:0 (Myristic)	10.3	9.5	11.9
C16:0 (Palmitic)	24.6	26.5	25.2
C16:1 (palmitoleic)	2.2	2.3	2.2
C18:0 (Stearic)	12.5	14.6	12.6
C18:1 (Oleic)	28.5	29.8	20.0
C18:2 (Linoleic)	2.2	2.5	2.1

Jandal (1996)

Table 3. Physical properties of milk

Properties	cow	sheep
Specific gravity	1.0231-1.0398	1.0347-1.0384
Viscosity, Cp	2.0	2.86-3.93
Surface tension (Dynes/cm)	42.3-52.10	44.94-48.70
Refractive index (nD^{20})	1.3344-1.3485	1.3492-1.3497
Conductivity ($ohm^{-1}cm^{-1}$)	.0040-.0055	.0038
Freezing point	-0.530 to -0.570˚C	-0.570˚C
PH	6.65-6.71	6.51-6.85
Acidity (Lactic acid %)	0.15-0.18	0.22-0.25

Anifantakis (1985)

Table 4. Casein fractions according to the total casein.

Casein fractions	Cow	Goat	Sheep
$\alpha\sigma_1$	36	12.6	15.5
$\alpha\sigma_2$	9.5		14.7
β_1	33	35.9	18.9
β_2		39.4	28.2
κ	9.4	8.1	7.3
γ	6.8	3.9	15.4

Assenat (1985)

in goat and $^{1}/_{3}$ in cow's milk. Those variations in percentages of casein explain the difference in micelle structure and the absence of bitter taste in sheep's milk cheeses.

Most of the sheep's milk produced in the world (with the exception of the United Kingdom) is transformed into cheese, and is rarely consumed directly. For this reason, Bencini and Pulina (1997) refer to the quality of sheep's milk as its capacity to be transformed into high quality products and to produce high yields of these products (referred to as the processing performance of the milk). The processing performance of the milk (yield, composition and taste) mainly depends on the milk's clotting properties, a combination of renneting time, rate of curd formation and consistency of the curd. The clotting properties of the milk are widely affected by its composition.

Factors affecting the composition of sheep's milk

Bencini and Pulina (1997) cite several factors that affect the composition of the milk.

Somatic cell count

In sheep's milk, only 10% of the somatic cells are mammary gland cells (eosinophils, epithelial cells), normally secreted together with the milk as a result of cellular turnover in the mammary gland. The remaining 90% of the somatic cells are blood cells (macrophages, leucocytes, lymphocytes). These normally contribute to the immune defense of the mammary gland, but their number increases considerably in the case of inflammatory or pathological processes within the mammary gland. Therefore, a high somatic cell count is a sign of general infection in the animal. The most common pathology of the mammary gland in sheep is mastitis (see chapter 8).

In the U. S. states where sheep's milk is recognized as milk, it cannot legally have a somatic cell count higher than 1,000,000 cells/ml. A higher level at two consecutive tests could result in the revocation of the milk producer's license.

A high somatic cell count results in changes in the composition of milk (table 5) with a higher pH, a reduction in fat, casein, total solids, soluble calcium, and an increase in total nitrogen, non-protein nitrogen and whey proteins (Pirisi et al., 2000). These changes in composition lead to a considerable slow-down of coagulation and serious difficulties in the structuring of the curd and consequently a lengthening of the cheese making process as well as a decrease in cheese yield (Pirisi, 2000). High somatic cell count in cow's milk has been associated with problems in the quality of cheese. However, Pirisi et al. (1993, 2000) report that, in a study conducted in sheep's milk, although cheese yield was reduced, ripened cheeses did not show significant differences for chemical parameters and sensorial characteristics. Wendorff (2000), however, found a greater tendency for cheese to develop a rancid flavor.

Some cheese makers might set an artificial limit of somatic cells over which milk would be discounted. This is a very serious incentive for producers to make all possible efforts to decrease their overall (bulk tank) somatic cell count.

Table 5. Composition of sheep milk with different SCC

		SCC<500	500<SCC>1000 x 1000/ml	1000<SCC>2000
SCC	x 1000/ml	229 ± 55	653 ± 250	1200 ± 214
Ph		6.52	6.62	6.68
Dry Matter	g/100g	17.03	17.15	16.89
Lactose	g/100g	4.74	4.54	4.38
Fat	g/100g	6.61	6.34	6.36
True Protein	g/100g	5.25	5.45	5.51
Casein	g/100g	4.18	4.26	4.20
Soluble Casein	%	6.51	6.98	7.77
Whey Protein	g/100g	1.07	1.19	1.30
Non-Protein N	gN/100g	.06	.05	.05
Casein:Protein	%	79.71	78.16	76.27
Urea	mg/100ml	54.21	54.18	52.86
Total Ca	g/l	2.21	2.14	2.26
Soluble Ca	g/l	.46	.38	.36

Pirisi et al. (2000)

Microbial count

Many microorganisms present in the milk are advantageous for its transformation into cheese (*Lactobacillus* spp., *Lactococcus* ssp., *Streptococcus* spp.). However, others can cause serious human diseases (*Salmonella, Listeria, Brucella*), or create problems in the maturation of cheese (Enteriobactericeae, coliforms, psychrotrophs). Some psychrotrophic bacteria thrive at temperature below 7˚C and produce enzymes that destabilize the casein and modify the clotting properties of the milk.

In the U.S. (at least in Wisconsin) the legal limit for bacteria count in the milk is less than 300,000 cells/ml for grade B milk and less than 100,000 cells/ml for grade A milk. A higher level at 2 consecutive tests could result in the revocation of the milk producer's license.

Breed of ewes

The breed of sheep can affect the composition of milk, mostly because there is a negative correlation between milk yield and milk components. Therefore, breeds highly selected for dairy production tend to have a lower concentration of fat, protein and total solids. As a consequence, with high milk production, the total amount of cheese produced from the milk will be higher but the relative yield of cheese from each liter of milk will be lower.

Age and parity

Although reports are somewhat contradictory, it seems that the milk of young ewes contains a lower concentration of fat, proteins and total solids. The concentration of total solids increases with the parity number.

Stage of lactation

The amount of fat, protein, total solids, and somatic cells is high at the beginning and at the end of lactation and low at the peak of lactation. The processing performance of the milk tends to decrease as the lactation proceeds, with an increase in renneting time and rate of curd formation and a decrease in the consistency of the curd (Ubertalle, 1989, 1990 cited by Bencini and Pulina, 1997).

Season of milking

Many researchers cited by Bencini and Pulina (1997) have shown that sheep milk produced in summer has poor cheese making performance due to long renneting time, poor consistency of the curd, and high proteolytic and lipolytic activities. Mendia et al., (2000) also found that Idiazabal cheeses made in February earned higher sensory analysis scores for characteristic odor and taste and higher sensory scores than cheese made in June. It seems that hot temperatures do not affect the composition of the milk as much as the length of days. Long days result in a lower protein concentration and reduced secretion of fat and protein.

Nutrition

Nutrition affects the total milk production as well as the quality of the milk. The concentration of fat in the milk is correlated with the concentration of fiber in the diet (see chapter 5).

Conservation of milk

Fresh milk

To avoid the multiplication of bacteria, the milk must be cooled to 1˚C–4˚C and maintained at this temperature from milking to delivery to the processing plant. The low temperature will prevent bacterial multiplication for 24–48 hours. However, the presence of psychrotrophic bacteria, that is, those able to multiply, albeit slowly, at 5˚C, can result in marked increases in bacterial count during longer storage periods. Cousins and McKinnon (1977) have shown a significant increase in bacteria numbers after 3 days at 5˚C and that the effects of relatively small increases in storage temperature were dramatic.

Ineffectively cleaned and disinfected milking equipment, particularly the bulk tank, is the major source of psychrotrophic bacteria in milk.

It is recommended that fresh milk be chilled to 1˚C–4˚C in the 2 hours following milking and that it not be stored longer than 72 hours. Extreme care should be taken in cleaning of the equipment.

210 gallon bulk tank

Frozen milk

In North America, sheep dairy producers are few, separated by great distances and producing modest amounts of milk daily. Therefore, the collection of fresh milk on a daily basis by a processing plant is economically difficult for the time being. American producers generally freeze the milk until a sufficient quantity is stored for delivery to a cheese maker. Moreover, the production of sheep's milk is very seasonal and fresh milk becomes unavailable from October to February.

It is recommended that milk be frozen as quickly as possible, and at a temperature of at least -25˚C. In general, a home freezer cannot provide this type of freezing. A commercial grade freezer with inside ventilation should be used.

The freezing of milk helps remedy the shortcoming of production. Bastian (1994) at the University of Minnesota, studied the effect of freezing on the quality of the milk for cheese making. He found that freezing and thawing of sheep's milk did not change rennet coagulation properties, compared to fresh, unfrozen sheep milk. Wendorff and Rauschenberger, (2001) at the University of Wisconsin–Madison determined the storage stability of milk frozen at 2 different temperatures (table 6). Samples of raw sheep milk were frozen at -12˚C and at -27˚C. Samples were thawed at 1, 2, 3, 6, 9, and 12 months and analyzed for total bacteria, coliform bacteria, acid degree value (ADV), and intact protein. Intact protein was defined as the total protein content of milk minus the protein present in sediment at the bottom of the recipient in which the milk was frozen. Results indicate that milk frozen in a standard home freezer at -12˚C was not as stable as milk frozen in a commercial hardening room at -27˚C. After 6 months of storage at -12˚C, about one third of the casein was destabilized and precipitated out upon thawing. The raw milk stored at the lower temperature was stable up to 12 months. No evident protein precipitation was noticed throughout the study.

The best freezing is obtained when the milk is placed in plastic bags approved for food use with a cap (75 cm x 40 cm) and holding approximately 18–20 liters of milk. The bags are placed flat on shelves inside the freezer so that the thickness of the bags is no more than 6–7 cm, allowing for a quick and uniform freezing. As soon as the milk is solid, the bags can be stacked easily in the freezer.

Sheep milk in FDA approved bags and placed on shelves for quick freezing.

Sheep milk stored in a commercial freezer at-25˚C.

Table 6. Properties of frozen raw milk stored at -12˚C and -27˚C for various time periods

Time of storage (Mo)	Coliforms (CFU/ml)	SPC (CFU/ml)	ADV	TCA-ppt. Protein
Stored at –12˚C				
0	44	8200	.220	5.09
1	26	4100	.250	5.06
2	21	2500	.420	5.01
3	12	3400	.350	5.06
6	<1	2200	.410	5.02
9	<1	340	.420	3.37
12	<1	610	.490	3.90
Stored at –27˚C				
0	44	8200	.220	5.09
1	10	4100	.260	5.05
2	9	3200	.320	4.99
3	12	3700	.290	4.96
6	8	2800	.310	4.89
9	8	2700	.280	4.92
12	5	1800	.350	5.07

Wendorff and Rauschenberger, (2000)

The type and size of freezing containers, however, depends on the cheese makers and on the thawing capabilities. Before deciding on a freezing method the producer or group of producers should discuss with the cheese maker the best suitable method.

Yogurt produced from milk frozen and stored at -27˚C was comparable to that produced from fresh milk (table 8).

Freshly made yogurts

Uses of sheep's milk

Fluid products

Sheep's milk has some unique nutritional qualities that could be used in specific markets. It is richer in vitamins A, B and E, calcium, phosphorous, potassium and magnesium than cow's milk. Sheep's milk contains 1.08-1.44% whey proteins while cow's milk contains only 0.54-0.88%. It is also richer in C4-C12 fatty acids. Sheep's milk provides some relief for allergy sufferers who cannot tolerate cow's milk proteins.

In spite of the added nutritional qualities, only small quantities of sheep's milk are consumed as fluid milk. In Spain, for example, only 7.2% is consumed this way. This is certainly due to the fact that most of the sheep's milk is produced in countries where consumption of fluid milk has always been traditionally low. Moreover, with the high solids content of sheep's milk, it is more readily accepted for manufacturing of semi-solid or hard dairy products such as yogurt or cheese. In Great Britain, however, a large portion of the sheep's milk produced is consumed as fluid milk. The milk is pasteurized and stored in 1/2-liter carton containers (pint). The milk is then generally frozen and sold to health food stores.

Dried products

In spite of the high solids content of sheep's milk, there is report of its use in the area of dried or non-fat milk products. There appears to be a significant demand, at the current time, for dried sheep's milk to blend with cow's milk for specialty cheese production. Some concerns about these products revolve around the stability of the milk fat and shelf life.

Yogurts

The solids content of sheep's milk make it a natural for production of premium yogurt products similar to the Greek-style yogurts. With solids content of 16–18% in the milk, yogurts can be produced without the need of added solids or stabilizers. With the higher fat in the sheep yogurt, the potential harshness of the lactic acid may be lessened. Sheep yogurt also shows a greater cold storage stability as shown in table 7. Sheep yogurts needs to be marketed as a premium specialty product to avoid competing with commodity yogurts produced from cow's milk. Low fat yogurts can also be made after separation of the cream; the cream can be used for the manufacturing of butter.

Table 7. Cold storage stability of yogurts

	Separated serum (ml)	
Type	1 day	10 days
Cow	41	40
Sheep	6	7
Goat	23	15

Kehagias et al (1986)

Table 8. Characteristics of yogurts produced from ovine milk frozen and stored at -12˚C and -27˚C for 12 months.

Characterisics	Initial milk	Stored at -12˚C	Stored at -2˚C
Titratable acididty, %	1.25	0.90	1.18
Syneresis, %	75.1	79.7	77.5
Water holding capacity, %	28.5	25.7	30.4
Firmness, g	125	72	109

Wendorff and Rauschenberger (2001)

Famous sheep's milk cheeses produced in the world

White fresh cheeses

Burgos (Spain)
Villalon (Spain)
Cachat (France)
Perail (France)

Brined cheeses

Feta (Greece, Italy, France)
Teleme (Romania)
Sirene (Bulgaria)
Halloumi (Cyprus)

Hard and semi-hard cheeses

Pecorino Romano, Sardo, Siciliano, Toscano (Italy)
Kefalotyri (Greece)
Idiezabal (Spain)
Manchego (Spain)
Roncal (Spain)
Ossau-Iraty (France)

Blue-veined cheeses

Roquefort (France)
Cabrales (Spain)

Stretched curd cheeses

Kashkaval (Bulgaria/Romania/Macedonia)
Kaseri (Greece)

Whey cheeses

Ricotta (Italy)
Manouri (Greece)

Cheese

Traditionally, cheese production is the greatest market for sheep's milk throughout the world. With its high solids and smaller fat globules, sheep's milk is an outstanding substrate for manufacturing high quality cheese. Normally, 15% solids in milk are about the most efficient for obtaining maximum output per vat per day, while allowing for sufficient syneresis (exudation of liquid) of the curd for proper moisture control in the final cheese. Typical cheese yields for cow and goat milk are 9–10% while sheep's milk yields approximately 18–25% according to the type of cheese.

Cheese yields can be estimated according to the composition of the milk in fat and protein.

For the prediction of blue-veined cheese yield (Roquefort) Pelligrini (1995) uses the following equation:

Blue-veined cheese yield =

$$0.05 \text{ Fat(g/Kg)} + 0.32 \text{ Protein (g/kg)} + 1.81$$

For the prediction of hard or soft cheese yields Jaeggi et al. (2004) have shown that the Van Slyke formula can be reliably used:

Hard or soft cheese yield =

$$\frac{[(RF \times \%\ \text{Fat in milk}) + (RC \times \%\ \text{Casein in milk})] \times RS]}{(100 - \%\ \text{Moisture of cheese})}$$

Where:

RF = .84 for hard cheese and .82 for soft cheese

RS = 1.08 for hard cheese and 1.01 for soft cheese

RC = .96 for hard cheese and .96 for soft cheese

A method of milk payment could therefore be based on either formula according to the type of cheese made by the manufacturer. A method of payment based on cheese yield encourage production of milk with high fat and protein content.

Composition of whey

Ovine whey has a higher fat, protein and lactose content than caprine or bovine whey (tables 9 and 10). This is expected because sheep's milk contains higher fat, protein and ash than the other two species. Ovine whey contains more b-lactoglobulin (b-LG) and less serum albumin (SA) and immunoglobulins (IgG) as a percentage of total whey protein than bovine whey (table 9). There is as much a-Lactalbumin (a-LA) in ovine whey as in bovine whey but significantly less than in caprine whey. Whey protein composition varies during lactation. The proportion of a-LA decreases throughout lactation while SA proportion increases. Also, b-LG grows significantly during mid lactation and then falls back to concentrations that are similar to those in early lactation. Ovine whey protein concentrate (WPC) has a better foam overrun, foam stability and gel strength than bovine or caprine WPCs (Casper et al., 1999).

Conclusion

Sheep's milk is a unique product with high nutritional qualities containing more short chain fatty acids, more protein, more calcium and more vitamins than cow's milk. It is recognized by many as non-allergenic, which could open the door to a larger fluid milk market. It is an outstanding product for the manufacture of yogurts and cheeses, giving a cheese yield twice as high as cow's milk. The composition of the whey could allow for the manufacture of a vast array of products, improving the financial return of the cheese maker.

Table 9. Gross composition of caprine and ovine wheys from the manufacture of specialty cheeses and bovine whey from the manufacture of Cheddar cheese.

	Goat		OVINE	Bovine
Components	**Cheddar**	**Chèvre**	**MANCHEGO**	**Cheddar**
PH	6.2	4.6	6.3	ND[1]
	(% wt/wt)			
Total solids	6.61	6.40	7.46	6.7
Water	93.39	93.60	92.54	93.30
Fat	0.51	0.03	0.82	0.36
Ash	0.61	0.76	0.43	0.52
Lactose	4.71	5.07	5.16	4.50
Total protein	0.77	0.53	1.05	0.60

[1]Not determined

Casper et al., 1998

Table 10. Distribution of whey proteins in specialty cheese whey from caprine and ovine milk compared with that in Cheddar whey from bovine milk.

Whey protein	**Goat**		**OVINE**	**Bovine**
fraction	**Cheddar**	**Chèvre**	**MANCHEGO**	**Cheddar**
	(% of total protein)			
Serum albumin	4.0	3.8	4.1	6.5
IgG	9.7	6.4	7.3	13.0
β-LG	58.6	59.2	74.0	64.9
α-LA	27.0	31.7	14.8	15.6

Casper et al., 1999

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Chapter 2

Choosing a breed

Any breed of ewe can be milked with varying levels of success.

Two questions a potential sheep dairy producer should ask are: 1) What breeds can be milked? and 2) Can domestic American breeds be milked? The answer is that any breed of ewe can be milked—with varying levels of success.

The mechanism of milk ejection in a ewe suckled by her lamb and a ewe milked by machine is quite different (see chapter 7). Therefore, a ewe that apparently has enough milk to successfully raise 2 or 3 lambs might dry up very quickly as soon as her lambs are weaned and machine milking starts. The growth of her lamb during the first 30 days of lactation is not necessarily a sign of good milking ability when it comes to commercial milk production. A ewe's commercial milking ability should be determined during the machine-milking period only. Daily production, total number of days being milked by machine, percentage of fat and percentage of protein are the main factors to consider.

Domestic breeds

What breeds are available in the U.S. or might become available in the near future?

Beginning in 1984, several U.S. sheep breeds were evaluated at the University of Minnesota for their milk production potential. Ewes were chosen from available breeds and machine-milked twice a day following weaning of their lambs at 30 days of age. Ewes were subsequently milked for 120 days. Table 1 shows the performance of these breeds for milk production and milk composition over a two-year period. With the exception of the Finn and Romanov breeds, all other domestic breeds studied seem to have an identical potential for commercial milk production.

The average daily milk production of all ewes is .47 kg per day. With such low production one might wonder if it is economical to raise these breeds for milking. Early pioneers of sheep dairying in the U.S. were using popular breeds such as Polypay and Dorset in their first attempts at milking. These pioneers were soon looking for ways to improve average production. But even given low production, these breeds should not be disregarded all together. They offer certain advantages that the dairy-type breeds might not possess, such as good adap-

Table 1. Least-square means for several milk traits by breed (1989–1990). Milking period only.

Breed	Milk (liters)	Fat (%)	Protein (%)	Lactose (%)	Solids (%)
Overall mean	**57**	**6.6**	**5.8**	**4.7**	**17.9**
Suffolk	69	6.7	5.9	4.7	18.1
Finnsheep	44	6.1	5.5	4.5	16.7
Targhee	62	6.9	5.9	4.8	18.4
Dorset	61	6.3	5.7	4.5	17.2
Lincoln	53	6.8	5.8	4.7	18.0
Rambouillet	65	6.6	6.1	4.9	18.3
Romanov	44	7.1	5.9	4.8	18.6
Outaouais	54	7.3	6.1	4.6	18.7
Rideau	77	6.6	5.8	4.8	18.0

W.J.Boylan (1995)

tation to a wide array of environments, good lamb and/or wool production, ability to breed out of season (Polypay, Dorset), predictable behavior and wide availability at a reasonable price. If they are selected carefully, these breeds' overall production could increase dramatically.

Jordan and Boylan (1988) suggest that by selection and screening of the best milking ewes, overall milk production could increase by 30–40% in just a few years. Selection is a powerful tool since there is always a large variation (CV = 30%) between individual animals. In France, in 1969, the 800,000 Lacaune ewes on which 65% of the French sheep dairy industry is based were producing only 80 liters per lactation. After progeny testing more than 8500 rams since 1970, the Lacaune ranked as one of the best milking breeds with more than 250 liters per lacation by 1998.

Lower milk production may actually be quite acceptable in some segments of the industry. It is well known that a strong negative correlation exists between the total amount of milk and the percentage of fat. Generally the higher the production the less fat in the milk. To produce a very high quality sheep's milk cheese, the milk needs to be high in butterfat (6–8%). Domestic breeds producing a moderate amount of milk do have a higher butterfat content.

If the dollar value of the milk depends on its quality (the sum of fat and protein being the total useful dry matter) the discrepancy between a pure dairy breed such as the East Friesian and a domestic breed is much reduced in terms of overall return per ewe. To remedy this problem, French scientists included fat and protein in their selection index of the Lacaune breed as early as 1985, making the breed a high milk producer with high fat and protein content.

The East Friesian *(Ostfriesisches Milchschaf)*

This breed is now readily available in the United States. Many entrepreneurs in Canada or the U.S. sell live animals, embryos or semen of different origins (mainly from England, Holland and Sweden through New Zealand).

It might be of interest to report here on the breed's controversial beginnings as recorded by Flamant and Ricordeau (1969) in their excellent literature review on the East Friesian.

The breed has its origin in Germany along the North Sea coast. Some authors think that the East Friesian is the result of a cross between several Dutch breeds and a breed imported from the Gulf of Guinea in the early 17th century. The progenies of this crossbreeding formed the nucleus of this new breed, which was fixed fairly quickly since, as early as 1750, it was exported toward Lithuania. The traits then were already the same as those that make the breed famous today: prolificacy, milk production and wool production. Other authors, however, observed the very distinct similarities between the East Friesian and other breeds traditionally milked for family use before the expansion of dairy cows such as the Dutch Friesian, the Belgian Flammish and the Flander in

Table 2. Milk production of East Friesian ewes in Germany

Authors	Number of ewes	Total milk production (kg)	Lactation Length (days)	Fat (g/kg)	Total fat production (kg)
Spottel (1954)					
Milk recording 1929	59	639		63	40.6
Muhlberg (1934)					
Milk recording 1933	97	708	263	62	43.6
Leonhard (1954)					
Milk recording 1936	470	529			
Ulrich (1953)					
Milk recording 1938	829	489	249	61	
Spottel (1954)					
Milk recording 1942	544	471.5		64	
Ebbinghaus (1949)					
		450–550	200	60–90	27–40
Buitekamp (1952)					
Oriental Friesland 1951	287	556	245	62	34.6
Brauns (1953)					
Thuringe 1951	70	374	255	60	22.4
Schirwitz (1953)					
Saxonie 1953	507	393		64	25-27
Ver. Rhein. Schaf.					
Rhenanie 1958		582		64	37

Flamant and Ricordeau (1969)

France. According to the same authors the East Friesian would be the last representative of this type of animal.

Whatever its origin, the East Friesian is considered by many to be one of the best milking sheep in the world. Average production of 450–500 kg per lactation of 220–240 days and more has been recorded. **However, as Flamant and Ricordeau (1969) state, the total production includes the quantity of milk produced before the weaning of the lambs. This quantity is often estimated by multiplying the quantity of milk obtained at the first testing by the number of days between the first testing and parturition (see chapter 3). The production capability is therefore overestimated since the first testing often corresponds to the peak of lactation.**

Table 2 shows the milk production of East Friesian ewes in *Germany*. All data presented in the table are old (between 1920 and 1950) but are apparently the only reliable information available for that period. The lack of reliable and new data on the milk production of the East Friesian breed is understandable given the absence of a selection scheme and meaningful milk recording system since this time. Therefore, a certain degree of heterogeneity has to be expected in the breed.

Table 3 shows production data of a few East Friesian ewes in England. As one can see there might not have been much progress in milk production after the 19th century.

Although the East Friesian is one of the highest milk producing breeds, it has one of the poorest fat and protein contents (5.5–6.5% and 5% respectively). Moreover, the increment of the fat content during the lactation is very small (1–2%). The poor fat and protein content is very detrimental to the production of high quality sheep's milk cheese, which depends entirely on fat and protein for yield, flavor and texture.

Size and conformation

The East Friesian has a large frame. Adult females weigh between 70 and 90 kg and adult rams weigh up to 120 kg. The breed's legs are long and thin and it has narrow hips. Its head, legs and tail are devoid of wool and should be white with a pink, thin skin. The lack of wool on its tail gave the East Friesian the nickname "rat tail." All animals are generally polled; some scurs can be found.

The udder is generally large, presenting an important cistern capacity. There is a wide variation in udder morphology among individuals of the breed. Often teats are implanted high and on the side making the complete emptying of the udder by the machine difficult. Milkers often have to lift the bottom of the udder above the level of the teats either by hand or with a "Sagi hook." This results in slower milking that might be detrimental to the farm operation.

Wool

The fleece is white with a long staple (10–15 cm) and medium quality (52/54 on the Bradford's scale). Fleece weighs between 4–6 kg. Hand spinners generally appreciate this type of wool. Some colored (black or brown) East Friesian sheep can also be found.

Reproduction

A prolificacy rate of 230% has been reported, making this breed one of the most prolific. At the Spooner Agricultural Station (University of Wisconsin), Berger (1998) reports prolificacy of 200% on 12-month-old and 230% on adult crossbred ewes. With their high milk production and high prolificacy, the East Friesian breed is an efficient lamb producer. Although it has a rather poor carcass conformation, lambs produced from crossbreeding with a terminal breed such as Suffolk, Hampshire or Texel have a remarkable growth with all desirable carcass traits.

Table 3. Milk production of 15 East Friesian ewes in England

Age of ewes (in years)	Suckling and milking period (in days)	Total kg of milk for each period	Average fat percentage	Protein percentage
9	51+144=195	224+228=452	6.71	5.36
8	59+167=226	201+443=664	6.93	5.48
3	53+175=228	313+438=751	5.85	5.19
1	52+175=227	68+385=453	5.72	5.28
3	61+172=233	140+683=823	5.61	4.84
3	58+172=230	290+480=770	6.22	5.23
4	41+154=195	86+319=405	5.08	5.01
3	51+168=219	275+294=569	5.22	5.04
3	53+168=221	127+277=404	5.88	5.39
1	48+154=202	86+168=254	6.22	5.41
4	63+190=253	334+581=915	6.27	5.46
2	55+190=245	220+450=670	5.92	5.57
1	48+190=238	77+281=381	6.61	5.77
5	37+190=227	100+281=N381	6.32	5.21
2	52+187=239	192+292=484	6.41	5.36

Olivia Mills (1989)

Table 4. Arithmetic means for survival of lambs born alive by breed of sire and dam's percentage of East Friesian breeding at the Spooner Agricultural Research Station

Breed of sire	Dam's % EF breeding	Dam age, yr	Lambing dates	No. lambs born alive	Survival rate, % Birth to weaning	Weaning to 7/1/99	Birth to 7/1/99
EF	0	1-9	2/4-5/28	60	95.5	93.0	88.4
EF	>0 to <50	2-4	3/13-4/13	19	84.2	93.7	78.4
EF	= or >50	1-2	2/4-5/18	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	= or >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 of the flock				483	91.7	94.6	86.7
Percentage of dead lambs that died from pneumonia					45.9	91.3	63.3

Thomas et al. (1999)

According to Flamant and Ricordeau (1969) the East Friesian has a rather short breeding season starting 12 to 18 weeks after the longest day of the year. The best breeding period is between September and November. Ewe lambs are precocious enough to be bred successfully at 7–8 months of age.

Health

The East Friesian has a reputation for being fairly susceptible to pneumonia and having trouble adapting to new environments. Flamant and Ricordeau (1969) note that the importation of East Friesians in many countries has seldom resulted in a durable implantation of the breed in the country. This is particularly true in countries where the climate is radically different from the climate of the country of origin (Germany). Gootwine and Goot (1996), in their study of East Friesians in Israel, report a disappointing performance with a prolificacy of only 160% and a milk production of 160 liters. Milk production decreased with increasing age rather than increasing as in other breeds. Katsaounis and Zygoyiannis (1986) reported especially poor viability of East Friesian sheep in Greece.

Table 5. Least squares means for lamb survival by percentage of East Friesian breeding.

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)*

Thomas et al. (1999)

Boyazoglu et al. (1979) arrived at the same conclusion in Sardinia. In countries with climate rather similar to Germany (England for instance) it appears that the East Friesian is doing rather well. Olivia Mills (1989) reports that the harder it is kept, provided a good level of nutrition, the healthier it appears to be. However, this is only the author's opinion and scientific and accurate data are lacking.

Early results from the Spooner Agricultural Research Station (University of Wisconsin) seem to indicate that lambs with more than 50% East Friesian breeding may have reduced survival rates. Table 4 presents the survival rates of all lambs born alive in the station 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. The various groups also differ on the age of dams and lambing dates which may also affect lamb survival. However, given these limitations of the data, the data have been regrouped by expected proportion of East Friesian breeding in the lambs and presented in table 5.

In all lamb growth intervals, lambs with over 50% East Friesian breeding had lower survival rates than lambs with less East Friesian breeding. There was a tendency during the postweaning period for lambs of 50% East Friesian breeding to have lower survival rates than lambs of less than 50% East Friesian breeding.

Use in crossbreeding

The improvement in milk production obtained by crossbreeding with East Friesians is generally spectacular. Flamant and Ricordeau (1969) report that increases of 30–80% were observed on F1 issues of crossing local breeds with East Friesian rams. In most cases, however, it was not possible to determine the effect of heterosis in the superiority of F1 ewes, since pure East Friesian ewes were not present.

Results of the crossbreeding experiment between East Friesian and Dorset type ewes carried out at the Spooner Agricultural Research Station (University of Wisconsin–Madison) are reported in chapter 3.

Table 6. Summary of the evolution of the selection program of the Lacaune Lait.

	1970	1980	1990	1999
number of ewes in milk recording program (% of population)	45,129 (9%)	296,400 (49%)	558,500 (74%)	714,000 (90%)
numb er of ewes in AI program	31,100	93,700	294,000	322,300
number of rams progeny tested/year	40	332	453	450
Milk yield in nucleus* (liters)	115	155	245	270
Milk yield in base population* (liters)	110	125	200	220

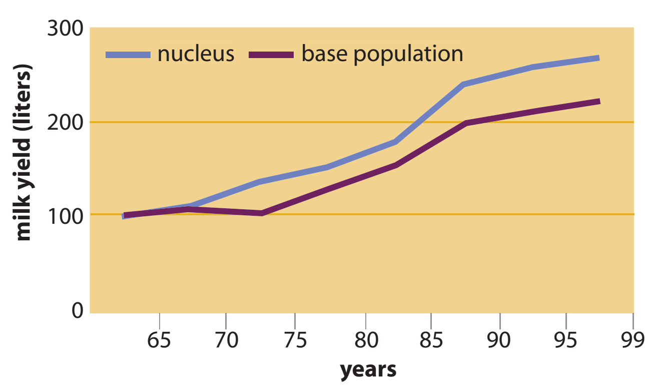
** milking period only* *Upra Lacaune (1999)*

The Lacaune

The Lacaune was introduced in the United States in 1998 by the Spooner Agricultural Research Station (University of Wisconsin–Madison) with the importation of two Lacaune rams from Canada and frozen semen from Great Britain.

The Lacaune is the most important sheep dairy breed in France with 800,000 ewes being milked mostly for the production of Roquefort cheese. It is important to note that before 1965 the Lacaune breed, although used traditionally as a milking animal, could not be considered a "dairy" animal. With the advance of milking techniques (the milking machine) and its expansion in the 1960s, as well as the high demand for sheep milk products, an intense selection program was started. With an improvement of 6.3% per year (annual phenotypic gain 3.9%, annual genetic gain 2.4%, Barillet, 1995), the milk production of the Lacaune breed increased from 80 liters to 270 liters in about 30 years (figure 1 and table 6). Contrary to East Friesian records, the numbers given for the Lacaune breed, always refer to the *milking period only* (165 days) excluding the suckling phase (Barillet et al., 2000)a. In 1985, fat and protein

Figure 1. Phenotypic evolution of the milk yield (milking period only) of the Lacaune



content was added to the selection program to enhance the cheese making properties of the milk. Since 2001 the selection scheme includes the resistance to sub-clinical mastitis and udder morphology.

Size and conformation

The Lacaune is a large-frame breed. Adult females weigh 70–75 kg and males around 95–100 kg. The carcass conformation of the dairy type Lacaune is average.

Wool

The Lacaune breed has very little wool. Its head, legs and a good portion of its belly are bare (see photo on p. 6). The fleece has a very short staple of medium quality and weighs no more than 1.5–2.5 kg. This lack of wool has an enormous advantage when it comes to milking. However, management of the Lacaune breed in areas of the U.S with cold winters needs to accommodate the scant wool cover.

Reproduction

The Lacaune adult has an average prolificacy of 170–180% (induced estrus) with a rather long breeding season starting early (June–July) making it an ideal breed for late fall or early winter lambing. Ewe lambs can be bred very successfully at the age of 7–8 months and have a prolificacy of 140% (Perret, 1986).

Health

Since 1992, the dairy Lacaune breed has been imported by 17different countries (Barillet et al, 2000)b for use either as purebred or in crossbreeding systems. Lack of adaptation or poor livability of adult animals or lambs have not been reported. As shown in table 4, 50% of Lacaune lambs born in 1999 at the Spooner Research Station have a good survival rate (95%). No major health problem was recorded by the original importer of the Lacaune breed in North America, a dairy sheep producer in Ontario, Canada (Regli, 1999).

Use in crossbreeding

Very little information is available on the milking ability of Lacaune crossbred ewes. Barillet (personal communication, 2000) indicates that early results seem to show a higher milk production in Sarda x Lacaune crossbred ewes than in Sarda purebred ewes while maintaining a high level of butterfat. Apparently the Lacaune could be successfully used to increase milk production of domestic breeds. The Spooner Research Station recently began a comparison between East Friesian x Dorset (or Polypay) and Lacaune x Dorset (or Polypay).

It is important to note that there are three types of Lacaune in France. One has been selected solely on its milking performance (Lacaune lait), one type on growth and conformation (Lacaune viande) and one because it possesses a major gene for prolificacy. Producers wishing to introduce the Lacaune on their farms should be aware of the difference among the three types. The meat type Lacaune (Lacaune viande or prolific Lacaune) does not possess any dairy characteristics.

The Assaf

The Assaf is a synthetic breed formed in Israel in the '60s and '70s, composed of 5/8 Awassi and 3/8 East Friesian. The Assaf became very popular in Israel mostly because of an increase in lamb production due to the higher prolificacy of the East Friesian. It was already an excellent milker. The Assaf breed has been exported to several countries such as Portugal and Spain where it can be found in large numbers.

The British Milksheep

The British Milksheep is a medium-large polled sheep with a predominantly white face and legs. It was developed in the UK using the East Friesian as one of the breed components to fill the demand for a high performance crossing sire and for a high yield dairy ewe. The British Milksheep is highly prolific (200% in ewe lambs to 300% in adult ewes). It can achieve an average milk yield of 450 liters in a 7-month lactation with a particularly high solid content (National Sheep Association, 1992). No real data concerning the milk production of the breed could be found. The traits do not appear to be definitively fixed and the percentage of East Friesian blood could be variable.

Some British Milksheep animals are already present in Canada.

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Chapter 3

Improving lactation through genetics

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Selection in a purebred system or creation of a synthetic breed requires a long time and a complex organization.

Producers have four options to improve the milking ability of ewes:

(1) selecting a domestic breed to be maintained in a purebred system;

(2) using an F1 crossbreeding system with an improving breed;

(3) creating a synthetic line after determining which breed combination results in the most efficient production system; and

(4) upgrading a local breed to a dairy breed by systematic mating of all female progenies with a purebred ram of the improved breed.

Each option has its advantages and pitfalls, and the choice is not easy. Barillet (1995), one of the leading dairy sheep geneticists, explains that if no more than 50% germplasm of the improved breed is desirable: "…improvement of native sheep population through reliance on improved breeds appears in most cases to be too difficult to manage (option 2: F1 crossbreeding system). Breeding strategies involve either the creation of synthetic lines through crossbreeding of local and imported productive breeds to avoid having more than 50% of the genes coming form the imported breed (option 3), or through dairy selection of local breeds in their native area of production (option 1). The balance between cost/time and specific situations must therefore be taken into account for any final decision. In practice the genetic and economic comparisons carried out in the 1970s in Western Europe concluded most often that it was wiser to rely on implementing the dairy selection of the local breeds in their specific area and condition of production."

Without denying its accuracy, this statement should be examined in the context of the North American sheep production system. Selection in a purebred system or creation of a synthetic breed requires a long time and a complex organization that might not yet exist in North America's burgeoning dairy sheep industry.

Genetic traits to consider

The main trait to consider for improvement of dairy ewes is **milk yield.** With a moderately high heritability (0.30) it is quite possible to significantly increase the milk production of a breed. With an optimum selection program, a genetic gain of 2.4% annually can be expected (Barillet, 1995).

The fat and protein composition of milk determine its manufacturing qualities. Since the vast majority of sheep's milk is made into cheese and a lesser amount into yogurt and ice cream, milk composition is economically important to sheep milk processors. Fat and protein composition have a heritability as high (or higher) as milk yield (table 1). Therefore, progress from selection can be expected in these traits.

Selection for high fat and protein content may become an issue in the very near future because both traits correlate negatively with milk yield. Barillet (1995) reports a negative genetic correlation of -0.40 for protein content and of -0.30 for fat content (figure 1). As milk yield improves through genetic selection (or crossbreeding with a high producing breed such as the East Friesian), the fat and protein content of the milk is expected to decrease, making it less desirable for cheese manufacturing. Therefore, it appears essential that fat and protein be included in a selection program as soon as possible but not before tangible gains are obtained on milk yield because the genetic gains are small during the starting period (figure 2).

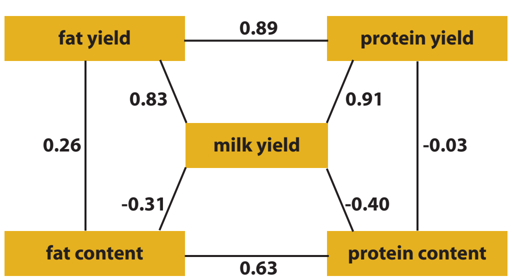
Although milk yield, fat and protein percentages are the main traits to consider at the start of a breeding program, other economic traits are now becoming more and more important and should not be ignored. These traits range from feed efficiency and milkability to udder health and genetic resistance to diseases.

Table 1. Heritabilities of milk traits in Lacaune first lactation

Traits	h^2 estimated from 3-4 test days	h^2 estimated from all lactation
Milk yield	0.30	0.32
Fat percentage	0.35	0.62
Protein percentage	0.46	0.53
Fat yield	0.28	0.29
Protein yield	0.29	0.27

Barillet et al. (2000)

Figure 1. Genetic correlations of milk traits in Lacaune first lactation

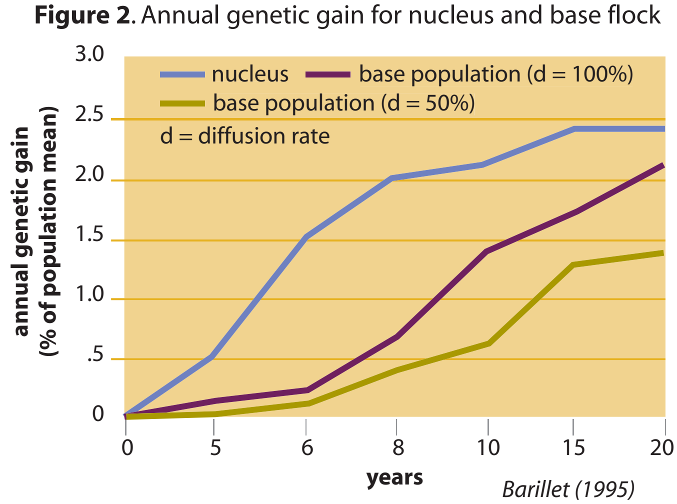


Barillet et al. (2000)

Feed efficiency

The effect of selection for high milk production on feed efficiency has been studied by Marie et al. (1996) in the Lacaune breed. **In a management system in which there was no individual feeding according to the level of production, the authors found that animals selected for high milk production tended to have better feed efficiency because more of their body reserves went toward milk production.** The authors conclude that it is therefore not necessary to include feed efficiency in the selection program but that feed effi-

Figure 2. Annual genetic gain for nucleus and base flock



Barillet (1995)

ciency should be monitored to avoid any possible genetic drift. For the last few years, because of better feed efficiency resulting from selection based on milk production, Lacaune dairy farmers have been able to reduce drastically the amount of expensive concentrates in the ration of their ewes without affecting the milk yield, although forages (hay) are given freely.

Milkability

An identical favorable indirect response on milkability has been found in the Lacaune when selection for high milk production is combined with simplified machine milking techniques (suppression of machine and hand stripping). Ewes were indirectly selected for better milk flow, and lower stripping yield (Marie et al., 1998). However, de la Fuente et al. (1999) observed a degradation of the overall udder conformation with an increase of cistern height. The teats also tended to be in a more horizontal position, leading, in the long term, to more difficult milking routines (falling off of clusters). It seems that a selection on udder morphology based on udder scores developed by de La Fuente (chapter 6) should accompany a selection on milk traits, but not before obtaining tangible improvement on milk yield.

Genetic resistance to disease

Mastitis. Somatic Cell Count in milk has been established as a good indicator of udder health. A high somatic cell count indicates some sort of mastitis (clinical or sub-clinical). A high somatic cell count not only decreases overall milk production; it also influences the quality of the milk and can have some negative effects on human health. The United States and Canada have put a maximum limit on the number of somatic cells sheep's milk can contain and many cheese processors have included a penalty in the payment of milk with high somatic cell count. Heritability of somatic cell count of 0.10 to 0.18 has been estimated (Barillet et al., 1999) and indicates that selecting against sub-clinical mastitis is possible and desirable.

Scrapie. Scrapie is an infectious disease of sheep that attacks the central nervous system and is always fatal. It is one of a number of transmissible encephalopathies found in various animal species including humans. Upon necropsy, infected sheep show holes or vacuoles in the brain tissue. Scrapie has a very long incubation time—several months to a few years—so the disease is seldom seen in animals under 1 1/2 years of age.

While the disease affects relatively few sheep, scrapie is of major concern to federal animal health officials because feed ingredients made from scrapie-infected sheep in the United Kingdom may have been the initial cause of BSE (mad cow disease) in cattle in that country. Consumption of meat from BSE-infected cattle has been implicated as a cause of a new encephalopathy in humans in western Europe. The presence of scrapie in the North American sheep population also limits the opportunities for breeding sheep exports to many countries.

Studies in Europe and North America indicate that certain alleles at the prion protein locus have an effect on an animal's susceptibility to scrapie. Differences in amino acids of the prion protein in at least two positions, or codons, appear to affect susceptibility to scrapie strain A and strain C. At the 136 codon, two amino acids have been identified in sheep populations: alanine decreases susceptibility and valine increases susceptibility to scrapie strain A. At the 171 codon, the amino acid arginine is associated with decreased susceptibility, and the amino acid glutamine is associated with increased susceptibility to scrapie strain C. Table 2 summarizes these results.

Table 2. Genetics of scrapie susceptibility

Prion protein composition	Genotype	—Scrapie susceptibility— Strain A	Strain C
Codon 136:			
alanine (A)/alanine (A)	AA	Low susceptibility	No effect
alanine (A)/valine (V)	AV	High susceptibility	No effect
valine (V)/valine (V)	VV	High susceptibility	No effect
Codon 171:			
arginine (R)/arginine (R)	RR	No effect	Low susceptibility
arginine (R)/glutamine (Q)	QR	No effect	Low susceptibility
glutamine (Q)/glutamine (Q)	QQ	No effect	High susceptibility

If strain A is the prevalent form of scrapie, sheep of genotype AA at codon 136 of the prion protein should be selected, but if strain C is the prevalent form, sheep of genotype RR at codon 171 should be selected. Sheep with genotypes AA,RR or AA,QR should have a low susceptibility to both strain A and C. Strain C scrapie is the major strain in the U.S. because all recent scrapie-positive sheep tested for codon 136 and 171 genotype have been of genotype QQ at codon 171 and either AA or AV at codon 136.

National or regional programs to increase the genetic resistance to scrapie through prion protein genotyping and selection of resistance genotypes are underway in several sheep breeds in several European countries including the Manech dairy breed of the Pyrenees Region of France (Smits et al. 2000). Many breeders of blackfaced meat breeds (e.g. Suffolk, Hampshire) in the U.S. are DNA testing and selecting sheep for resistant genotypes, but there is currently no active effort to genotype dairy sheep flocks.

Internal parasites. Ruvuna and Taylor (1994) reviewed the genetics of parasite resistance. Internal parasites have a major effect on the efficiency of sheep production. The major economic costs associated with internal parasitism are loss of production, veterinary and drug (anthelmintic) costs and ultimately, the death of infected animals. In the U.S. alone, losses in sheep and goat production due to internal parasites were estimated at $45 million annually. Control of internal parasites can be an important problem for dairy sheep producers because there are no anthelmintics approved for ewes during the commercial milking period. Parasite eggs in sheep feces (EPG = eggs per gram of feces) is accepted as an accurate indicator of the number of internal parasites. Heritability of EPG is moderate to high (25–40%) so selective breeding for low EPG is expected to increase resistance. Selection studies have verified this expectation with a reported decrease in EPG of 3.5–5.0% per year.

While selection for parasite resistance through selection for low EPG is possible, such a selection program has not been undertaken on a commercial basis. To obtain maximum response from within-flock selection, all potential breeding animals must have individual feces samples collected and assessed for EPG. The labor involved in feces collections and laboratory analyses are expensive.

A more attractive selection strategy is to select a group of ram lambs for your own use or for sale to others based on high genetic value for lactation traits. Determine EPG on this select group, and use or sell only ram lambs with the lowest EPG.

Selecting a North American breed for dairy ability

Selection of a local breed for dairy ability clearly offers many advantages:

- The breed chosen is generally well adapted to its environment.
- Animals are widely available and affordable.
- The improvement obtained is generally permanent.
- The improvement benefits many producers.
- The traits to be improved have moderate to high heritabilities (as shown in table 1).

The development of the Lacaune breed into a dairy breed is a true success story. In the late 60s the Lacaune, although traditionally used for milking, was producing only 70 to 80 liters of milk. By the late 90s, it was one of the best dairy sheep in the world, producing more than 270 liters in 165 days **(milking period only).** The introduction of fat and protein content in the index of selection elevated the useful milk component.

The selection scheme used on the breed is being adapted for other breeds (Manech in France, Latxa in Spain, Sarda in Italy) with varying levels of success. Several factors, listed below, have contributed to the success of the Lacaune program. They include:

- The existence of a large population of Lacaune. In 1970 there were 5,661 producers milking more than 500,000 ewes.
- The willingness of most producers to increase the average milk production of each ewe.
- The support of all sheep milk processors organized into a coherent industry.
- A coherent and rigorous selection program developed and supported by INRA (National Institute for Agronomic Research).
- A vast array of support for the recording of performance, data analysis and progeny testing.
- The development of artificial insemination centers, estrus synchronization, collection of fresh semen on more than 450 rams, and systematic artificial insemination of about 400,000 ewes (UPRA-Lacaune, 1999) for the rapid diffusion of genetic gain.
- The development of technical support for the producers on forage production, nutrition, management and equipment.

The combination of factors allowed for an improvement of 6.3% per year consisting of a phenotypic gain of 3.9% (management, nutrition) and a genetic gain of 2.4%. Since 1995 the phenotypic gain has been negligible (Barillet, 1997).

Obviously none of these favorable factors are present in the small dairy sheep industry of North America. Producers interested in developing a local breed into a dairy breed would have to rely on systems requiring fewer resources such as a **Sire Referencing Scheme (with AI)** or Ram circle (without AI). In countries without requirements for ram registration, cooperative nucleus schemes and/or sire referencing schemes seem likely to become the basis of wide-scale breed improvement programs (Banks, 1997).

Sire referencing scheme

An individual flock owner working independently faces severe limitations. Individual flocks are often small, making it difficult to get good genetic comparison between animals—and the choice of animals is often restricted. Typically, single flock owners practice selection at a very low level with limited accuracy. This is especially true with rams, which are selected from the "best" ewes without adjusting for non-genetics effects. The accuracy of estimated genetic merit of a ram from the production of his mother is only $\sqrt{1/4\,h2} = 0.28$ (if $h2 = 0.32$). The producer might be forced to select an animal that is not quite what was expected. The other alternative would be to turn to another producer with the uncertainty of the genetic merit of the supplying flock. The solution to these problems lies in producers with similar goals working together.

In a selection program, only producers working together toward the same objectives will achieve tangible genetic gain.

Sire referencing uses a team of common sires over a group of flocks in order to create genetic links between member flocks. With genetic links between flocks it becomes possible to compare animals between flocks regardless of the different environment, management, nutrition or other non-genetic effects. EPDs (Expected Progeny Differences) can be calculated. An EPD calculation has a prospective ewe or ram replacement would use the milk yields (or any other trait) of the individual's dam, maternal grand-dam, paternal grand-dam, full-sisters, half-sisters and any other female relatives with milk production records. Rams with the highest EPD become reference rams and are used on a certain percentage of ewes (generally the ones with the highest EPDs) of each member flock either with natural mating or, better yet, with artificial insemination. The conditions of use of the rams and reward to producers (payment, time of use, cost etc…) need to be sorted out by the group of producers.

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

The Sire Reference Scheme is not a new concept since most selection schemes use similar principles of nucleus and diffusion throughout the base population. New Zealand, however, pioneered the method of ram circles working with smaller population and achieved good results on meat and wool breeds. Some similar breeding programs are being developed in other countries (Spain for example) on commercial dairy sheep operations.

Any type of selection program is a long term operation and spectacular improvement cannot be expected in just a few years. It might take as long as 10 years to observe genetic gains although phenotypic gains will occur as soon as 5 years.

Organization of a sire referencing scheme

The organization of a Sire Referencing Scheme should include include the following steps:

1. Formation of a group of producers with similar goals. Ten producers with 200 ewes each would be a good starting number. Taking advantage of groups already existing such as marketing cooperatives would be desirable.
2. Definition of the selection criteria. Establishment of standardized methods of performance recording (milk testing and pedigree recording).
3. Calculation of intra flock EPDs (or calculation of milk production adjusted for age) for the determination of the best 30 ewes of each flock (10%–20 % of the total flock). The best 30 ewes of each flock

form a nucleus of selection, which is kept fragmented rather than being kept together on one farm only. Generally the best ram lambs will come from this nucleus. Ewes of the nucleus are replaced with the best EPDs ewes.

4. Determination of 3 to 4 initial rams to use the first year to create genetic links between flocks.
5. Collection of semen and insemination with fresh or frozen semen of the best 30 ewes of each flock (see figure 1). The rest of the ewes in each flock are bred with rams of the producer's choice.
6. Calculation of EPDs on the first lactation of progenies.
7. Selection of 3–4 ram lambs with best EPDs.
8. Collection of semen of those rams and insemination of the best 30 ewes of each flock. The rest of the ewes are bred with rams of the producer's choice, generally rams with second best EPDs from his own flock or purchased from any member of the group.

Improvement is rather slow during the first 3–4 years because of the different phases essential for the set up, but the speed of improvement increases rapidly.

Improvement through crossbreeding

There is no doubt that by using high milk producing breeds such as the East Friesian or perhaps the Lacaune, spectacular improvement can be achieved very quickly. An average milk yield of 160–180 liters per ewe can be obtained in just 3–4 years after starting with an original flock of Dorset type ewes as observed at the Spooner Agricultural Research Station.

Milk production of 1-, 2- and 3-year-old ewes (corresponding to their number of lactation) is shown in table 3. East Friesian cross ewes have a lactation length 30–40 days longer than Dorset type ewes and produced more than twice as much milk. Fat and protein percentage of milk from Dorset type ewes is approximately 0.5 percentage units higher compared to milk from EF-cross ewes. No difference can be found between milk production, fat and protein percentages between ewes of different EF percentage. Fifty percent EF ewes do not produce more milk than 25% EF ewes. Higher milk production of crossbred ewes with up to 50% EF breeding compared to local ewes has been reported by Ricordeau and Flamant (1969b), Kalaissakis et al. (1977), Katsaounis and Zygoyiannis (1986), Newman and Stieffel (1999). However, ewes with greater than 50% EF breeding have been reported to produce both less (Kalaissakis et al., 1977) and more (Ricordeau and Flamant, 1969b) milk than local breeds. Gootwine and Goot (1996) found that pure EF and EF-cross ewes were either

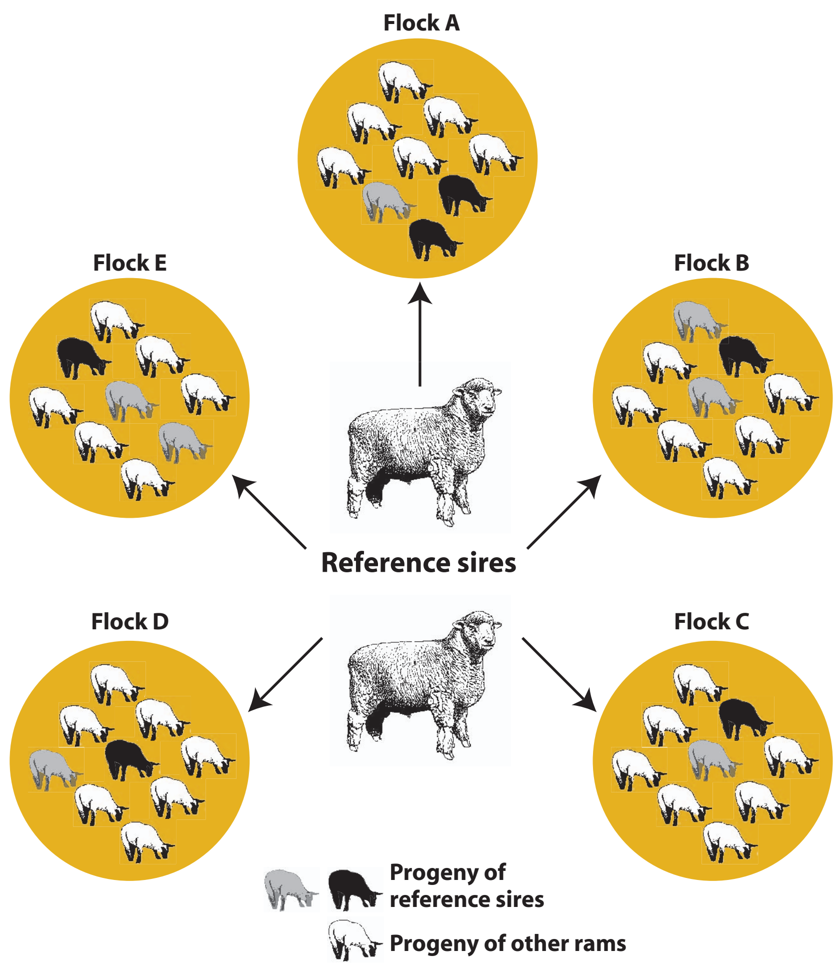


Figure 3. Sire referencing scheme

inferior or similar to the improved Awassi ewes (one of the best milking breeds in the Middle East) for milk yield. The poor lactation performance of ewes of high percentage EF breeding in these Mediterranean environments is thought to be due to poor adaptability of the breed to high temperatures (Boyazoglu, 1991).

In North America, the level of EF breeding, however, still needs to be determined but it seems rather certain that a high level of EF is not necessary to achieve correct level of production. A high level of EF might result in lower productivity due to a lower degree of adaptability to a new environment, and to a higher incidence of health problems (See Chapter 2, Choosing a breed).

The management of a first generation (F1) crossbreeding system is theoretically simple but difficult to sustain in a long term. Very few examples of successful long term systems exist.

Management of an F1 crossbreeding system

The management of a crossbreeding system in which the desired animal should not have more than 50% breeding of the improved breed is rather straight forward and much simplified if the producer can purchase F1 replacement ewes. Starting with a group of unimproved ewes (Dorset for example) the producer would breed these ewes with a purebred dairy breed ram. All females born are kept and put at milking as soon as possible. The following year the same system is used, mating only a certain number of unimproved ewes to provide enough F1 replacement ewes for the dairy flock. The producer who cannot purchase F1 replacement ewes must keep a sufficient number of unimproved ewes to provide replacement F1 ewes and replacement unimproved ewes. F1 ewes should be mated to a terminal sire breed (Suffolk, Hampshire, Texel) for the production of slaughter lambs.

The management of F1 ewes has the great advantage of providing hybrid vigor to the ewes and to their lambs born from a terminal sire breed. However, although the milk production of these ewes would be at a correct level, there is very little possibility of improvement since the dairy traits will come only from the sire breed on which no selection pressure is applied for the time being in North America. Dairy type rams used for the production of F1 ewes would need to come from a proven selection program. Moreover, not all ewe lambs put at milking will prove suitable for high milk production. A producer can expect to eliminate about 20% of the ewes put at milking the first year, forcing him to produce or purchase more ewe lambs than necessary.

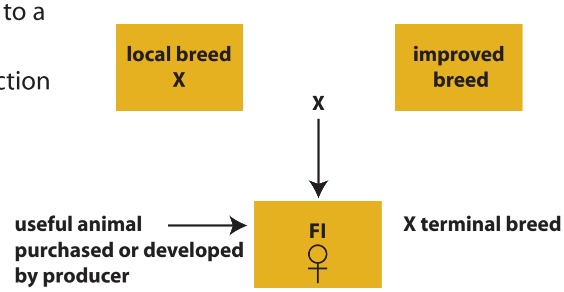


Table 3. Milk production of Dorset-cross and EF-cross ewes.

Breed	age	Number of ewes	Milking only length (days)	Total milk (kg)	% Fat	% Protein
Dorset-cross	1	73	79 ± 5	62 ± 9	5.9 ± .6	5.3 ± .05
	2	43	94 ± 7	91 ± 12	5.5 ± .7	5.8 ± .10
1/4 EF-cross	1	124	112 ± 4	139 ± 7	5.5. ± .4	5.1 ± .04
	2	92	152 ± 5	206 ± 8	5.1 ± .5	5.4 ± .04
	3	35	173 ± 7	246 ± 13	5.3 ± .7	5.1 ± .07
3/8 EF-cross	1	69	101 ± 5	122 ± 9	5.3 ± .5	5.1 ± .05
	2	40	146 ± 7	190 ± 11	5.0 ± .7	5.3 ± .07
	3	13	160 ± 12	250 ± 21	5.1 ± .5	5.2 ± .10
1/2 EF-cross	1	71	99 ± 5	128 ± 9	5.1 ± .5	4.9 ± .04
	2	16	145 ± 11	187 ± 18	5.0 ± 1.1	5.4 ± .10
	3	12	178 ± 12	250 ± 22	5.0 ± 1.3	5.1 ± .10

Berger, 1996, 1997, 1998

Creating a synthetic breed

The lack of possible selection (that is, improvement of one or several traits) as well as the constraint for producers to keep breeds of several genotypes on the farm, or to purchase replacement ewe lambs leads to the creation of synthetic lines.

A synthetic breed is the combination of several breeds (at least 2) obtained by successive cross matings and for which traits have been fixed over several generations. An example of a successful composite breed in the United States is the Polypay. In Canada the Arcott Rideau became a popular all-purpose breed. Israel created the Assaf from the Awassi and the East Friesian ($^3/_8$ EF) and France developed the FSL (Friesian x Sarda x Lacaune) which, although promising, was not diffused. Producers chose to select the Lacaune for milking performance rather than adapt to a breed with which they were unfamiliar.

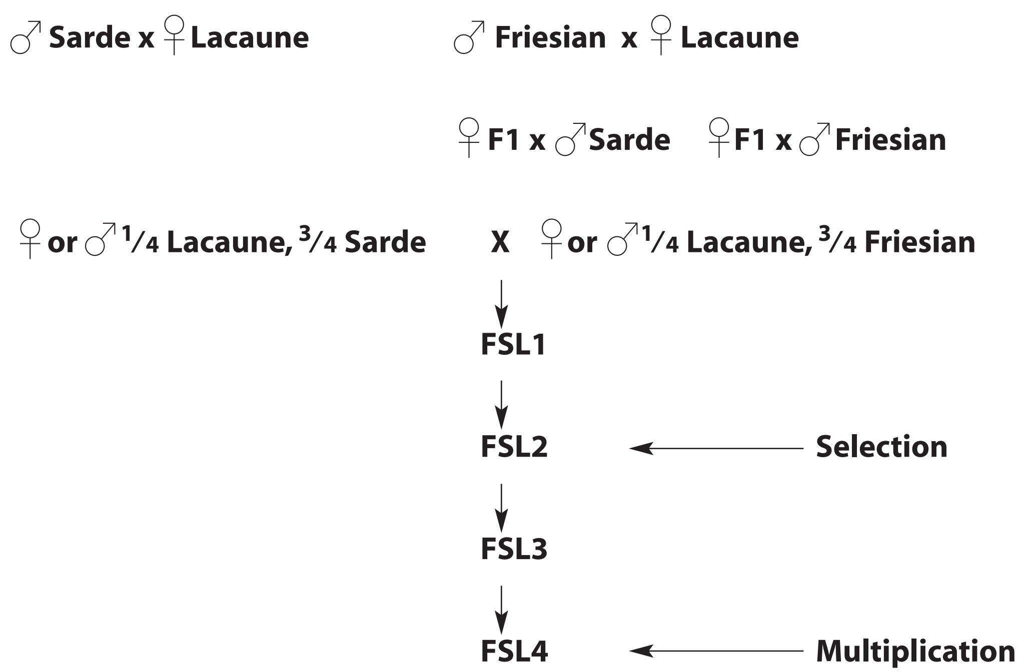
Composite or synthetic breeds are generally created to respond to the demands of producers facing new market strategies. Many breeds are created but very few are widely accepted. The creation of a synthetic breed is generally carried out (but not always) on research stations. The process requires the breeder to:

1. Choose the initial breeds and determine which traits are interesting in each.
2. Evaluate the initial crossbred animals on their performance and general overall adaptation.
3. Determine the optimum breeding percentage of each breed that the final breed should possess.
4. Multiply this optimum cross and start an intense selection on the chosen traits. A minimum of 4 generations are generally necessary for the traits to become fixed so that the cross animal can be called a "breed."
5. Multiply the final animal to have a sustainable population.

Considering 5 years of initial study, 2.5 years per generation and 10 more years for the reproduction of animals to a sustainable population, the total number of years to develop a new breed is roughly 20. This corresponds to the number of years it took to develop the Lacaune into a dairy breed with an optimum selection program.

It takes as long to create a new breed as to select a breed for a considered trait. The advantage of a synthetic breed resides in the combination of the most favorable traits of all the breeds involved in its creation.

The example of the FSL (Friesian, Sarda, Lacaune) helps show how a new breed is created. The Friesian was chosen for its milk yield, which at the time (1965) was far superior to the Lacaune. The Sarda was chosen for its superior milkability (rapid let down of milk at milking time). Finally the Lacaune was included because of being the traditional breed used by the local dairy producers and for its excellent adaptation to its environment. The following diagram shows the successive crosses necessary before being ready for diffusion.



Upgrading a local breed with an improved dairy breed

The principle and management of an upgrading system are simple and very attractive to many producers. The process involves crossing domestic ewes with rams (or semen) of improved dairy breeds. Crossing with the dairy breed continues until ewes make up a very high percentage of the introduced dairy breed, virtually indistinguishable from pure individuals of the introduced dairy breeds.

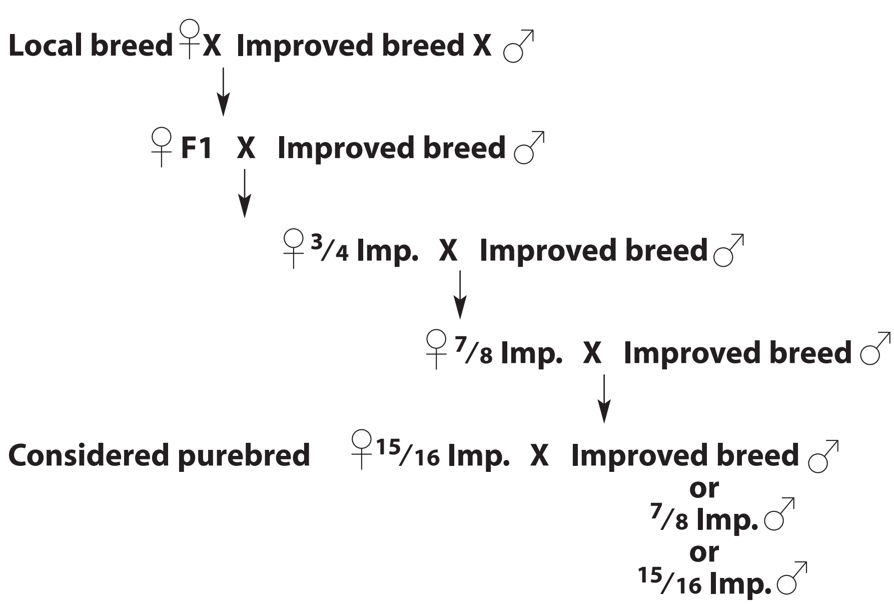
The advantages of such a system are numerous:

- Any base population can be used.
- Improvement in dairy traits are obtained as soon as the first generation (F1) is born.
- Improvement continues over the years.
- The new breed acquires all the traits of the improved dairy breed in a few years.
- Management is relatively simple.

However, there are also some very serious considerations:

- New rams from different lines are necessary on a regular basis to avoid inbreeding. Rams should be chosen from a reliable source, and selected for milk production or any other desirable traits. The number of new rams can be limited if the upgrading program is accompanied by a Sire Referencing Scheme which promotes the use of the same rams in different production units.
- Determine with absolute certainty that the improved breed can adapt to a new environment. Chapter 2 explained that the East Friesian breed has serious adaptation problems to some environments and that many countries have abandoned or limited its use to no more than 50% breeding in their improvement program as a result. The Lacaune is being evaluated at the Spooner Agricultural Research Station, which is characterized by hot summers and extremely low winter temperatures. The little wool cover of the breed could be a concern in the typical sheep management system of the region but might be an advantage in other parts of the country. Another breed such as the Awassi (Middle East) is a fat-tail animal, which, as F1 (50%) would be accepted by producers and by the industry, but would have an adaptability problem when managed as purebred.

Whatever system a producer or a group of producers uses, no genetic improvement or determination of the best milking animals can be conducted without recording pedigree and the performance of individual animals.



Milk recording

All parties involved must use the same language to have a reliable comparison of animals. These common terms are defined in the following section.

Definition of milk traits

- The **suckling length** corresponds to the lambs' suckling period or the simultaneous suckling and milking period. *If the lambs suckle only during the colostral phase, the suckling length is considered to be zero.* If there is an initial suckling phase, milk yield during this period is equal either to the milk suckled if suckling only, or to the milk suckled plus that milked (should there be partial milking during the suckling period).
- The **milking-only length** corresponds to the period during which the ewe is milked after the lamb(s) has (have) been weaned until drying off.
- The **lactation length** is equal to the sum of the suckling length plus milking-only length: it is also the difference in days between the date of lambing and the date of drying off.
- The **total milk yield per lactation** is the sum of the milk yield of the suckling period (milk suckled, or milk suckled plus that milked) plus the milk yield during the milking-only period. Only the milk yield during exclusive milking can be measured simply and accurately as part of milk recording on farms.

If the suckling period is not of zero length, the milk yield in dairy sheep takes into account only the exclusive milking and the length of the milking-only period (which starts when the lambs are fully weaned and finishes when the ewe dries off).

Milk recording methods

In 1992, the International Committee for Animal Recording published guidelines for milk recording of sheep. The first test day for the flock takes place 4–15 days after the start of milking for that year or season. Subsequent test days should take place at 28- to 34-day intervals until all ewes are dried off. Three basic choices are given for recording milk.

1. **Method A4.** This is the method of reference. On each test day, milk yield is recorded at both milkings (a.m. and p.m.) and combined to determine daily yield. This method is the most time consuming and the most expensive.
2. **Method AC**. Individual milk yield is recorded at one milking only (either a.m. or p.m.), and total flock yield is determined by the quantity of milk in the tank after the 2 milkings. The total milk yield of the flock is divided by the sum of the individual yields. The resulting factor is used to determine the individual daily milk yield for the day of the control. This procedure eliminates the need to individually record ewes twice at each test day. Expenses and time are therefore reduced. However, the milk in the tank must come only from ewes that were tested.
3. **Method AT.** This method is also called the alternative method. Tests are performed at one milking only. On any given test day, ewes are recorded at the a.m. milking. On the next test day ewes are recorded on the p.m. milking. At each test the recorded figure is multiplied by 2 in order to obtain the total daily milk yield. The method is simple and accurate at the condition that the alternation is respected. This method avoids difficult calculations.

Any method is acceptable but cannot be changed in the middle of lactation. The producer has to decide which method to use before the milking season starts.

Milk samples should be taken from each ewe, and analyzed for fat and protein content, and for SCC, at least three times during the milking period. The precision of milk yield estimates between the A4 and AC as well as the precision of milk quality between samples taken at each test day and only 3 times during the lactation is shown in table 4.

Milk yield can be recorded by weight or volume, although volume is preferred. Since the rest of the sheep dairy world uses metric measurements, it is good to use the weight measures of grams or kilograms or the volume measures of milliliters or liters. The volume to weight conversion for normal sheep's milk is: 1 liter = 1.036 kilograms, or 1 liter = 2.28 pounds, or 1 gallon (U.S.) = 8.64 pounds.

Individual milk production per milking only period can be estimated using the following formula (Fleischmann method):

Estimated milk yield =

[production 1st test day x no. days between start of milking and 1st test day]

+ [(production 1st test day + prod. 2nd test day)/2 x no. days between 1st and 2nd test day]

+ [(production 2nd test day + production 3rd test day)/2 x no. days between 2nd and 3rd test day]

+ ….

+ [(production next to last test day + production last test day)/2 x no. days between next to last and last test day]

+ [production last test day x no. days between last test day and end of milking]

Milk recording is best performed by professional organizations such as DHIA. For a minimal fee DHIA in the United States will perform milk recording and milk sampling of dairy sheep using its staff, equipment and laboratories to analyze the milk. DHIA will also calculate the total milk production of each individual ewe.

It is strongly recommended that dairy sheep producers use a specialized organization such as DHIA for the milk recording of their ewes.

Milk recording and milk sampling at La Fage Research Station (INRA), France

Table 4. Precision of estimating milk yield with AC testing and milk quality with part-lactation samplings.

	——————Comparison with A4 testing————		
Trait	**Loss of precision**	**Heritability**	**Genetic correlation**
Milk yield	1-2%	0.25 similar	0.99
Fat yield	3-5%	0.25 similar	0.99
Protein yield	2-3%	0.25 similar	0.99
Fat content	15-20%	0.35-0.40 decreasing	0.96
Protein content	10-15%	0.40-0.45 decreasing	0.98

Barillet (1991)

Electronic test jar

Adjustment factors

If BLUP analysis (EPD calculation) cannot be done (for example, if producers do not belong to a genetic improvement program) an animal's total production should be adjusted with a correction factor for age. It is also well known that the total commercial milk production is affected by the type of lamb management (see chapter 10). The correction factors for lamb management are shown in table 6. Therefore, estimated yields should be adjusted for this non-genetic effect so ewes of different ages can be fairly compared inside the same flock where environmental factors are the same. Estimated lactation yields should be multiplied by the appropriate adjustment factor shown in table 5 to adjust estimated milk yield to that expected from a 4- to 7-year-old ewe.

The age of ewe adjustment factors in table 5 are based on a limited amount of European data and may be different for U.S. breeds of sheep and under U.S. production conditions. More refined adjustment factors will be developed as U.S. milk production data become available. In the interim, use of these adjustment factors is preferable over not using any age of ewe adjustment factors.

Other information to record

Milk recording is a valuable improvement tool only if calculations of milk yield are performed accurately and attributed to an individual animal. Therefore the following information is needed:

- Identification of the animal. Each animal should be identified permanently either by tattoo or by a double ear tag. Electronic ear tags should be strongly considered especially if the flock is enrolled in a scrapie eradication program.
- Date of lambing.
- System of weaning (at milking after lambing, milking after 30 days of suckling…).
- Date of weaning or date of first milking.
- Date of last milking (dry off).
- Sire and dam of animal.

Considering that the income derived from the sale of milk in a dairy sheep operation represents only 50–55% of the total income, lamb production cannot be neglected and information about reproduction performance and growth of lambs should be recorded, such as:

- number of lambs born; and
- number of lambs weaned.

Individual producers should record whatever they believe to be valuable information for their operation. Since computers are now widely present on every farm, it is strongly suggested that a database system be used for record keeping, queries, forms and reports (see appendix A).

In any selection program, recording the performance of individual animals and each animal's pedigree (which necessitates controlled matings) is essential for the success of the program.

Table 5. Multiplicative factors to adjust milk yield to a mature (4–7 years of age) equivalent.

Ewe age, years	Adjustment factor
1	1.44
2	1.24
3	1.13
4 to 7	1.00
8 and older	1.04

Thomas, 1996

Example:
A 2-year-old ewe has a milk yield of 206 liters. Her age adjusted milk yield is 255 liters (206 x 1.24 = 255 liters).

Table 6. Multiplicative factors to adjust milk yield to the same lamb management systems

Management systems	Adjustment factor
DY1	1.00
DY1	1.10
DY30	1.51

Berger and Thomas, 2004

Example:
A 2 year old has an age adjusted milk yield of 255 liters. Her management systems adjusted and age adjusted milk yield is 385 liters (256 x 1.51).

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Chapter 4

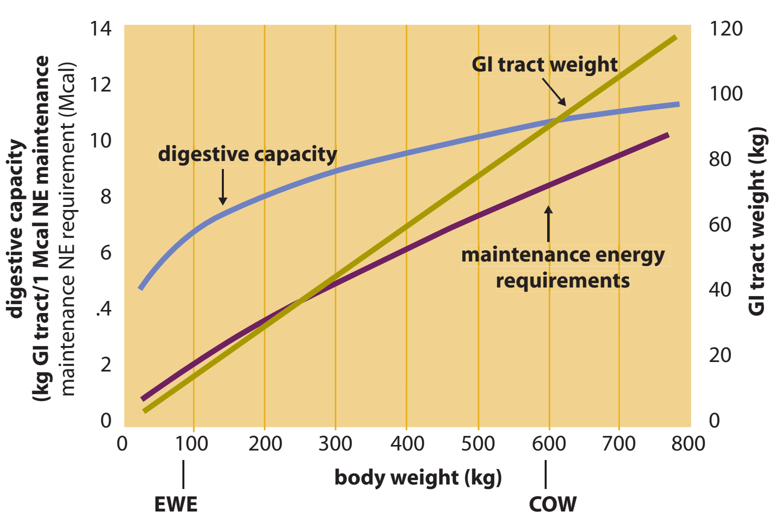
Nutrition of the dairy ewe

Adequate feeding requires proper ration balancing.

Milk production with dairy ewes requires more intensive systems and nutrients per animal than meat or wool production systems. During lactation, nutrient requirements may be very high. Inadequate feeding may reduce both the daily milk production and the length of the lactation.

Adequate feeding requires proper ration balancing. This, in turn, requires estimating animal nutrient requirements, feed intake and the nutritive value of feed. Proper feeding strategies of the lactating ewe cannot be based simply on those of dairy cows. Even though much of the information available for dairy cattle is valid for dairy sheep, being aware of the differences between the two species is vital to avoid using improper feeding strategies for the lactating ewe.

Figure 1. Effect of body weight on gastrointestinal tract (GI) size, maintenance energy requirements (net energy, NE) and digestive capacity.



Dairy sheep are not small dairy cows

Recommendations for feeding dairy sheep are often derived from dairy cows, whose nutrition and feeding management have been studied more extensively. Even though both sheep and cattle are ruminants with many similarities, they tend to have different feeding strategies and physiological functions.

Some of the most important differences between the two species relate to their body sizes. Dairy sheep are, in general, 10–12 times smaller than dairy cows. Many studies have shown that in both species the total volume of the gastrointestinal (GI) tract varies between 13–18% of the body volume (Parra, 1978, cited by Van Soest, 1994). As adult ruminants increase in size, GI tract volume increases in direct proportion to body weight. This means that the GI tract of a 60 kg sheep is, on average, 10 times smaller than that of a 600 kg cow. However, as the body weight increases, there is a less than proportional increase in energy requirement for maintenance. Maintenance energy requirements are usually proportional to the 0.75 power of body weight (BW0.75, often called metabolic weight, MW). This means that maintenance requirements of a 600 kg (MW= 121.2 kg) cow are only 5.6 times higher than those of a 60 kg (MW= 21.6 kg) sheep. Dividing the weight of the GI tract by the maintenance energy requirements, it is possible to estimate the digestive capacity (kg of GI tract available per unit of energy requirements).

The digestive capacity curve in figure 1 shows that cattle tend to have more kg of GI tract available per unit of energy required for maintenance than sheep. This implies that cattle can "store" more feedstuff in the GI tract for each unit (e.g. Mcal) of energy required for maintenance than sheep. This holds true even considering that the maintenance energy requirements for sheep per kg of MW are lower than those of cattle.

Fiber can be fermented only if it stays in the rumen for several hours. **The longer it stays, the more it is digested (up to a limit). In practice, if sheep and cattle are fed the same fibrous feedstuff, cows tend to digest better because they have larger digestive tracts and they can keep the feedstuff in the rumen for a longer time** (table 1). The intake per kg of BW was higher in goats and sheep than in cattle. As a result, rumen retention time and dietary total tract digestibility were highest in cattle. This difference in digestibility is maintained even when in both species the intake is much higher than that typical of dry animals (Blaxter et al., 1966).

There are important practical implications related to these facts. **To compensate for their low digestive capacity, sheep have to speed up the passage of feedstuff in the rumen (high passage rate, i.e. lower retention time). Therefore, they need to eat more feed per day (as % of BW) than cattle to satisfy their requirements.** Since the feed stays in the rumen for a shorter period, each kg of feed is digested less thoroughly. Despite this, due to the higher intake of dry matter, the total amount of nutrients digested per day is usually increased. This explains why high producing dairy sheep may have a level of intake between 5% and 7% of their body weight, while high producing cows usually do not exceed 4%.

Another way sheep face this problem is to *be more selective about what they eat* (Van Soest, 1994). Since sheep have less room for the feed per unit of requirement than cattle and they have to speed up the passage rate, **they naturally tend to choose feeds or parts of feeds that are good quality and highly digestible.** Even if the feed stays in the rumen for a shorter time, its digestibility is sufficient to allow the animal to meet its energy requirements.

Sheep differ from cattle in *chewing activity* as well. **Sheep require between 9 and 16 more times than cows to eat and ruminate 1 kg of dry matter** (De Boever et al., 1990). Sheep have to chew more than cattle because they are smaller animals and their chewing activity is less powerful. Sheep also have to grind the particles more finely than cattle to allow them to pass through the rumen and other compartments of the foregut (Van Soest, 1994). This behavior was clearly shown when lactating dairy cows (Holstein) and dairy sheep (Sarda breed) were fed a pelleted total mixed ration as the only feed (table 2).

Table 1. Apparent digestibility and retention times for ruminants fed the same medium quality timothy hay ad libitum

Item	Goats	Sheep	Heifer
Body weight	29	30	555
Intake of dry matter			
g/d	700	650	7830
g/kg BW	24.3	21.7	14
g/kg BW0.75	56	51	68
Digestibility (%)			
Dry matter	47	47	54
NDF	44	44	52
Retention time of forage particles			
Rumen (hr)	28	35	47
Whole GI tract (hr)	52	70	79
Ratio: rumen/whole tract	54	50	59

BW = body weight NDF = neutral detergent fiber

Uden et al., 1982; Uden and Van Soest, 1982

Table 2. Intake and chewing activity of cows and sheep fed the same pelleted total mixed ration as only feed.

		Dairy cows	Dairy sheep
Intake	(kg of DM/day)	8.4	1.2
Eating time	(min/day)	110.7	56.0
Rumination time	(min/day)	19.4	78.5
Total chewing time	(min/day)	130.1	134.5
Eating efficiency	(min/kg of DM)	13.1	46.3
Rumination efficiency	(min/kg of DM)	2.3	64.9
Total chewing efficiency	(min/kg of DM)	15.4	111.2

Rossi, 1994, cited by Van Soest et al., 1994

While sheep spent more than an hour ruminating 1 kg of dry matter, cows ruminated very little. Indeed, while sheep were doing well with this diet and producing a good amount of milk, cows dropped milk yield, had milk fat depression, and showed clear signs of acidosis.

Since there is a limit to the amount of time an animal can spend ruminating (10–11 hours per day), intake tends to be limited by the particle size of coarse diets containing long hay more in sheep than in cattle. This fact, as well as the lower digestive capacity of sheep, explains why grinding often increases intake of forages and why the response is stronger in sheep than in cattle.

Greenhalgh and Reid (1973) compared the intake of sheep and cows fed 3 types of diets: (A) high quality; (B) medium quality; and (C) dehydrated ryegrass and a mix of medium quality ryegrass with barley presented in either long or ground and pelleted form. Their results (table 3) showed that grinding and pelleting: 1) increased intake more in sheep than in cows; 2) increased intake more in young animals than in adult animals; 3) increased intake in inverse proportion to dietary quality (B> A > C). Even in ground diets, however, the total daily intake of digested dry matter was higher in high quality than in low quality diets.

Intense rumination activity in sheep can also have important implications when the diet includes grains. Rumination reduces the particle size and increases rumen digestibility of grains and therefore of starch. Sheep tend to chew grains more finely than cattle. This may explain why diets with high digestibility (> 66%) tend to be digested better by sheep than by cattle, while cattle are more efficient with diets that are harder to digest. (Mertens and Ely, 1982).

Differences between cows and sheep

Sheep:

1. **Must eat more than cows to satisfy their maintenance requirements. This results in a higher passage rate of feed and lower fiber (forage) digestibility.**
2. **Tend to have more selective feeding behavior than cows.**
3. **Are more affected in their intake by particle size and fiber content of the forages than cows.**
4. **Have to spend more time eating and ruminating each kg of feed than cows.**
5. **Tend to have higher digestibility of grains and high energy diets than cows.**

Table 3. Effects of grinding and pelleting various diets on intake in sheep and cattle.

			Sheep			Steers		
		Age (months)	6	18	36	6	18	36
		Body weight (kg)	49	72	83	272	464	614
Diet	**Form**	**Intake**						
A	Long *	g/kg of BW	21.9	18.1	23.8	20.5	19.9	15.7
	Ground & pelleted**	difference in %	+59	+46	+29	+18	-17.1	+5
B	Long*	g/kg of BW	17.8	15.2	18.0	19.6	15.9	13.7
	Ground & pelleted**	difference in %	+76	+74	+61	+31	+21	+30
C	Long*	g/kg of BW	22.0	17.5	24.6	20.5	19.7	17.3
	Ground & pelleted**	difference in %	+49	+25	+11	+20	0	0

A= perennial ryegrass, 2nd cut, harvested 7 weeks after the 1st cut (NDF 59%, CP 19%, ADL 3.3%)

B= perennial ryegrass, 2nd cut, harvested 12 weeks after the 1st cut (NDF 64%, CP 16.6%, ADL 4.1%)

C= 60% hay B and 40% milled and pelleted barley

** = long (baled) for cows, coarsely chopped (5 cm screen) for sheep*

*** = ground (1.44 cm screen) and pelleted through a 16 mm die*

Greenhalgh and Reid, 1973, modified

Requirements of the lactating ewe

Energy requirements

Energy requirements of lactating dairy sheep are calculated in the same way as those of lactating ewes of non-dairy breeds. Different organizations have published equations to estimate energy requirements of sheep. A comparison of the requirements calculated with the French (INRA, 1989), Australian (CSIRO, 1990) and British (AFRC, 1995) systems is reported in table 4.

The sheep NRC (1985) system does not specify energy requirements for milk production, probably because it was written primarily for meat and wool sheep. For dry ewes, NRC (1985) tends to have higher requirements for maintenance than the other systems (see footnote in table 4). The CSIRO (1990) system is peculiar because its energy requirements for maintenance grow in proportion to milk yield. The rationale behind this is that when the sheep produces milk, she requires some extra energy. Indeed, when animals (not only ruminants) produce milk they have higher feed intakes and require extra energy to process the extra feed (Ortigues and Doreau, 1995). This leads to higher maintenance requirements during lactation than during the dry period.

The requirements reported in table 4 include some activity allowance for housed sheep. If the ewes are grazing, an additional allowance should be made for their extra movement.

On average, grazing activity increases maintenance requirements by 20% if the ewes are on good quality flat pastures and by 35–40% in more extensive, hilly pastures (CSIRO, 1990).

If the ewes must walk long distances to the pasture, a more precise calculation can be done considering the following values (CSIRO, 1990).

Activity	Unity	Live weight 50 kg	60 kg	70 kg	80 kg
Walking (horizontal component)	(Mcal/mile)	0.04	0.05	0.06	0.07
Walking (vertical component)	(Mcal/mile)	0.60	0.73	0.85	0.96

A component of maintenance requirements often overlooked is that associated with conditions of cold stress. **Cold stress affects sheep much more than cattle.** Indeed, since small animals have higher body surface per kg of BW than large animals, they disperse more heat. Even though the wool of sheep is a much better insulator than the hair of cattle, its additional insulation is less than the effects of body size.

Table 4. Energy requirements for housed mature sheep (Mcal of ME/d).

FCM ** (6.5%) (kg/d)	50 kg of live weight * AFRC total	INRA total	CSIRO total	CSIRO maint.	60 kg of live weight * AFRC total	INRA total	CSIRO total	CSIRO maint.	70 kg of live weight * AFRC total	INRA total	CSIRO total	CSIRO maint.
0	1.53	1.79	1.57	1.57	1.76	2.05	1.79	1.79	1.99	2.30	2.01	2.01
1	3.22	3.54	3.45	1.74	3.45	3.80	3.65	1.96	3.67	4.05	3.90	2.19
2	4.90	5.29	5.33	1.91	5.14	5.55	5.51	2.13	5.36	5.80	5.78	2.36
3	6.59	7.04	7.22	2.08	7.13	7.30	7.36	2.30	7.05	7.55	7.66	2.53

** NRC (1985) = maintenance requirements (Mcal of ME/d): 50 kg = 2.00; 60 kg = 2.20; 70 kg = 2.40*

*** 6.5% FCM (6.5% fat-corrected milk) = actual milk yield x (0.3688 +0.0971 x % butterfat) (Pulina et al., 1989).*

Cannas, 2000

The effect of cold stress in sheep was simulated by Cannas (2000) by using the CSIRO (1990) model. The results (table 5) showed that lactating animals are less affected by cold stress than are dry animals. This is because the high energy intake necessary to sustain milk production increases the heat produced by the body and by the rumen and, therefore, alleviates the effects of cold stress. Wool depth is also very important in reducing the effects of cold stress, because of its thermo-insulation properties. However, wind or rain can markedly reduce its protective action. In the simulation, the combined effects of all these factors increased maintenance requirements up to 3 times.

Protein requirements

Calculating the protein allowances for lactating ewes can prove to be a daunting task. Proteins supplied by the diet are in part fermented in the rumen and in part digested in the intestine. In most feeds, a totally indigestible fraction is also present.

The protein fermented in the rumen **(degradable intake protein, DIP)** is used by bacteria (if proper amounts of fermented carbohydrates are present). Ruminal bacteria then pass to the intestine, where they represent a major source of high quality protein for the ewe. The protein requirements of the ewe are then satisfied in part by feed protein that is not fermented in the rumen and is digested in the intestine **(undegradable intake protein, UIP)** and, in part, by bacterial protein digested in the intestine.

The problem is that the amount of protein fermented in the rumen (and consequently, the amount of UIP) and the ability of bacteria to use that protein is affected by many variables like type and amount of feed eaten (usually related to milk production), feeding frequency and amount of energy fermented in the rumen. In practice, this means that it is difficult to estimate the amount of protein needed to meet the requirements of lactating ewes. Similar problems exist for cattle, but more information for cattle is available. Thus, most of the information used for lactating ewes is based on information derived from dry ewes or from dairy cows and may not reflect actual requirements and feed utilization.

Table 5. Effect of coat depth, wind, rainfall and current mean daily (24 h) temperature on cold stress requirements of adult, non-lactating ewes of 50 kg of BW, with an MEI sufficient for maintenance in a thermo-neutral environment, and of lactating ewes weighing 50 kg, producing 1.5 kg/d of milk with 6.5% fat, and with MEI sufficient to satisfy maintenance and milk production requirements in thermo-neutral conditions (15–20 °C). Total maintenance requirements are expressed as index, with maintenance requirements in thermo-neutral condition equal to 100.

	25 mm coat				50 mm coat			
Wind (km/h)	calm		30		calm		30	
Rainfall (mm/d)	0	30	0	30	0	30	0	30
Adult, dry								
Temp. +5 °C	115	134	234	247	100	103	183	195
Temp. 0 °C	129	149	267	280	100	114	208	220
Temp. -5 °C	144	164	300	313	109	124	233	245
Adult, lactating								
Temp. +5 °C	100	100	125	133	100	100	107	114
Temp. 0 °C	100	100	137	145	100	100	116	123
Temp. -5 °C	100	104	149	157	100	100	125	132

Cannas, 2000

The French (INRA 1989), Australian (CSIRO, 1990) and British (AFRC, 1995) systems express protein requirements in terms of metabolizable protein (the total amount of protein, of bacterial and feed origin, absorbed by the intestine). Table 6 reports the requirements of metabolizable protein (MP) calculated by these systems. As in the case of energy, the CSIRO (1990) system considers variable protein requirements for maintenance. Despite the different approach used, the INRA (1989) and the CSIRO (1990) systems predict very similar MP requirements, while the AFRC gives the lowest estimates for lactating ewes.

Using metabolizable protein may give more precise estimates but requires information sometimes not available. In this case, crude protein can be used as a base for balancing the diet of dairy ewes. The NRC (1985) uses crude protein (CP) instead of MP and gives practical estimates of protein requirements for maintenance of dry females:

Body weight (kg)	**50**	**60**	**70**	**80**
Crude protein requirements (g/d)	95	104	113	122

Crude protein requirements for milk production are around 120–125 g of CP per kg of milk with 5% CP. If the milk has a different protein content, CP requirements for its production should be proportionally corrected.

Feed protein values should be expressed in terms of MP, the same as for the requirements. Each of the systems mentioned in table 6 uses a different approach to estimate MP value of the feeds. The description of the methods used by each system is beyond the scope of this chapter. Briefly, all of them require the knowledge of the degradability in the rumen of the feeds, which can be obtained experimentally by in vitro or in situ degradability measurements. When experimental measurements are not available (most of the times for field application of these systems), the values reported by the feeding systems for feeds similar to those under evaluation can be used. Due to these difficulties, quite often ration balancing is based on CP feed values only. Being very clear that CP gives only a rough idea of the protein value of the feeds, some guidelines for its use in the field are reported here.

Optimal crude protein intake and concentration in the diet can vary substantially depending on the intake of the animals, the source of protein and energy used in the diets, and the feeding method. The NRC (1985) suggests CP concentration between 13% (90 kg of BW) and 14.5 % (50 kg of BW) for ewes producing 1.74 kg/d of milk and between 14% (90 kg of BW) and 16.2% (50 kg of BW) for ewes producing 2.6 kg/d of milk. These values may be adequate in many situations.

However, in many other cases, diets with up to 18.0–18.5% of crude protein can give an extra boost to milk production, especially when protein sources with low rumen degradability are supplied.

This is supported by some experimental results, both in early lactation (Gonzalez et al., 1984) and in late lactation (Pulina et al., 1990; Cannas et al, 1998). Animals with high levels of production need diets with more UIP proteins. In these ewes, in fact, microbial protein may not be able to completely satisfy the high protein demand of the ewe.

Table 6. Metabolizable protein requirements for adult sheep, expressed as g/d and relative to the AFRC requirement for dry sheep that was set to 100. MP requirements for wool production were not included.

5% true protein milk	—50 kg of body weight— AFRC				—70 kg of body weight— AFRC			
		CSIRO[1]		INRA		CSIRO[2]		INRA
	total	total	maint.	total	total	total	maint.	total
(kg/d)	g/d of MP[3]							
0	41	41	41	38	53	52	52	49
1	115	126	54	123	126	137	65	134
2	188	210	67	207	200	221	78	218
3	262	295	80	292	274	305	91	303

[1] based on the hypothesis that DMI is equal to 1.2, 1.8, 2.4, and 3.0 kg/d for dry ewes or lactating ewes producing 1, 2 and 3 kg/d of milk, respectively.

[2] based on the hypothesis of DMI is equal to 1.5, 2.1, 2.7, and 3.3 kg/d for dry ewes or lactating ewes producing 1, 2 and 3 kg/d of milk , respectively.

[3] MP requirements to produce 1 kg of milk with 5% true protein: 74 g for AFRC; 71 g for CSIRO, and 85 g for INRA.

Serra et al. (1998) defined practical dietary CP concentrations for lactating sheep of different body size and milk yield (table 7). Their values were based on a extensive review of feeding experiments on dairy sheep published in the literature and tend to be higher than those reported by the NRC (1985) for sheep, implying a low efficiency of protein utilization by sheep. This may be justified by the fact that sheep have high requirements of sulphur-containing amino acids, such as methionine, due to their wool production (Bocquier et al., 1987). Methionine is often the amino acid first limiting milk production even in cows. Lynch et al. (1991) showed that the supplementation of rumen protected methionine and lysine caused a marked increase in milk production in lactating sheep. **In summary, protein quality and amino acid composition may have large effects on milk production.** An example of the combined effects of protein intake and quality on milk yield is given in figure 2.

Fiber and non-structural carbohydrate requirements

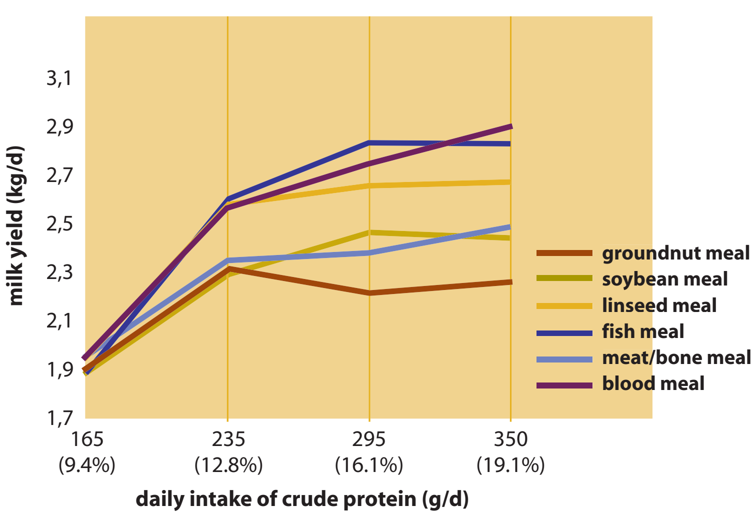
Information is scarce that defines the *minimum fiber requirements* of lactating sheep. Pelleted complete diets with NDF as low as 32% and small particle size were fed *ad libitum* as the only feed to dairy ewes (Pulina et al., 1995). The level of intake was about 4.75% of body weight and the ewes had similar milk production to the ewes fed more fibrous diets. It is important to notice that if concentrates are fed separately from fiber sources, they may induce acidosis or sub-acidosis even when as average the dietary fiber content is high. **The optimal fiber intake to maximize milk production is not known.** When dairy goats were fed diets containing from 14% to 26% ADF, there were no differences in intake and milk yield compared to those fed higher fiber diets, while milk fat content was increased in the more fibrous diets (Santini et al., 1991).

Table 7. Dietary CP concentration (as % of DM) suggested for different BW and milk yields.

5% true protein milk (kg/d)	Body weight (kg) 30	35	40	45	50	55	60	65	70
0.5	16.6	15.8	15.1	14.8	14.5	14.0	13.7	13.3	12.9
1.0	17.7	16.9	16.5	15.9	15.6	15.0	14.5	14.3	13.9
1.5	18.5	17.7	17.4	16.7	16.4	15.9	15.7	15.2	14.8
2.0	19.1	18.7	18.1	17.7	17.2	16.6	16.4	15.9	15.7
2.5			18.9	18.3	17.8	17.5	17.0	16.6	16.4
3.0					18.6	18.0	17.6	17.3	16.9
3.5							18.3	17.8	17.6
4.0									18.0

Serra et al., 1998

Figure 2. Effect of different amount and source of protein in ewes (67 kg BW) in the first month of lactation. The lower protein level corresponds to a basal diet of hay, barley and molasses. Dry matter intake was restricted to 1.8 kg per day for all diets. Numbers in brackets represents CP concentration in the diets (adapted from Gonzalez et al., 1982, and Robinson, 1987b).



Non structural carbohydrates (NSC). Supplied mostly by grains, NSC are composed mainly of starch and sugars. They tend to decrease when the fiber content of the diet increases. NSC are very important energy sources for ewes and their rumen bacteria. However, excess NSC may induce acidosis and other digestive and metabolic problems (Ørskov, 1986). High roughage diets (60: 40 forage to concentrate ratio) gave much lower milk yield than low roughage diets (20: 80 forage to concentrate ratio, lower NSC content) in Finn-sheep ewes in the first weeks of lactation (Brown and Hogue, 1985).

However, in dairy goats in the fourth month of lactation milk yield was only slightly higher when 45:55 forage to concentrate ratio diets were compared with diets having a 75:25 ratio (Kawas et al., 1991). In contrast, Cavani et al. (1990) found higher intake and milk yield in East Friesian ewes fed, from the fifth to the seventh month of lactation, diets with 20% starch + sugars compared to ewes fed diets with 35% starch + sugars, which in turn had higher positive BW variations.

In lactating dairy sheep, diets ranging from 14–21% CP were compared from the fifth to the eighth months of lactation at two levels of NSC (as average, 29% vs. 40%) (Cannas et al., 1998). The ewes fed the diets with the lowest NSC concentration had higher intake (2411 vs. 2195 g/d) and produced more milk (1428 vs. 1252 g/d). This may have been the result of too much starch in the rumen of high NSC diets, causing sub-clinical acidosis. Indeed, in these diets milk fat, milk lactose and milk pH were slightly lower than in the diets with the lower NSC concentration.

It is also possible, however, that with the high NSC diets the energy was used more for body fat deposition than for milk production, due to likely high propionate production, following a mechanism proposed by Ørskov (1986). In a recent experiment, Cannas et al. (2000) fed three diets, differing for their forage to concentrate ratio (90:10, 70:30, 50:50) and chemical composition (NSC ranging from 32% to 43% and NDF from 43% to 31%), to dairy sheep in the last month of lactation. The results showed that as the forage to concentrate ratio decreased, milk production decreased and body weight increased.

Therefore, in the second half of the lactation dietary NSC concentration should not be higher than 25–30% (maximum 20% of starch + sugars),

The practical implication of these trials is that during early lactation large amounts of grains (NSC up to 35–40%) may help the ewe in negative energy balance to produce more milk, while later on large amounts of grains (and then of NSC) may be detrimental.

with the lower values for grass-based diets and the highest for legume-based diets. This is because legume forages contain fairly high amounts of pectins, that are included in the NSC fraction but induce different fermentation products than sugars and starch. Comparing NSC utilization by cattle and sheep, it should be considered that rumen digestibility of the NSC tends to be higher in sheep (that chew grains intensely) than in cows, while fiber digestibility tends to be lower. This means that at similar NSC dietary concentrations sheep should have a lower acetate to propionate ratio than cows of comparable levels of production.

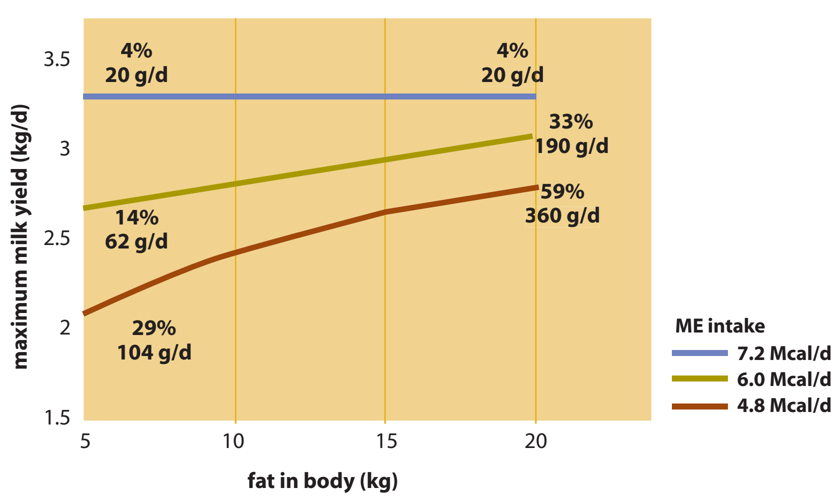
Practical feeding of the lactating ewe

First part of the lactation (first 8–10 weeks)

The first part of the lactation has been studied intensely because of its interest in wool and meat breeds. Milk production in this period, in fact, dramatically affects lamb growth and body weight at weaning. In the case of dairy sheep, milk yield in early lactation strongly affects the persistency and the length of the lactation.

In the first weeks of lactation, intake is usually low but the requirements of the ewes are very high. Peak intake usually occurs some weeks after the peak of lactation. This brings the ewe into a negative energy balance. Milk production, then, relies in part on the mobilization of body reserves. For this reason, a very important aspect of dairy ewe feeding is to allow the animals to begin the lactation with appropriate amounts of body fat reserves (Louca et al., 1974; Robinson, 1987a). Robinson (1987a) clearly demonstrated the critical importance of body fat reserves and energy intake

Figure 3. Effect of body fat reserves and daily intake of metabolizable energy (ME) on maximum milk yield in ewes in the first weeks of lactation. The numbers represent the percent of milk obtained from body fat mobilization and body weight losses in grams per day (from Robinson, 1987a, modified).



in this period. In his experiments, milk production in ewes consuming high levels of energy was independent of body condition, while milk production of animals consuming low or medium energy rations was strongly affected by it (figure 3). The lower the body reserves, the lower the amount of milk that could be produced from fat mobilization. Excess body fat in this period, however, may reduce the space available for the rumen and negatively affect intake (Stern et al., 1978).

Regardless of the condition score of the animals, at this stage it is critical to provide diets that maximize intake, to avoid excessive negative energy balance and fat mobilization that occurs too fast. Even in the first weeks of lactation, very high intake (almost 7% of body weight) was obtained by ewes nursing triplets when pelleted concentrate was fed at will with a fixed amount of hay (Hogue, 1994). This strategy promoted high growth rate of the lambs and even some body weight gain of the mothers (table 8) but was probably costly for practical application. In general, high intake in the first weeks of lactation can be achieved using high quality forages, finely chopped silages, chopped hay, and concentrates. To limit the risk of grain overload, cereal grains should be mixed with high energy feeds that are less prone to induce acidosis, such as beet pulps, soybean hulls, or citrus pulps.

An easy and practical way to make sure ewes have enough body fat reserves at the onset of lactation is to monitor their body condition score (BCS) throughout pregnancy and to adjust the diet accordingly. At lambing, dairy ewes should have a body condition score around 3.5 (figure 4) (INRA, 1989). At lower values of BCS, milk yield may decrease because of insufficient fat reserves; at higher values it may decrease because of low feed intake.

Table 8. Observed feed intake and body weight gains of triplet-rearing ewes and their lambs.

Feed intake of the ewes[a] (kg DM/day)		Daily gain (41 days) (grams/day)		Number of animals
Hay[b]	1.3	Ewes	250	14
Pellets[c]	3.1	Lambs[d]	322	42
Total	4.4	3 lambs	966	

[a]mean body weight at the beginning of the trial (1-2 weeks postpartum): 64.35 kg
[b]limit fed [c]high energy lamb pellets, fed ad libitum [d]lambs had access to pellets in a creep
Hogue, 1994

Table 9. Milk yield and composition from ewes administered sustained-release bST.

	bST wks 3 to 8 of lactation			bST wks 11 to 23 of lactation*		
	0 mg	80 mg/ 14 d	160 mg/ 14 d	0 mg	80 mg/ 14 d	160 mg/ 14 d
Milk yield, ml/d	997	1198	1337	618	873	947
6% FCM, ml/d	1072	1301	1467	770	1071	1169
Milk fat, %	6.7	6.8	6.9	8.6	8.4	8.4
Milk fat, g/d	66	80	92	50	71	77
Milk protein, %	5.2	5.1	4.9	6.0	5.5	5.2
Milk protein, g/d	51	59	65	36	47	48

** For experimental purposes, the ewes were milked only once per day beginning at 18 weeks. This markedly reduced the difference in milk production between the control and the treated animals.*
Fernandez et al., 1995

Second part of the lactation

Dairy sheep nutrition in the second part of the lactation (from the third month until drying) has not been investigated as completely as the early lactation period. It is clear that dairy sheep breeds have not been subjected to the same intense genetic selection that has occurred in dairy cows. This means that the persistency of lactation is often not as good as in cows. **In many dairy sheep breeds, after the first months of lactation the ewes tend to use the nutrients more for body fat deposition than for milk production.** This mechanism is even more evident when ewes of meat/wool breeds are used to produce milk. In later lactation, dairy sheep (Manchega breed) remarkably increased their milk yield when treated with bovine somatotropin (bST), as shown in table 9 (Fernandez et al., 1995).

Dairy cows treated with bST behave as genetically superior cows (Peel and Bauman, 1987) and tend to use the nutrients more for milk production than for body fat deposition. It is possible that the high response of bST-treated ewes is a sign that there is room for genetic improvement of milk production. Basically this hormone is producing a hormonal status that in the future may be achieved by genetic selection.

Experience and experimental results, previously reported in the NSC section, suggest that feeding large amounts of grain in the second part of the lactation stimulates fattening but has negative effects on milk synthesis.

This is probably due to the stimulating effect of the volatile fatty acids produced by grain fermentation (mainly propionate) on body fat deposition, as previously discussed. A better feeding strategy should be based on the maximization of forage intake, the use of by-products with fast-fermented fiber (such as beet pulps or soy hulls) and the use of protein supplements whose protein content and quality should be chosen considering the type of pasture or stored forages available. Large amounts of protein supplements should be used if the pasture is made of mature grasses. When the pasture consists of legumes or grasses in early stages of growth, protein supplements are usually unnecessary. Protein supplements used during the mating season can improve reproductive parameters of lactating ewes (Molle et al., 1995), but only if the protein content of the pasture is scarce.

Feeding housed lactating ewes

The lactation of dairy ewes can last between 7 and 10 months. This means that, in most cases, ewes are fed stored forages (hay or silage) for part of the lactation.

The quality of the forages fed to lactating ewes is extremely important, especially if hay or silage make up a large part of the diet. **It is clear that milk yield and forage quality are closely related. High quality forages and small amounts of concentrate supplements allow milk production levels that cannot be obtained with low quality forages, no matter how much concentrate is given.**

A major problem of stored forages is how to supply them. Many different feeding strategies are used on commercial dairies. The simplest strategy is to feed loose hay during the entire day and some concentrate supplements at milking. The most complex involves feeding total mixed rations.

Loose hay is often used as the only source of fiber in the diet. Because of the low digestive capacity of sheep, high intake of hay can be achieved only if its quality is high (low fiber content). If hay quality is low (high fiber content), intake will be low and this can lead to low milk yield and higher probability of acidosis even when moderate levels of concentrate are used. One way to increase the intake of hay is to allow the animals to select. The lower the quality of the hay, the higher the amount of hay the ewes discard. Van Soest et al. (1994) reported practical refusals for optimal lactation performance in goats (table 10).

To satisfy the requirements of lactating small ruminants, it is necessary either to provide high quality hay or to accept extensive selection and large refusals. It usually ends up costing more to feed "cheap" low quality hay with high refusal levels than to invest in the production of excellent forages.

Quality is even more important for silages because when chopped, they are less readily selected. As for hay, silage feed intake can be increased by further reducing its particle size (Apolant and Chestnutt, 1985), unless other factors controlling intake are involved (bad flavors and taste, molds). However, finely chopping should not be considered a tool to

Table 10. Estimates of practical refusals for optimal lactational performance in goats.

Forage	Predicted[a] digestibility (%)	Refusals (%)	Digestibility of ingested forage (%)	Utilization[b] (%)
Alfalfa hay	65	15	69	59
	58	25	66	50
	50	35	60	39
Grass hay	70	20	75	60
	60	35	69	45
	50	50	60	30

[a] *From composition of the offered forage*

[b] *Digested matter actually ingested as percent of amount offered*

Van Soest et al., 1994

force sheep to eat poor quality feeds or an excuse to overlook the quality of the forages: What is eaten is not always digested.

When the forages are given in a total mixed ration (TMR), do not follow the same procedure used for dairy cows. Sheep are more selective than dairy cows and their intake is more affected by particle size. If the particle size of the forages of the TMR is too large, it is likely that the ewes will first eat all the concentrates. This may lead to acidosis even when the average diet does not have too much starch, as sometimes is observed in Italian dairy sheep enterprises.

When "cow-like" TMR diets are used for dairy sheep, another problem observed is low intake and low milk yield. This usually occurs because the particle size that maximizes intake and milk yield in dairy cows is too coarse for lactating ewes. The strategy to use is to either produce very finely chopped silages or to allow more grinding of the forages in the mixer wagon. The result in most of the cases is an increase in both intake and milk yield. This practical observation is supported by some experimental evidence. Brown and Hogue (1985) compared TMR diets with two forage to concentrate ratios (60:40 and 20:80) in which the forage (alfalfa hay) was ground either through a 32 mm screen or a 8 mm screen. Milk yield increased 25% in the 8 mm diets, without any change in intake. More extreme grinding may be beneficial ,too.

In a trial at Cornell, Dorset and Finn ewes were fed grass hay that was ground through 12-mm (coarse), 2.4-mm (medium) and 1mm (fine) screens (Cannas, 1995). The reduction of the particle size increased intake, milk yield and milk protein yield and markedly decreased rumination activity, while milk fat yield was not affected (table 11).

It seems that sheep can produce well even when fed diets that are very finely ground. On farms, it is almost impossible to have diets ground as fine as in that trial. Dairy sheep producers should not be worried about grinding feeds too finely for lactating ewes. Particles that are too coarse are a much more likely problem.

Table 11. Effect of dietary particle size on feeding behavior and milk production in lactating ewes in the 6th week of lactation. The results reported are the means of the last experimental week covariated with those of the preliminary period.

	Diet			
	Fine	Medium	Coarse	sem
Dry matter intake (g/d)	4005	4132	3767	147
Rumination (min/d)	45^{a}	165^{a}	431^{b}	38
Milk yield (g/d)	2400	2492	1991	192
Milk fat (%)	7.86^{ab}	7.03^{a}	9.08^{b}	0.56
Milk fat (g/d)	187.7	185.1	178.6	18.9
Milk protein (%)	4.37	4.13	4.26	0.11
Milk protein (g/d)	105.3^{a}	109.7^{a}	83.8^{b}	8.1

^{abc} Means with different subscript differ (P<0.05)

Diets: 54.9% grass hay, 30.1% cracked barley; 13.0% soybean meal, 2% mineral supplements (CP 16.4%, NDF 41.6%, ADL 3.05%); Hay ground through: 1 mm screen (FINE diet); 2.4 mm screen (MEDIUM diet); 12 mm screen (COARSE diet).

Cannas, 1995

Feeding grazing lactating ewes

Pasture management and grazing techniques in producing ruminants have been extensively analyzed in many books and reviews and are beyond the scope of this chapter. A major problem in feeding grazing lactating ewes is the choice of the amount and of the quality of the supplements. This section will try to give some criteria on supplement management.

Nutritional indicators for choosing proper supplements

The main problem to be faced with grazing animals is that it is very difficult to estimate both their intake and the composition of their diet. For this reason, any decision on quality and quantity of supplements is often the result of a pure guess. A practical and often more effective approach may be based on the utilization of the information available to the dairy sheep breeder to estimate the nutritional status of the ewes and to define the characteristics of the supplements. Indicators commonly used are milk yield and quality, body condition and health status of the animals, and quality and quantity of the pasture. The relationships between milk production and nutrition are investigated in details in another chapter of this book. Some other indicators are discussed here.

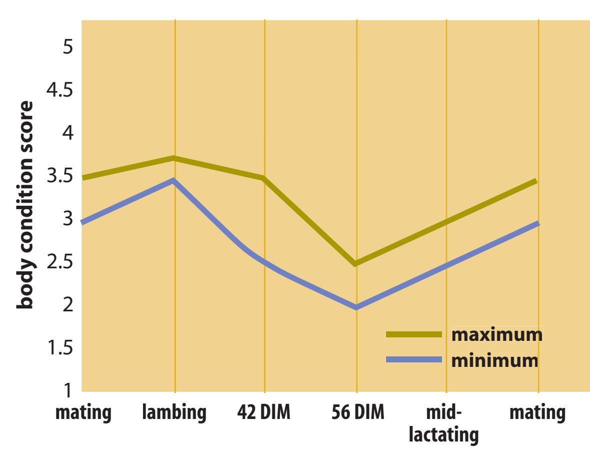
The nutritional status of the ewes can be monitored by measuring their body condition score (BCS). This technique is very useful to check if the ewes are losing too much body fat in the first part of the lactation or if they are over-eating and becoming too fat in the second part of the lactation. The proper BCS of the ewes in different physiological stages is given in figure 4 (INRA, 1989). If the flock is large, body condition can be monitored on only some of the ewes (about 20 % of the ewes in medium size flocks and 10–15% in larger ones). Supplements can then be dosed according to the body condition score of the animals and to the target BCS.

The **feces** are another good indicator of the nutritional status of ewes. Liquid or loose feces often result from excessive protein in the diet. Ewes grazing on young pastures rich in soluble proteins (first spring growth or regrowth after the harvest) often have this type of feces. The use of readily fermented carbohydrates (molasses, barley, oat) can reduce these problems because bacteria need energy to use a large amount of the fermented proteins (Stephenson et al., 1992). These types of pasture are usually low in fiber. The addition of some hay to the diet may overcome this problem. Excess starch and subsequent acidosis can also produce liquid or loose feces. In this case, however, it is often possible to notice small particles of undigested grains in the feces. Excess dietary NSC and rumen acidosis are also indicated by the classic typical behavioral signs. The addition of fiber in the diet limits this problem. Pellet-like dry feces containing visible forage particles indicate that fiber is not properly fermented, either for its poor quality or for the lack of rumen-fermented dietary protein.

In dairy cows **milk urea** content is considered a good indicator of the protein status of the animals (Roseler et al., 1993). Urea is produced in the liver to excrete N unused by the animals. Most of the urea is excreted in the urine, but it also found in the blood and in the milk. Milk and blood urea concentrations are closely associated, although milk urea tends to be a more stable parameter and is more easily sampled. Blood and milk urea are often reported as blood and milk urea nitrogen (N). Blood or milk urea nitrogen = blood or milk urea * 0.4665. Some research on lactating ewes showed that blood urea was a good predictor of the protein status of the ewes (Egan et Kellaway, 1971). Cannas et al. (1998) reported that in dairy ewes in mid-lactation milk urea N was highly associated with the dietary CP concentration but less associated with the daily intake of CP (figure 5). Our unpublished calculations, based on data from the scientific literature, showed that when compared to lactating cows fed diets with equal dietary CP concentration, lactating sheep had 2–7 mg/dl more urea N, with highest differences at highest CP concentrations. Cannas et al. (1997), Cannas et al. (1998) and Ubertalle et al. (1998) found that milk urea was little influenced by protein source. First lactation ewes had higher milk urea N concentrations (4 mg/dl) than mature ewes (Cannas et al., 1997).

Other important information obtained from the measurement of urea regards the reproductive efficiency of the ewes. In dry ewes, high blood urea concentrations have been associated with detrimental effects on early development and survival of sheep embryos (blood urea N between 16 and 23 mg/dl; Bishonga et al., 1994). In lactating ewes, blood urea N and conception rates were inversely correlated, with significant effects for concentrations higher than 23 mg/dl (Molle et al., 1998). Moreover, excess dietary proteins and high urea values are often associated with several diseases (e.g. mastitis, lameness) and cause an increase in energy requirements (the energetic cost of excretion as urea of 100 g/d of dietary CP in excess to protein requirements is equivalent to the cost of production of 200 g/d of sheep milk). In a preliminary way, a safe range of milk urea N for lactating sheep may be between 9 and 18 mg/dl. Optimal values may be calculated by considering the optimal dietary CP concentrations reported in table 7 as the X value of the regression equation reported within figure 5. It seems that there are many reasons to justify the application in the field of this index. It is important to notice that individual values of milk urea have little significance. At least 8–10 sheep should be sampled to use milk urea as a nutritional indicator. To reduce the analytical costs, individual milk samples of ewes of the same age, stage of lactation and fed the same

Figure 4. Target body condition score during the production cycle of dairy ewes (based on INRA, 1989). DIM = days in milk.



diet can be pooled. Based on our experience, the application to sheep milk of the commercial strips commonly used to measure milk urea in cow milk has been unsuccessful. Milk urea is currently used in Sardinia (Italy) as a predictor of the nutritional status of dairy ewes by the extension service of the local Breeders Association (Associazione Regionale Allevatori della Sardegna). The values observed throughout the year in Sardinian flocks mimic almost perfectly the availability of pasture and its protein content, with highest values of milk urea N (>28 mg/dl) in the early growing season (March-April), when both grasses and legumes are very rich in soluble protein, and lowest (<14 mg/dl) in the dry season (early summer) (personal communication, Associazione Regionale Allevatori Sardegna).

Milk urea gives important information regarding the type of supplements to use. In the Sardinian case, for example, the use of protein supplements would be, for most of the winter and the spring, not only unnecessary but harmful.

Concentrate feeding

The most common method to supply concentrates to dairy ewes is to give them during milking (twice per day). If the amount of **grain or starchy feeds** given each time is large (400-700 g), the ewes will likely have a surge of propionate production in the rumen. This may lead to reduced fermentation of fiber and stimulation of body fat deposition. In the worst cases, acidosis (grain overload) may occur. Sometimes, even if the average amount of grain supplied per animal is not too high, some animals, usually the most productive or competitive, may eat too much grain. To reduce the surges of propionate production (Ørskov, 1986) and the risks of low rumen pH, excessive fattening and acidosis, the daily amount of grain should be divided in more than two meals. An extra meal could be given at night in the barn or just before bringing the ewes to the pasture, after the morning milking. The latter option is particularly useful when the ewes are brought to the pasture several hours after the morning meal. The supply of energy-rich concentrates just before grazing is strongly suggested in the case of ewes kept on protein-rich pastures. The goal in this case is not only to increase the number of meals, but also to optimize the ruminal fermentation of the proteins of the pastures and to reduce the risks associated with excessive rumen ammonia concentrations.

In the case of highly fermentable grains like barley, wheat and oat, using whole grains instead of processed ones (cracked, steam-flaked, ground) is definitely beneficial for sheep (Vipond et al., 1985; Ørskov, 1986). Whole grains stimulate rumination and slow down ruminal fermentation. Sheep chew grains more finely than cows and large losses of whole grains in the feces are unlikely. Only when slowly fermenting starch sources (corn and sorghum grains) are given, cracking or flaking may be beneficial, especially in animals with high intake and passage rate.

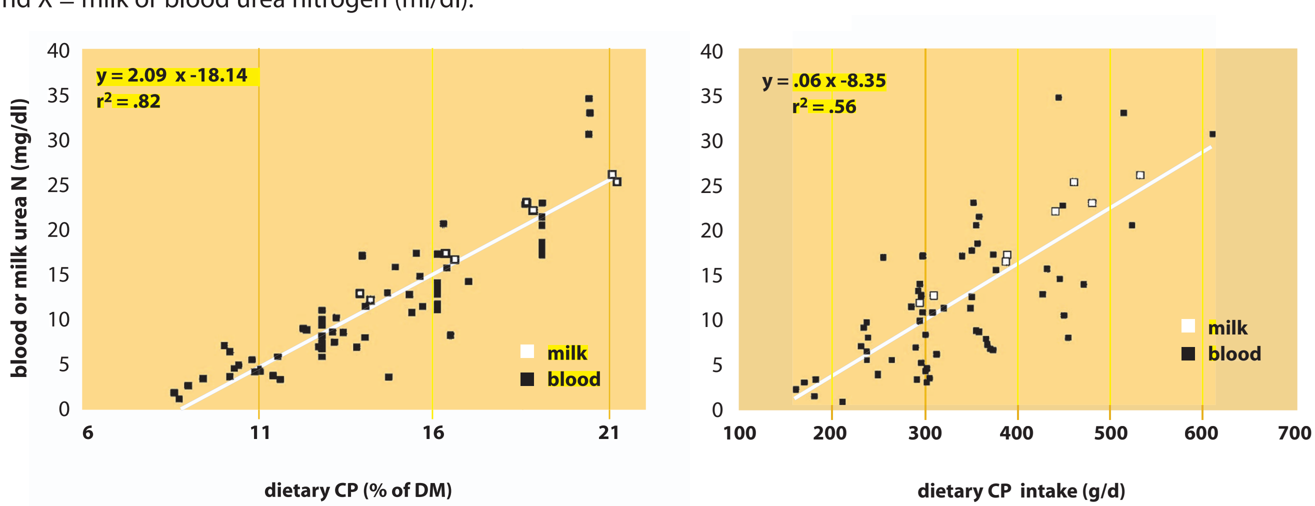


Figure 5. Relationships between CP content of the ration, left, or daily CP intake right, and concentration of milk or blood urea N in housed lactating ewes (Cannas et al., 1998). Each square represents a treatment mean. If milk or blood urea nitrogen are used as predictors of CP % in the diet, the following equation should be used: Y = 0.48 X + 8.68, where Y = CP in the diet (%) and X = milk or blood urea nitrogen (ml/dl).

The high passage rate of feeds in lactating ewes poses limits to the utilization of some by-products with slowly digested fiber and small particle size. Some of them (brewer grains, distillers) may be eaten in large amounts but may be poorly digested (Van Soest et al., 1994).

The utilization of bicarbonate can be beneficial when high grain diets are fed. Rumen pH was increased and maintained above the level inhibitory to fiber digestion when a mix of sodium bicarbonate (64%) and potassium bicarbonate (34%) was added at the rate of 3.5% of the dry matter to the diet of lambs fed large amounts of barley grains (Mould et al., 1983).

Acidosis and other digestive disorders are frequent in Mediterranean areas during the winter, when the ewes are in the first months of lactation but the pasture is scarce due to the low temperatures. In this period, the ewes are usually fed with large quantities of hay and concentrates. However, the intake of hay is frequently low due to its poor quality. In these cases, acidosis is frequently observed even when only 400-600 g/d of concentrates are supplied. With the aim of solving this problem, Rossi et al. (1991), developed a "safe" pelleted feed. This feed is made of a mixture of energy and protein sources plus about 30% chopped dehydrated alfalfa. The amount of fiber and its particle size have been calibrated to stimulate intake and rumination and to slow down the rates of intake. The energy concentration of this feed ranged between 1.55 and 1.70 Mcal of NEL when no fats were added. This product was used as the only feed as long as 20 weeks (Rossi et al., 1991) or as pasture supplement, without giving any type of digestive or metabolic problem (Cannas et al., 1992; Calamari et al., 1991). When used as a complete feed, its intake ranged between 5.5% to 7% of the body weight and always induced much higher milk yield than traditional diets. In Italy, this type of feed is currently produced by several feed companies in different formulations. It has been used mostly in periods when the pasture is scarce or is very young (high in soluble proteins and low in fiber). In this case, it has been beneficial in increasing milk production and in reducing many of the diseases related to nutritional stresses.

Conclusions

Feeding programs for lactating ewes should consider the peculiar characteristics of sheep. There are substantial differences between sheep and cattle in feeding behavior and digestive capacity. These differences are particularly important when ewes with high levels of production are considered. Since very few studies have been conducted with high-producing ewes, much more research is needed. In particular, more knowledge is needed to define energy and protein requirements of lactating ewes in the second part of lactation and fiber and NSC optimal level throughout the lactation. In order to determine the quality and the quantity of supplements required by grazing lactating ewes, it is important to use the available nutritional indicators and to develop new ones.

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Chapter 5

Effect of nutrition on milk quality

The merits of ewes' milk quality differ widely between breeds.

Introduction

Like other dairy ruminants, dairy ewe lactation curves, both in terms of milk yield and milk composition, are conditioned by 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, milk yield and milk composition (fat, protein, casein and serum proteins, but not lactose) correlate negatively (Barillet and Boichard, 1987; Molina and Gallego, 1994; Fuertes et al., 1998).

This phenomenon generally appears due to improved management practices. As a result, producers should strive to find a balance between practices that will increase milk yield and those that increase the milk content. The producer's income will reflect the combination of prices related to both milk volume and its quality.

Because ewe's milk is mainly used for cheese making, it is important to pay attention to fat and protein contents. When routinely measured, these precisely predict cheese yield (Pellegrini et al., 1997). In fact, the dairy sheep breeder's main objectives are to: 1) increase total milk dry matter output (cheese quantity); 2) stabilize year round production of the milk content; and 3) maintain a high fat:protein ratio to ensure an adequate fat content for manufacturing processes and good ripening properties. The primary and long-term objective of the breeder is to improve the ewes' dairy merit both in milk yield and milk composition.

As in the Lacaune breed, the objective of maintaining milk composition came only after a successful improvement of milk yield (Barillet et al., 1993). Other objectives can also include criteria such as milkability and mammary morphology (Marie et al., 1999). The merits of ewes' milk quality differ widely between breeds, with major variations in milk yield, composition and kinetics.

These discrepancies are compounded by the large variety of production systems (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). Most dairy sheep production systems include a short lamb-suckling period (3–5 weeks), and, after weaning, a long milking period (4–8 months), but "suckling-and-milking" can occur simultaneously during the first two months of lactation in some breeds (Caja and Such, 1991; Sheath et al., 1995).

In regard to 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, and increasing later in the 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 this chapter is to focus on the known effects of nutrition on dairy ewe milk composition (see review of Bocquier and Caja 1993, Bencini and Pulina 1997; Caja and Bocquier, 1998). Results obtained in dairy cattle and goats may not be successfully extrapolated to the dairy ewe. In addition, because dairy ewes are fed mainly in large flocks, it is necessary to briefly analyze the effect of 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 ewes' milk composition.

Level of nutrition

Energy supply and milk composition

The level of nutrition, mainly referred to as level of energy or of feed intake, is a major positive factor affecting milk yield and composition in dairy ruminants. Hence, a steep curve with an early and high milk peak 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, during the middle and 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, few experiments are based on 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.

Lactation period and reference	Breed	Diet: Energy (UFL/d)[1]	Diet: Protein (gPDI/d)[2]	Milk: Yield (l/d)	Milk: Fat (g/l)	Milk: 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
Gonzalez et atl. (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
Perez–Oguez et al. (1994)	Manch.	1.36–1.49	143–162	1.4–1.5	88–84	49
Milking:						
Treacher (1971)	Dorset	1.06–2.28	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
Perez-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 an early stage of lactation may have carry-over effects on milk composition during the milking period. Direct evidence of such effects are lacking; however (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 good quality forages ad libitum, the balance of energy reaches equilibrium within a 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 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 dairy ewe nutrition will reduce the percentage of milk fat.**

In comparison with fat content, and in agreement with cow and goat studies, 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 produces a 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 nutrition

Dairy ewes that graze in typical extensive or semi-intensive systems of the Mediterranean area periodically experience under-nutrition due to seasonal changes in forages or by-product availability (Caballero et al., 1992; Sheath et al., 1995). Moreover, in intensive large flocks of dairy ewes, even when food supply is theoretically sufficient, the stage of lactation and competition for food between ewes often leads to some individual underfeeding situations, especially in the cases of the most productive ewes in early lactation (or when rearing twins or triplets) which have higher nutrient requirements (Bocquier et al., 1995).

A negative energy balance produced by under-nutrition 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 under-nutrition is mostly physiological at the onset of lactation, its effects during mid- or late lactation are not well documented in dairy ewes (Bocquier and Caja, 1993) or in cattle (Coulon and Rémond, 1991). During this period, a severe and chronic under-nutrition of dairy ewes strongly reduced 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 a consequence of group feeding and is considered a normal way to restore body reserves in middle or late lactation. High levels of intake during lactation are achieved when ewes have high quality diets during early lactation (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 previously. The expected increment in milk protein content by increasing the level of nutrition during the milking period is 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 and as a consequence of group feeding practices, the observed global effects of level of nutrition (over- or under-nutrition) 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) indicates 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 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 nil above 300 gPDI/d. There is, however, no significant effect of protein (PDI) balance on milk content either on fat or 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 the 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 2.

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 significantly reduced 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 cows, and in general agreement with measures on Lacaune ewes.

Effects of concentrate in the diet

The effect of concentrate is positively associated with the energy level the diet produces as a result of its energy density. Another effect is that milk fat may be depressed and milk protein increased. Furthermore, using a high proportion of concentrates (>60% of dry matter) in diets may depress both the milk fat and protein contents during the first months of lactation (Eyal and Folman, 1978). These effects might be different according to the 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

Table 2. Effects of energy and protein content in the diet on milk yield and milk composition in dairy ewes.

	Energy level[1]		Crude protein (% DM) 14	16	19	Mean 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	54	52	54
	H	57	54	53	54	55
Milk urea N (mf/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 ENL/kgDM (i.e. 0.91 UFL/kgDM), H=1.65 Mcal ENL/kgDM (i.e. 0.97 UFL/kgDM).

Cannas et al., 1998

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 of lactating ewes, whereas bulk milk yield and composition are slightly or not significantly affected.**

Consequences of group-feeding on nutritional strategies

The dairy sheep allowances were established for an individual ewe or group of ewes with similar performance. They do not take into account differences 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 not possible and ewes' performance varies widely, it is common to supply more feed than the group's average recommended allowances. For example, in Lacaune dairy ewes, the main goal of feeding strategies is to give a diet that is adequate for ewes that contribute most to milk production (those that produce about 10% more milk than the group average). Therefore, the energy supply for such a group of ewes is calculated for individual milk production that is 10% above the actual mean milk yield.

The protein supply is generally calculated for 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 dietary protein induces protein waste, especially for the low producing ewes of the group. Few comparative trials of group-feeding strategies have been conducted in dairy ewes.

Bocquier et al. (1995) conducted an experiment to compare the effect of two strategies of group-feeding. Two similar groups of Lacaune dairy sheep (96 ewes each) were either fed all together (all levels of milk yield compounded) or after being separated into two subgroups according to milk yield (high and low). Total milk yield and milk composition were identical in both groups, but the "low-milk yield" subgroup showed a higher increase in body weight and body condition score at the end of the experiment.

Most of the beneficial effects of group feeding are obtained when concentrates are saved, with dairy performance generally maintained or slightly improved.

On the other hand, at any given time, milk yield variability in a flock comes from lambing dispersion. Direct effects of feeding on milk composition are hidden by the heterogeneity of performance. Studies conducted in France (Roquefort and Pyrenees) to measure the impact of within-flock lambing kinetic on annual milk production and its composition (Fraysse et al., 1996) factor this into indirect comparisons of flock performances.

Effects of specific nutrients on the composition of ewes' milk

Fat supplements

Interest in adding fat supplements to dairy sheep diets has increased in the past years as a result of the availability of new preparations of fat as food for ruminants and of favorable results obtained in dairy cows. Available information on dairy ewes is however, limited, and we especially focus on calcium soaps of long chain fatty acids (CSFA). The effect of protected fat on ewes' milk production and composition has been reviewed by Casals and Caja (1993) and Chilliard and Bocquier (1993). The main results regarding the milking period of dairy sheep are summarized in table 3.

First references (Pérez Hernández et al., 1986) in suckling ewes tried to improve lamb growth with contradictory results, but the 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 versus CSFA and Lacaune versus Manchega dairy ewes in indoor conditions. McKusick et al. (1999) studied the effect of CSFA in concentrate of East Friesian crossbred ewes.

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 milk protein content slightly 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 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 not significant after the ripening of cheeses. Change in the fatty acids profile of milk depended 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, milk production and composition. In this aim, Manchega and Lacaune dairy ewes were used during the 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 4.

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.

Table 3. 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	02	0.94	82	67
	"	72[1, 2]	1.00	84	63
Gargouri (1997)	Grazing	0	0.92	74	63
	"	961	0.83	83	61
Perez 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.*

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. Most of the references were obtained from suckling ewes, altering the practical significance of data of milk composition. In addition, some results are not significant or are 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 they included or substituted a degradable protein by fish meal (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 soybean and fish meal 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 fish meal, when compared with those fed soybean or peanut protein supplements. Effects of fish meal 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.

Protected proteins also gave interesting results, but in some cases are not significant or contradictory. Treatment of protein supplements with formaldehyde must be done at optimum doses (Caja et al., 1977). Ewes fed untreated soybeans compared to those fed fish meal and formaldehyde-protected soybeans 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 with lignosulphonate treatment is now available for ruminants. Evaluation of treated versus untreated soybeans 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 soybeans 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 with Methionine (0.11%) and Lysine (0.28%) of two concentrates for suckling ewes varying in its level of protein (10 and 16% crude protein). 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 also been shown that the protein content of milk can be increased by adding 3 or 6 g/d of protected Methionine at an early stage of lactation 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,

Table 4. 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.

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

The quality of milk can be defined in many different ways according to its final destination and/or to consumers' demands. In the future, however, on a very limited scale, some dairy ewes may be bred for their milk properties, because of the feasibility of producing pharmaceuticals in the milk of transgenic animals.

For the majority of breeders, the problem is to produce milk on a large scale. For them, the changes in the way to produce milk evolved gradually, based on scientific knowledge and technical progress. A major step was increasing the productivity of dairy ewes and controlling certain health aspects.

The second step was imposed by cheese manufacturers: Milk is now generally paid for on its ability to be transformed into cheese; that is, its fat and protein content. Nowadays, there are a wide variety of new objectives emerging from social groups. Among them, "natural" production, animal welfare, perennial land use and waste control are often cited.

These objectives appear somehow 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 determined collectively by breeders.

Hence, in France, it is illegal to treat dairy ewes with genetically engineered substances such as bST. In addition, in the Roquefort region of France, the use of some constituents of concentrates (ruminal-protected fat or amino-acids) or animal by-products is forbidden. The use of some substances found in feed is also being evaluated since these plants contain parts of transgenic plants.

Sheep milk producers are located mainly in the Mediterranean area. Their breeding system relies on local sheep breeds that are well-adapted to the environment and supported by local feed resources and cheese making and consuming traditions.

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Chapter 6

Udder morphology and machine milking

Interest in the dairy sheep udder has increased in the last few years.

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

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

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

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

Structure and development of the mammary gland

Origin and growth

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

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

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

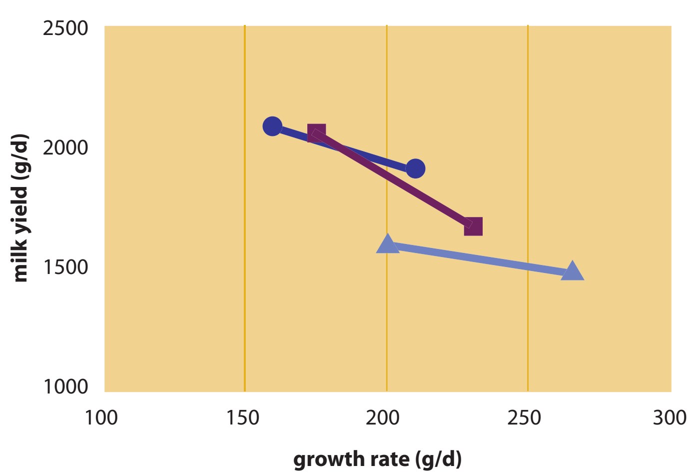
Puberty in most species is the quickest period of growth for ducts and stroma of the mammary gland (positive allometric growth), as a result of the action of sexual hormones. Nevertheless, the future milk capacity of the udder can be impaired at this stage by an excessive growth of the stroma (mainly adipose and connective tissues) in comparison to the parenchyma (tubulo-alveolar epithelium).

This critical phase occurs earlier in sheep than in cattle, with differences between breeds. Thus, the parenchyma growth ends in sheep before puberty and, as a consequence, mammogenesis in sheep will be affected by nutrition during and after the positive allometric growth phase (Bocquier and Guillouet, 1990).

The critical period for mammogenesis is from 2 to 4 months old. Early onset of puberty will bring forward the decrease in mammary development. According to Johnson and Hart (1985) and McCann et al. (1989), a relative low growth rate (50% of high rate) from weaning (week 4) to the end of rearing period (week 20) will increase the parenchyma growth and the milk production in the first lactation in non dairy ewe-lambs (figure 1). No negative effects were observed at the beginning of puberty. Nevertheless a low growth rate before weaning also negatively affects mammogenesis (McCann et al., 1989).

Unfortunately there is no detailed information available on dairy sheep, but Bocquier and Guillouet (1990) reported that **the restriction of concentrate in Lacaune ewe-lambs, after they reach approximately 28 to 30 kg, increases milk yield by 10% in the first lactation.**

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



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

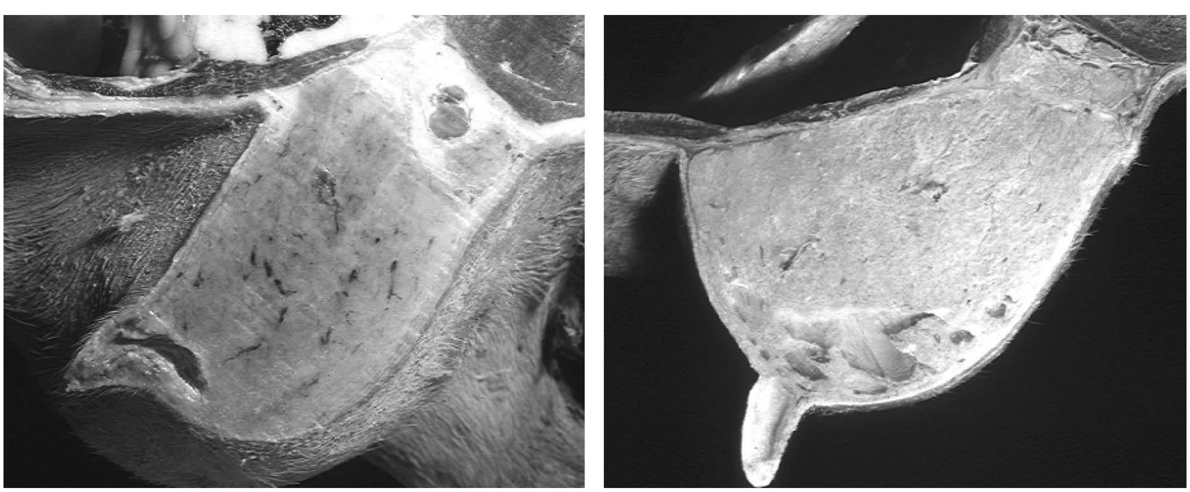
The presence of secretory lobes with alveolus in the extremes of the ducts can be observed in the second half of pregnancy. Delouis and Richard (1991) estimate a change from 10–90% in the relative weight of the parenchyma during pregnancy, where the lobulo-alveolar development of epithelial cells takes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

Internal structure of the mammary gland

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

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

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



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

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

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

In vitro anatomical studies are in some cases limited because the organ loses tone and becomes flaccid, which is important in the case of the udder. An *in vivo* image of the mammary gland structures can be obtained by the non-invasive technique of ultrasound scans.

A method for sheep mammography was proposed by Ruberte et al. (1994a) and its validity tested by Caja et al. (1999). The method has been used to show the milk ejection reflex in sheep (Caja and Such, 1999), to measure the cistern size and to compare the internal morphology of the udder in different breeds of dairy sheep (Rovai et al., 2000). This method demonstrates that the gland cistern is flat when empty after milking as a consequence of the pressure of the mammary suspensor system (figure 3). The method can also be used to estimate the distribution and movements of milk between the udder compartments and for non-invasive dynamic studies on cisternal milk.

Table 1. Cisternal and alveolar distribution in dairy sheep at mid-lactation according to the breed and the method used.

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

[1]*Oxytocin receptors blocking agent injected in jugular*

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

Rovai et al., 2000

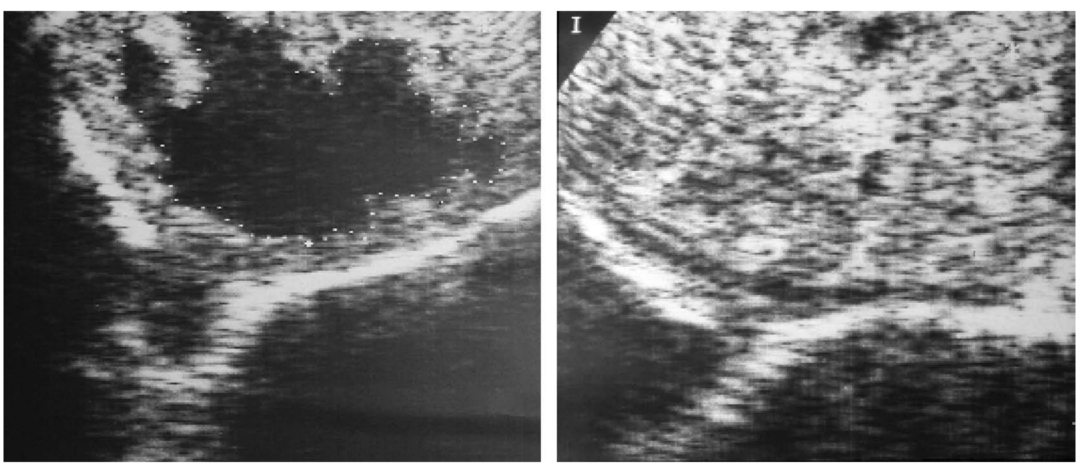
A different approach in the study of the cisterns and the lobulo-alveolar system in the mammary gland can be obtained by using the corrosion plastic cast method, normally used for the anatomical study of soft tissues (Ditrich and Splechtna, 1989; Ruberte et al., 1994b; Carretero et al., 1999). This method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

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

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

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

Ultrastructure of the mammary gland and changes during lactation in dairy ewes.



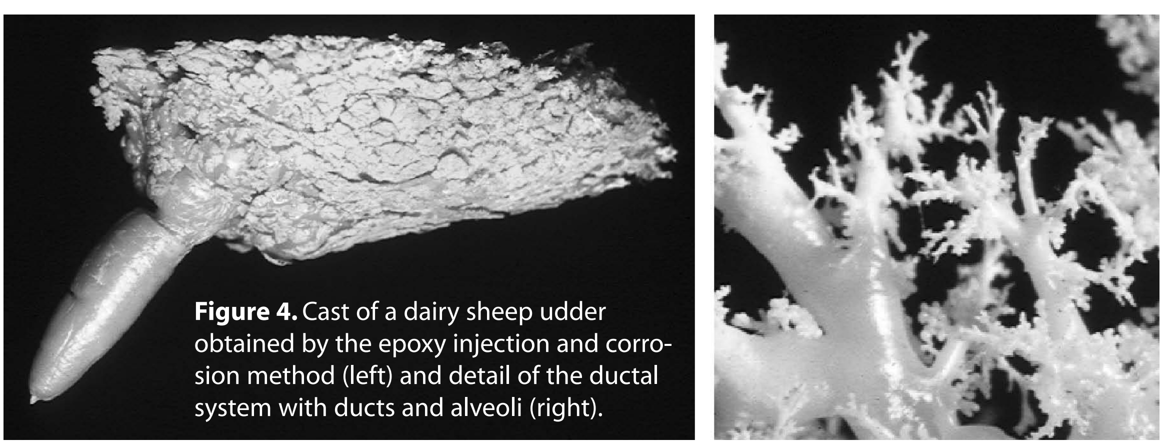


Figure 4. Cast of a dairy sheep udder obtained by the epoxy injection and corrosion method (left) and detail of the ductal system with ducts and alveoli (right).

al. (1999) in Manchega and Lacaune dairy ewes between weeks 1 (suckling) and 5 (start of milking) of lactation at the same time that a large number of alveolar sprouts were observed (figure 5.2).

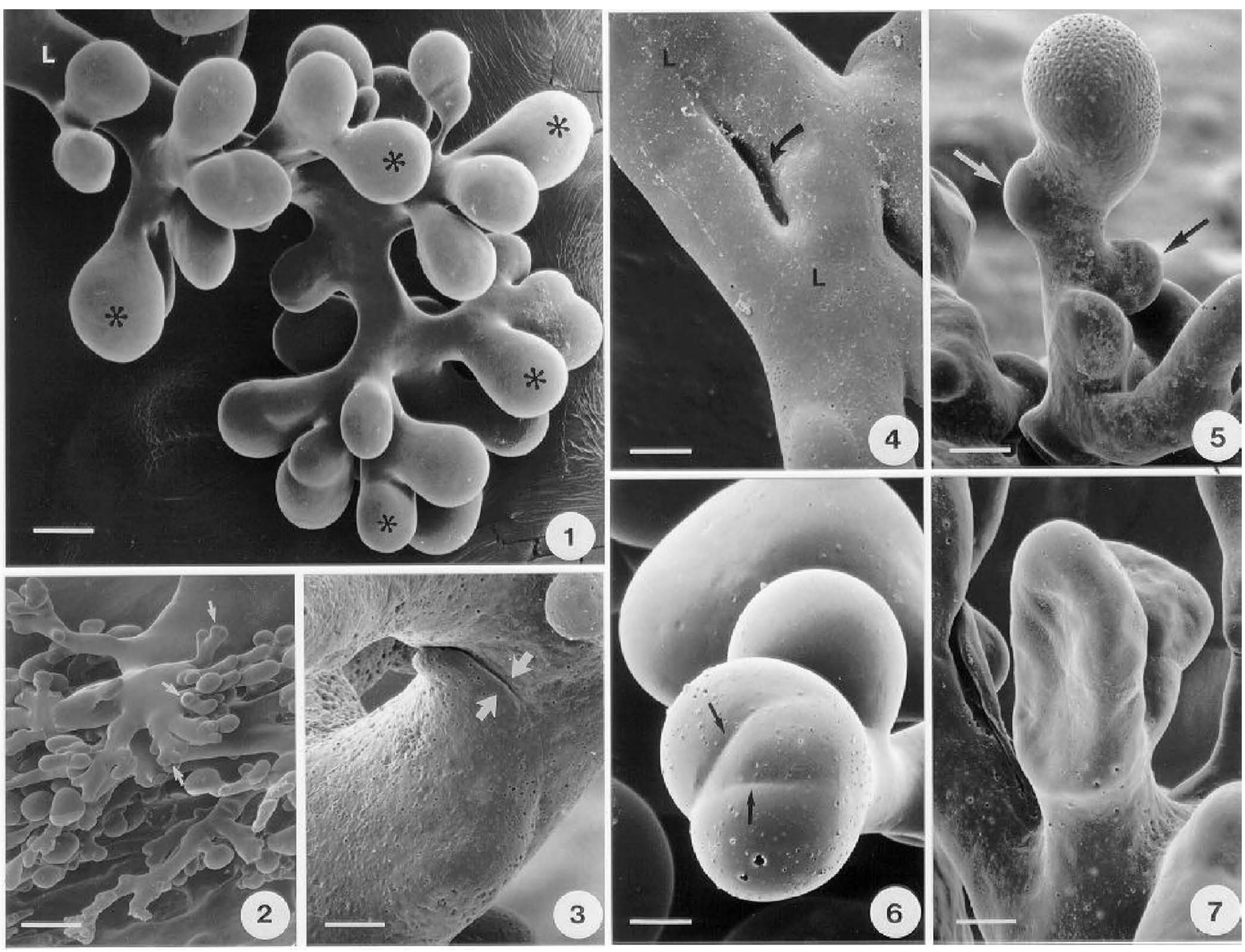
Both dairy breeds showed the same mammary structures and followed the same pattern of development during lactation despite the differences in reported milk yield. The development of the mammary canalicular system after parturition has already been described in primiparous sheep (Brooker, 1984) and goat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

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

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

At week 1 of lactation Carretero et al. (1999) reported the occurrence of 'intussusceptive growth' at the level of the lobular ducts in sheep during the suckling period. This new type of growth leads to an increase in the number of tubules from preexisting ones (figure 5.4). Intussusceptive growth has only been reported in some areas of the vascular system (i.e.,

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



lung vessels and widely during embryo development) and it is characterized by the formation of pillars of endothelial tissue in the lumen of the duct (Burri and Tarek, 1990; Patan et al., 1992). The pillars appear as transversal holes in the plastic casts. This convergence in the model of development of two different cellular lines, mammary gland ductal and vascular system cells, is produced despite their different embryonic origin (ectoderm and mesoderm origin, respectively).

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

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

External morphology of the mammary gland

Udder typology

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

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

- **Great volume, with globose shape and clearly defined teats.**
- **Soft and elastic tissues, with palpable gland cisterns inside.**
- **Moderate height, no surpassing the hock.**
- **Marked intermammary ligament.**
- **Teats of medium size (length and width), implanted near to vertical.**

Udder measurements

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

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

The most significant and repeatable udder traits agreed upon for a wide sample of sheep dairy breeds are:

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

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

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

Table 2. Mean values of udder traits and effects of breed, parity and stage of lactation in Manchega and Lacaune dairy sheep.

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

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

Rovai et al., 1999

Linear scores

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

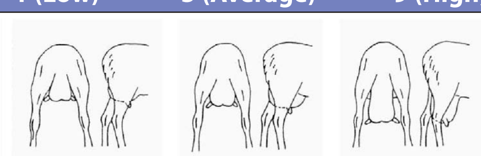
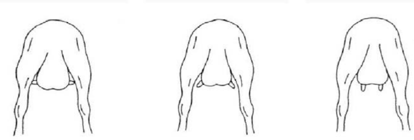
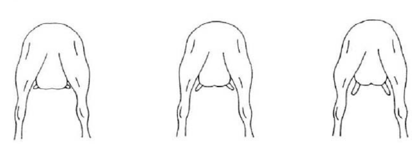
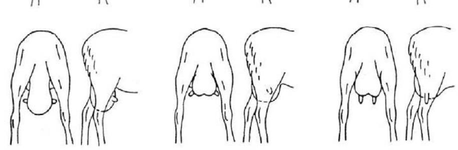
The four udder traits considered by De la Fuente et al. (1996; 1999) to be significant for machine milking are: udder depth or height (from the perineal insertion to the bottom of the udder cistern), udder attachment (insertion perimeter to the abdominal wall), teat angle (teat insertion angle with the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

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

This linear methodology has been used in Spain for the evaluation of different flocks (27 flocks and 10,040 ewes) of Churra, Manchega and Latxa dairy ewes (De la Fuente et al., 1999) and it is also being partially used in the Lacaune breed for the evaluation of morphological traits in relation to machine milking ability (Marie et al., 1999). Results for Spanish breeds are shown in figure 7 according to lactation stage and parity effects.

In regard to lactation stage, all linear scores decreased as lactation progressed, udder height and udder attachment being the traits that showed the greatest decrease during lactation. Teat size was only slightly modified. This evolution agrees with the loss of udder volume and milk yield but indicates a deterioration of udder morphology for machine milking as indicated by udder shape. Only udder height was improved. Regarding lactation number, udder height increased dramatically in the first lactations, while other traits decreased and teat size was steadily constant. As a consequence, udder shape deteriorated and its score decreased rapidly from first to third lactation and stabilized thereafter.

Table 3. Linear scores for the evaluation of main udder morphological traits in dairy sheep.

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

De la Fuente et al., 1996

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

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

Repeatabilities of udder linear scores obtained in the Lacaune dairy breed (Marie et al., 1999) were also high (r=0.59 to 0.71) and show moderate phenotypic correlation with milk yield in primiparous and multiparous ewes. Heritabilities of udder traits reported in Assaf (h^2= 0.23 to 0.42; Gootwine et al., 1980), Chios (h^2= 0.50 to 0.83; Mavrogenis et al., 1988), and Sarda with the seven expanded typologies (h^2= 0.55; Carta et al., 1999), gave higher values but, as indicated by the last authors, probably they were overestimated.

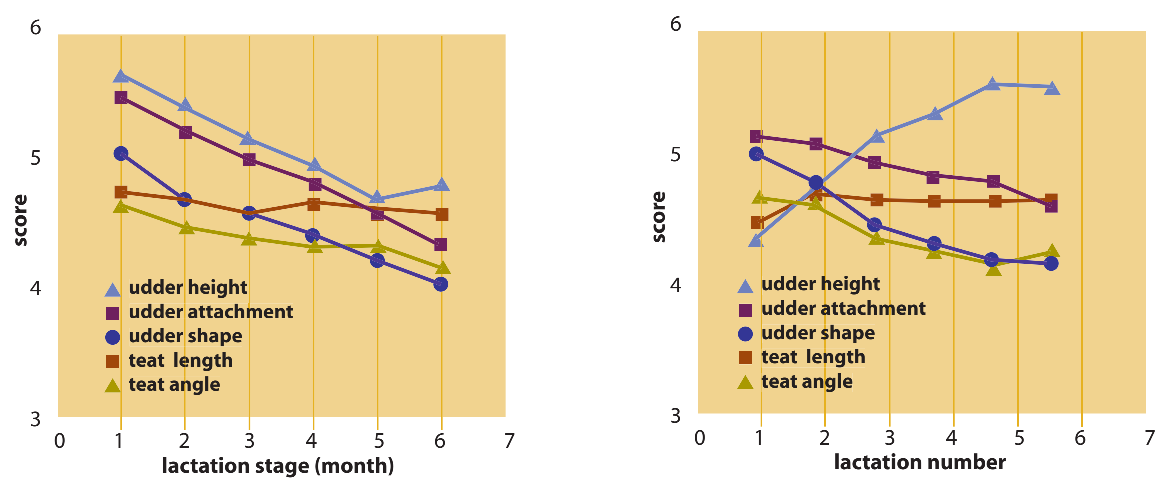
The genetic variability and heritability of the studied udder traits indicate that the efficiency of the breeding programs could be improved and some selection on udder traits in long-term breeding programs needs to considered.

Table 4. Genetic parameters of linear udder traits in dairy sheep.

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

Fernández et al., 1997

Figure 7. Evolution of linear scores of main udder traits in Spanish dairy sheep.



De la Fuente et al., 1999

Machine milking

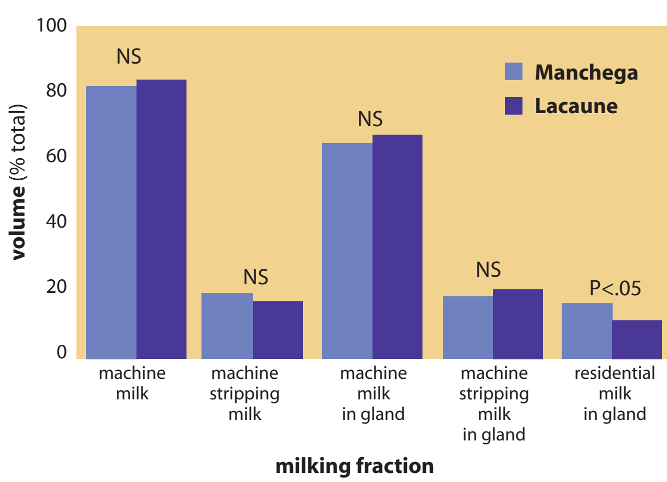
Machine milkability is normally estimated by fractional milking (machine milking, machine stripping, and extraction of residual milk after an oxytocin injection) or by analysis of milk emission curves obtained during machine milking without massage or extra stimulation of the mammary gland. The methodology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

Milk fractioning

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

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

Figure 8. Milk fractioning obtained during machine milking of dairy sheep according to the breed at the same stage of lactation (Such et al., 1999a)



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

Milk emission

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

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

Marie et al., 1999; Marnet et al., 1999), but results and conclusions of flow may be different in consequence (Rovai, 2000).

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

An early typology of milk emission curves was proposed by Labussière and Martinet (1964), and widely adopted for the study of sheep dairy breeds (Labussière, 1983, 1988). The milk emission typology considers curves of different shape: 1 peak (single), 2 peaks (bimodal) and others, the last corresponding to animals with irregular or multiple milk emission curves (≥ 3 peaks). In some cases, a ewe changes the milk emission typology on consecutive days, and more than two recordings are recommended in practice. The first peak occurs very early after cluster attachment and it is identified as cisternal milk, which is drained after the opening of the teat sphincter. The second peak corresponds to alveolar milk and occurs as a consequence of liberation of alveolar milk during the appearance of the milk ejection reflex by effect of released oxytocin (Labussière and Martinet, 1964; Labussière et al., 1969; Fernández et al., 1989b; Marnet et al., 1998).

Milking-related release of oxytocin has been measured in dairy sheep by Mayer et al. (1989a) and Marnet et al. (1998). The machine milk fraction is normally greater and high milk flow maintained during a longer time in the bimodal ewes, which are considered favorable for machine milking in dairy ewes. Milking of ewes showing a single milk emission curve can be completed by using a milking routine with machine or manual stripping ('repasse') after cessation of the machine milk flow, which is unfavorable and increases dramatically the total milking time per ewe. Moreover, simplified milking routines (without hand or machine stripping) are well accepted by bimodal ewes as indicated by Molina et al. (1989) in Manchega dairy sheep.

Distribution of animals in a flock according to number of peaks has also been used as an index of machine milkability in dairy breeds as indicated by Labussière (1988). Sheep breeds with a greater percentage of ewes showing 2 peaks are the most appropriate for machine milking. Nevertheless peak distribution in a flock changes according to the stage of lactation as observed by Rovai (2000) in a flock with breeds of different yield and milkability (table 4). Number of ewes in the 1 peak typology increased at the end of lactation and on the contrary the ≥ 3 peaks decreased compensating the losses in the 2 peaks group.

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

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

Table 4. Distribution (%) of milk emission curves obtained in dairy ewes during machine milking according to breed and stage of lactation.

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

[1] First week after weaning at day 35 [2] Number of emission curves analyzed *Rovai, 2000*

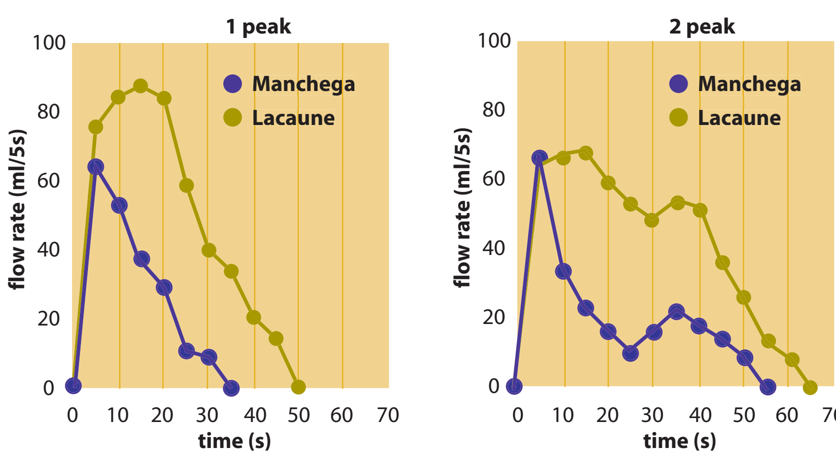
Significant differences in the values of maximum milk flow (76 vs 129 ml/5s) and milk peak volume (207 vs 586 ml) were observed for the 1-peak Manchega versus Lacaune ewes, respectively. The significant values for the 2-peaks ewes were: first peak (72 vs 94 ml/s; and, 171 vs 344 ml) and second peak (41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

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

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

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

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



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

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

Conclusion

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

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Chapter 7

Management for better milk yield and quality

Solutions lie in a better understanding and use of milk ejection mechanisms.

There are a number of methods to improve the quality and quantity of milk, some of which have been neglected in the past 20 years. Much work has been dedicated to feeding and genetic improvement of milk yield and composition, but the milking process has been considered secondary because milking equipment technology has not evolved sufficiently. In Europe, the extension of milk quotas (restriction to the right to produce) to small ruminants has encouraged farmers to seek technical solutions to improve the quality of the milk and at the same time simplify working procedures. Some solutions lie in a better understanding and use of milk ejection mechanisms.

Review of milk synthesis and ejection

After a phase of mammary growth (secretory alveoli and ducts) controlled mainly by ovarian steroids, the milk surge, or lactogenesis, will necessitate stimulation of secretory cells by a number of pituitary hormones; prolactin and ACTH in particular. Note that inducing lactation artificially only requires the administration of steroids to prepare the udder for these pituitary hormones before turning the animals to milking.

Milking, through udder stimulation, induces the release of a hormone compound necessary for the ultimate phase of mammogenesis and the induction of lactation. To maintain lactation, other hormones that preferentially act on mammary metabolism, such as growth hormone (GH) are needed. It is worth noting that udder clearance is always followed by GH release.

This also explains the so-called lactation maintenance reflex linked to mammary gland stimulation. Once the milk has been produced, it still has to be drawn from the udder, otherwise drying-out will occur very quickly.

This means that the accumulation of milk, adding to the lack of hormones required for milk synthesis, will stop the cellular mechanism. Two reasons have been put forward to explain this. First, pressure in the secretory alveoli crushes alveolar cells and impedes secretion vesicles' transfer and also slows down the passive passage of elements from blood to milk. The second cause is thought to involve one or several lactoserum peptides (Feedback Inhibitor of Lactation: FIL) which, by accumulating in the alveoli, have inhibitory effects on lactose synthesis.

This clearly demonstrates the importance of thoroughly draining all the milk contained in the alveoli at each milking. But thorough draining requires the active participation of the animal. Indeed, if between milkings the milk is partially discharged into the cisterns in the lower part of the udder, some remains in the alveoli and in the small galactophores at the top of the udder. That milk contains much more fat because fat cells are larger than the diameter of these small ducts.

To be extracted, that milk must be expelled from the alveoli by the pressure applied on the alveolar wall by myoepithelial muscle cells. These cells spontaneously contract (smooth muscle cells), but the ejection of milk will only be effective if their contractions are synchronized, which can only be achieved if they are stimulated by a neuropituary hormone, oxytocin. Again, the release of that hormone in blood results from a neuro-humoral reflex initiated in the udder. So optimizing milk ejection comes down to retrieving the milk and usable matter that was produced through genetic selection and feeding, and thus optimizing the animal's potential. The milk, by going down into the cisterns, increases the intramammary pressure and the pressure ratio between the cisterns and the mouth of the suckling lamb or the machine vacuum nozzle. This also accelerates draining and makes milking quicker.

Finally, if all information transits through the central nervous system, it is likely that the CNS may act as a modulator of response to udder stimulation. For instance, the connections of the oxytocin-producing hypothalamic nuclei (supre-aortic and paraventricular nuclei) to the limbic system, which is the emotion site, and the cortical areas which are the memory sites, explain why recognition of an anxiety factor (biting dog, stranger on the farm, sudden replacement shepherd, bleating of lambs, undergoing treatment such as injection or foot trimming, shearing noise) may inhibit oxytocin release and hence milk ejection.

Other factors, on the contrary, may facilitate milk ejection. In suckling farms, it is the sight and cry of the young and in dairy farming, when all is well, the sight of the usual milker, the starting of the vacuum pump and/or pulsation, entering the milking pen and above all concentrate feeding in the milking pen. It has to be noted that there is a close relationship between oxytocin and another peptide: CCK (cholecystokinine). Although this has not been proven in ruminants, the CCK released at the peripheral level when the feed bolus reaches the stomach is thought to induce oxytocin release and might therefore promote milk ejection. However, CCK may also be released at the central level, which controls rumination. But oxytocin may in turn induce CCK release. This implies therefore that rumination nearly always follows oxytocin release and milk ejection.

An animal that does not ruminate in the milking pen is not in favorable conditions and will not express its full potential.

Respecting the animal and stimulating it as much as possible may appear coarse (but not that easy), but is necessary to extract all the secreted milk as quickly as possible and to maintain lactation.

Milk ejection

Milk ejection, which in dairy cows usually occurs during massage and in the first minutes of milking, has to take place within only two milking minutes in ewes. It therefore requires careful animal selection and optimal setting of the milking machine. Milk ejection can be monitored during milking without using any invasive technique and without bothering the animals.

Measuring the milk emission output at milking is sufficient. The technique has produced very interesting results in terms of the distribution of milk in the udder and is still a reference method for selecting animals according to their milking easiness.

In ewes, milk generally flows in several stages. The first outflow peak corresponds to cisternal milk discharge. Then a second outflow peak occurs only if the nervous connection between the udder and the CNS is unimpaired. That outflow therefore depends on oxytocin and represents the volume of milk trapped in the small galactophores and the alveoli. That milk is called the alveolar milk.

Last, a third increase in outflow is noted at the time of stripping. That milk fraction represents the milk below the teat in the mammary gland pockets. If the ejection of alveolar milk is incomplete, the massage performed during stripping and the tap stimuli applied by the milker under the udder will help in retrieving all or part of it. Note that in the early days of mechanization, the poor performance of the machines, and the large number of ewes that did not respond to mechanical milking stimulation forced the milkers to perform hand milking to retrieve residual milk after removing the milking bundle. That operation is now rarely performed.

In 1982, almost all of French Lacaune ewes were unresponsive and necessitated time-wasting and tedious stripping and manual re-milking operations for all the milk produced to be retrieved and collected. In 1995, only 7–8% of these remained, mainly ewe lambs. Those ewes, which only emit their cisternal milk have lower milk yield, less rich milk (up to 70% of the fat can be trapped in the alveolar fraction between milking) and poor lactation persistence. These ewes therefore are removed from the flocks.

It should be noted also that ewes with poor reflex have a lower milk outflow, inducing protracted milking times. It is therefore important to carry on selecting ewes according to their milk emission kinetics.

Today, because of the sharp increase in the volume of milk produced, cisternal milk often does not finish flowing when the alveolar milk ejected by the action of oxytocin reaches the teat. As in cows and goats, it becomes difficult or impossible to distinguish between the two emissions and to measure their respective outflow. At most, the reflex is known to have occurred if the milk emission kinetics lasts for more than 40 seconds with a high outflow, which is the maximum time for effective oxytocin release.

There is a good correlation between the cisternal milk volume and milk yield. That volume currently represents as much as 38% of total milk yield on average. The alveolar milk volume is similar (34%) and so up to 28% of total milk is represented by stripping milk. Stripping is therefore mandatory. But a large part of that stripping milk is linked to the mammary gland morphology, not to a problem of effective milk ejection. Selection according to milk production performance has resulted in larger cistern volumes, partly due to the enlargement of the pockets at the base of the udder. Consequently, the teats are higher and their position precludes complete drainage of the mammary gland.

Furthermore, that teat position makes the fitting of nozzles more difficult and may induce air intake or bundle disconnection detrimental to the udder health (by the impact on teats and increased risk of germ contamination). It is therefore crucial, as in dairy cows, to select ewes considering their udder morphology and by choosing animals with teats as vertical as possible, properly draining the udder. Combined with a good oxytocin release, vertical teat placement will warrant effective milking, which can be simplified by automatic cluster removal, a technique known to reduce overmilking and improve teat health in cows. Among the various ewe breeds, some have milk emission kinetics with a single flow peak, high volume emission (a characteristic of Friesian ewes).

If there are fewer of these ewes with oxytocin release at milking than the more highly selected Lacaune ewes, it is nonetheless true that these animals offer large cistern volume and the ability to transfer alveolar milk into cisterns between milkings. This ensures that synthesis will not be hindered and that the secretory potential will not be reduced throughout lactation. In addition, poor setting of the milking machine or the presence of milking-refractory animals will have less impact and milking will be simplified.

The effect of oxytocin release between milkings on the distribution of milk in the udder and on milk yield has been verified. It appeared that if blood oxytocin is maintained throughout the day at the same level as during milking, the storage volume increases in proportion with total milk and the alveolar milk volume slightly decreases and holds. The result is an 18–25% increase in milk yield. Whatever the reason, good milk transfer between milkings appears to be as important a factor of better milk yield and easier milkings as milk ejection during milking. It is worth noting that luteal oxytocin could be among the factors causing that transfer, because milk transfer in the cistern increases when there is sexual activity. Other milk ejection factors have been evidenced in ovaries, which led us to deepen our knowledge of the relationship that exists between the ovarian sphere and the udder.

Oxytocin titration does not provide information about the occurrence of milk ejection because the important factor is the form of release rather than the amount of oxytocin released. Indeed, sustained oxytocin release results in high intermammary pressure during milking and thus, quicker and complete draining of the udder. There is also a very small number of cases when oxytocin release occurs and has no effect on the udder. There are multiple reasons for that but the most likely ones are the absence or deactivation of receptors on the mammary gland. Catecholamine release may also occur at the peripheral level, reducing mammary blood flow to a point where the oxytocin level is no longer sufficient to ensure effective alveolar contraction. Considering the costs of oxytocin assays and the necessity to perform several of these tests during the course of one milking, the methods should remain experimental or at the most be used to select the best breeding ewes in breeding units.

Ewe management at milking

There are many different ways to manage dairy ewes. In the very intensive Mediterranean systems, ewes are managed the same way as dairy cows. Weaning occurs immediately after lambing, followed by exclusive milking to the end of lactation (150–200 days). In that case, the lambs are artificially reared and difficult to train because they never learned from their mothers. In many cases, however, a variable suckling period precedes exclusive milking.

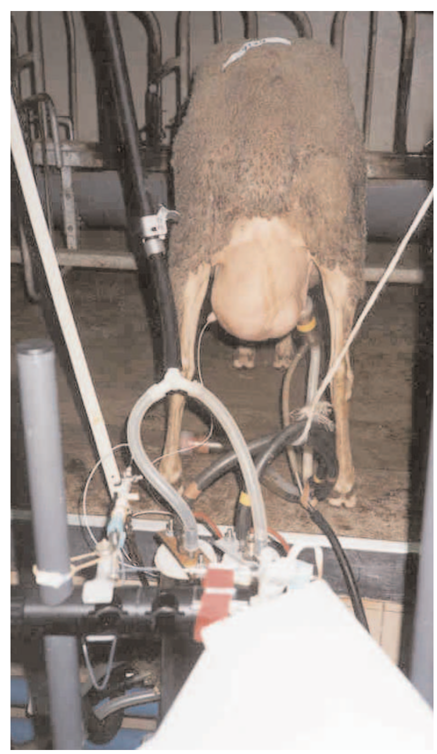
In the largest flocks, lambs are suckled to weaning. In smaller flocks, the point is to provide colostrum cover and to await the seasonal opening of specialized creameries such as those of the Roquefort region in France. In that case, however, milk production in Lacaune ewes, which has doubled in 20 years and largely exceeds the intake capacity of the lambs in the early stage of growth, no longer permits exclusive lamb suckling without hindering lactation. For that reason, milking has been combined with suckling for complete mammary gland drainage and to train the ewes to come to the milking pen. How to choose between those systems? According to Labussiere's results, it appears that the more the ewes suckle their lambs, the greater difficulty they have giving their milk to the machine while releasing oxytocin.

The drop in milk yield observed at weaning (23–35% according to breed) is explained mostly by the reduced frequency of daily drainage (-20 to -25%) but also by the mother-lamb separation effect (estimated at -3 to -7%). Mixed management never really reduced the drop in milk yield at weaning.

This is clearly explained because recent studies have shown that as long as the ewe has daily contact with her lamb, she refuses to release oxytocin at milking. However, she does it without any problem when suckled (selectiveness). The proximity of the lamb in the milking pen (unfeasible in practice) restores the milk ejection reflex, which demonstrates the necessity of the lamb effect (most probably olfactory and visual) for milk ejection to occur. Ewes however get used to the milking pen and passing to exclusive milking is made easier by their calmness. As early as 48 hours after lamb separation, the ewes begin releasing oxytocin at milking, contrary to exclusively suckling ewes, a proportion of which will never adapt. The rate of adaptation to milking is also the same as that observed in ewes turned to exclusive milking upon lambing. This latter method however has to be considered with caution. Our studies show that oxytocin release is less effective if the mother does not establish her maternal instinct; that is, if the first sucklings are not performed. So a 24-hour maximum contact between ewe and lambs is beneficial, and the lambs remain easy enough to train for artificial suckling.

Although this remains to be verified experimentally, our results and those of "controle laitier" (EN: official milk testing) would tend to show milk yield higher as mixed management lasts longer. These results could be easily explained by the establishment and repeated stimulation of a strong ejection and secretion reflex, effective in early lactation. Lastly, mixed management permits functional selection based on the morphology of the udder and teats because as a rule the ewes not capable of suckling their lambs are removed from the flock. Consequently, flock homogeneity is greater and milking is easier. Although no reliable data are available in that respect, the users of the various methods have not reported any significant effect on udder pathology.

Apparatus used for half udder studies by Professor Marnet in Rennes, France.



Machine milking

The milking machine must be stimulating enough to ensure strong milk ejection during the very short milking time. Also, ewe milking includes time-consuming manual operation (stripping and possibly "re-milking" that should be reduced to a minimum, in particular by selecting well formed udders).

Proper setting of the machine however may help increase the productivity of the milker and at the same time simplify his task. Initially, choosing a pulsation rate as high as 180 ppm was motivated by the need to emulate the natural condition of lamb suckling as best as possible.

All our experiments aimed at comparing pulsation rates from 60 to 180 ppm have shown that milk yield is very slightly higher when the rate is set above 120 ppm. The mechanical milking and stripping milk volumes do not vary significantly, but the most spectacular effect is an increase in the re-milking volume at 60 ppm, whether the pulsation ratio is 33% or 50%. Pulsation ratio trials tend to show that ratios below 50% would incompletely drain the teats. Oxytocin assays elicited significantly lower release in that case, and it can thus be concluded that a pulsation rate below 120 ppm is too low to stimulate Lacaune ewes and does not ensure total drainage and retrieval of all the usable matter. It should be noted also that cup drop is more frequent (with rubber liners) when the pulsation rate is low.

The vacuum pressure chosen is between 36 and 53 kPa. The most recent tests we performed showed that the vacuum effect is mainly sensitive on the milk retrieved after stripping. This may be due to a disruption of mammary drainage induced by teat elongation, liner clambering and very obvious congestion of the teats. This effect therefore is more a physical one. However, considering that the vacuum pressure setting is a trade-off dictated by the weight of the bundle and the need to prevent it from falling off, the solution could be to operate under lower vacuum pressure (36 kPa) with lighter bundles and better gripping liners (silicone). However, with no air intake at the clamp, the rated vacuum pressure under the teat may transiently exceed the regulator pressure and damage the teat while increasing the leukocyte count. It is therefore recommended to maintain some air intake, even if it means increasing the vacuum reserve slightly.

The best trade-off would be low vacuum pressure (36 kPa) and high pulsation rate (180ppm) with a 50% ratio.

Note that with such a setting the leukocyte count will be higher than with a lower pulsation rate. There is no upper aggression on the mammary tissue. In fact that effect is only sensitive in animals with leukocyte counts above 200,000 cells per milliliter (sterile controlled milk). So the increase in leukocyte count is only the result of the expulsion of the cells contained in the alveoli, through which they enter the udder. This clearly confirms better drainage induced by oxytocin and permits earlier detection of possible udder infections.

Finally, the choice of liner is crucial for the optimum application of the machine settings to the teat. There is no impact on milk yield if the milker performs proper stripping. This means that the teat liner has to be chosen carefully to facilitate physical drainage to the udder. Silicone liners appear to reduce cup drops and liner slipping and are therefore recommended. However, the most spectacular effects are produced by the design of the cup and the flexibility of the liner body. Stripping is highly reduced when the cup diameter is increased to restrict teat squeezing at the end of milking; otherwise air intake is facilitated and cup falls are more frequent. A very hard liner may increase stripping considerably because it moves more slowly and remains open longer than a softer liner. Indeed, milk outflow can be accelerated but the effect of that on the teat is deleterious (upper congestion) and the liner clambering is more marked. The flaring pressure for ewe liners is thought to be close to 10 kPa.

A number of factors are yet to be tested or re-tested because of the ongoing standardization of milking equipment for small ruminants. Further advances are still possible through blood oxytocin assays, measurements of teat congestion and udder immunological condition assessment, as indices of the physiological effect of the equipment and of udder health.

Conclusion

Adding the losses in milk and usable matter to those in milker time and discomfort that can be endured unknowingly when operating under poor conditions, the losses can add up to impressive figures (up to 20–25%). It is therefore necessary to use animals with good mammary conformation (large cisterns, well drained by vertical teats at their base), good sensitivity to stimulation by the milking machine, and good and sustained oxytocin release during and possibly between milkings.

High milk output at milking will ensue and working time will be reduced accordingly. In more intensive systems, ewes exhibiting low maternal instinct will be preferred to facilitate weaning and adaptation to mechanical milking. The equipment will be adjusted so as to be stimulating (high pulsation rate) and optimize oxytocin release and increase drainage effectiveness and non-aggressiveness (low vacuum pressure) to avoid tissue congestion and poor teat drainage, which would necessitate additional manual operations. All these operations, by better draining the udder, will ensure and maintain better milk yield throughout lactation, all the more so as they are performed frequently in early lactation. In that respect, mixed management appears to be an additional asset if the right to produce is not restricted.

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Chapter 8

Mastitis: detection and control

The pathogen bacteria found in the milk of animals with mastitis can pose a threat to human health.

The presence of mastitis in a dairy herd, either cows or sheep, can have an important impact on the financial returns of the operation. Mastitis (clinical or sub-clinical) lowers the total milk production, changes the composition of the milk, and affects quality.

More importantly, the pathogen bacteria found in the milk of animals with mastitis can pose a threat to human health. Therefore, it is important to reduce or eliminate the incidence of mastitis. This occurs by first detecting animals with the disease, treating or culling them, and by respecting some hygienic rules to prevent the recurrence of the disease in the flock.

Mastitis

Clinical mastitis

Peracute mastitis

This is the most well-known form of mastitis, easily recognized and generally characterized by acute and rapid inflammation of one side of the udder. The udder becomes hard, red and hot. No milk is secreted but there is a small amount of a clear, sometimes bloody, malodorous liquid discharge. The animal appears to be in pain and presents a high fever (41-42°C). Morbidity is high. Ewes can respond to high level of penicillin but the udder often becomes gangrenous. In case of recovery, the affected side stays non-productive because of extensive damage.

A milking ewe with peracute mastitis should immediately be removed from the milking group.

The incidence of peracute mastitis is generally no higher than 5%. It is caused by microbial agents such as ***Staphylococcus aureus*** and to a lesser degree by *Streptococcus uberis* and *Steptococcus suis* or by other agents such as *Pseudomonas aeruginosa* and *Aspergillus fumigatus*.

Peracute mastitis in dairy ewes caused by *Staphylococcus aureus* occurs mostly during the suckling period or immediately following the period of exclusive milking. Compared to dairy cows, the drying off period is not a high-risk period for peracute mastitis.

Acute or chronic mastitis

Acute mastitis can often be detected by palpation and observation of the udder, (asymmetric udder, nodules in one or two halves, hypertrophy of lymph nodules) and/or by the appearance of the milk, which may contain flakes, purulent material or be discolored.

Chronic mastitis may result from a spontaneous healing of a case of peracute mastitis. Ewes with chronic mastitis should be removed from the milking herd because of their lower milk production, but mostly because they represent a reservoir of infectious agents.

Sub-clinical mastitis

Sub-clinical mastitis is an insidious infection of the udder characterized by an inflammation that is not easily detected at its early stage. The animal might appear physically normal and its lower production might go unnoticed.

Sub-clinical mastitis in dairy ewes (as in goats) is due to Coagulase Negative Staphylocci (CNS) mostly ***Staphylococcus epidermis*** that live on the skin of the udder or on the teat. The proximity of the source of infection makes it very easy for a large number of ewes to become infected with the bacteria. Rates as high as 30–40% have been reported on Manchega and Assaf ewes by Las Heras et al (1998); 20–30% in the Roquefort area of France (Bergonier et al. 1997); but also as low as 7–8.5% in a flock of Corriedale milking ewes in Uruguay (Apollo et al. 1998).

The incidence of mastitis varies with the level of hygiene and the milking technique of the producer.

Sources of infection

The principal reservoirs of Staphylococci are the infected udders as well as the infected lesions of the teats. They can also be found on the skin of the udder and can survive a long time in the milk lines of the milking machine even when they are correctly cleaned. Other causing agents of mastitis can be found in bedding, molded forage and water. It is therefore easy to understand that the spread of bacteria can occur very easily from one animal to another when the hygienic conditions are less than satisfactory.

Reduce mastitis by observing the following rules:

- **Detect infected animals early; then follow up with either a treatment or culling.**
- **Wash hands frequently during milking. Milkers should wear latex gloves to decrease the possibility of spreading bacteria from one udder to the other.**
- **Shut off of the vacuum line when removing the teat cups to avoid possible infected milk droplets reaching the teat opening of the next ewe.**
- **Correct vacuum level and pulsation.**
- **Do not over-milk, which can cause trauma to the teat and increase susceptibility to infection.**
- **Clean the milking machine thoroughly.**
- **Clean air lines thoroughly.**
- **Change teat cup liners and milk lines periodically.**
- **Provide abundant fresh bedding for ewes in confinement.**
- **Clean the waterers.**
- **Conduct a post dipping program.**

Treatment of mastitis

In case of peracute mastitis due to microbial infections, the objective is to prevent the animal's death by administering high doses of penicillin. Success is not always guaranteed. If the animal recovers, the affected half udder always presents lesions and becomes non-functional, justifying the immediate removal of the infected animal from the milking flock.

Treatment of sub-clinical mastitis is more ambiguous because it necessitates the detection of the infection. In dairy ewes the spontaneous elimination of the infection by natural biological defenses of the animal has been estimated at 60% in a dry-off period of four months (Bergonnier et al. 1997). Therefore, a large reservoir of animals that can carry the infection from one lactation to the next and be a source of infection may still be present.

Antibiotic treatment by intramammary injection of antibiotic **after dry-off** is a viable solution in flocks with high incidence of sub-clinical mastitis. The procedure has to be performed in the utmost hygienic conditions to avoid spreading infection to healthy animals.

Prevention, detection and elimination of problem animals should be a priority. The detection of animals with sub-clinical mastitis is fundamental but not easy. Bacteriological examination of the milk can be done but it is a long and expensive process. It cannot be done to detect mastitis on a regular basis. Somatic cells in the milk on the other hand can be observed rapidly and counted with electronic devices (Fossomatic type) which count all nucleated cells present in the milk including epithelial cells.

Somatic cells

Somatic cells are an integral part of mammary secretion and are found commonly in milk. According to Ranucci and Morgante (1997) somatic cells in the milk of healthy sheep are constituted of **macrophages** (55–70%), of **Polymorphonucleated Neutrophyl Leukocytes** or PMNL (15–40%) which have the important biological function of phagocytic activity, of **lymphocytes** (6–14%) and of other cell types (eosiniphils, epithelial cells and non identifiable cells) in lower percentage (0–5%).

When the mammary gland becomes inflamed, different cell types remain the same but change markedly in their distribution. PMNL become more prevalent, as do lymphocytes in the case of staphylococcal mastitis (the most common mastitis in dairy sheep). Therefore, the main variations of somatic cells as well as their increased number are caused by an inflammatory condition of the mammary gland that may be clinically evident or sub-clinical. **All studies indicate that a significant increase of SCC in milk represents an inflammatory condition of the mammary gland.**

Because of the strong relationship between udder health and the amount of somatic cells in the milk, regulations in most countries have put a limit in the SCC above which milk cannot be marketed or above which penalties in terms of payment have been imposed by milk processors.

A rise in somatic cell count is not always due to an infection. There are some non-infectious factors that might have an impact on the detection of infection.

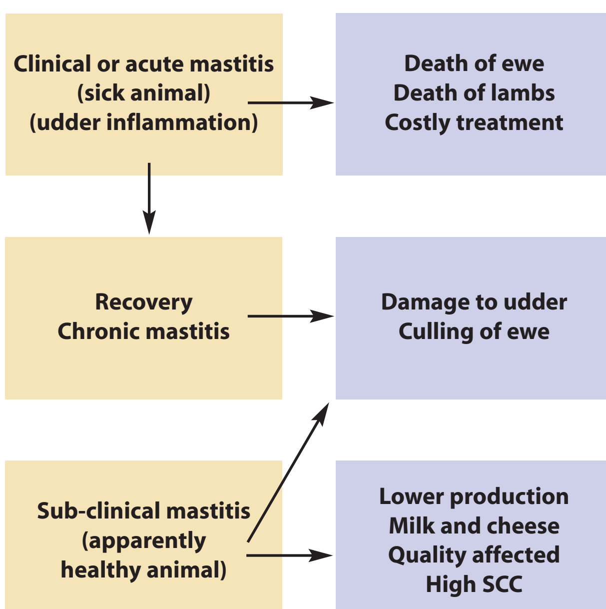
Non-infectious factors of variation of SCC

The non-infectious variation factors of somatic cell counts have been well reviewed by Bergonier et al. (1994).

Variation between milking fractions

Stripping milk, (milk obtained at the end of milking by massaging the udder) contains 1.7 times more SCC than the foremilk, milk obtained before applying the teat cups. The milk sample taken for the counting of somatic cells should therefore be taken from the total milk obtained during milking.

A high somatic cell count is generally an indication of an inflamed udder.



Variation between morning and evening

Somatic cell count is generally greater in the evening milk than in the morning milk. The differences are particularly important when the intervals between milkings are irregular. The greater the interval between evening and morning milkings, the larger the difference. To minimize discrepancies between samples it is important to keep a constant milking interval.

Variation between days or weeks

Variations from one day or one week to the other have been reported but not always quantified in dairy sheep. In cows, daily variations of 20–30% are not uncommon. Those variations are due to unknown causes. Therefore it is not possible to conclude that an animal has an intramammary infection because of higher SCC at the view of only one sample.

Variation during the lactation

In healthy dairy ewes put at exclusive milking after a 30-day suckling period, the SCC is generally elevated at the start of milking. This is due to the stress caused by the change of several udder evacuations per day (suckling) to only twice a day (milking). The SCC rapidly decreases after a week or two and stays stable for a good portion of the lactation. At the end of lactation, SCC increases either progressively or brutally when close to dry off. Average SCC of 50,000–200,000/ml in mid lactation can rise to 250,000–500,000/ml during the last month of lactation or close to dry off. This increase in SCC is equivalent to an elevation due to an infection with Staphylococci. Because of the variation of the SCC during the lactation (high-low-high) it is impossible to determine if an infection exists based on controls performed at the beginning or at the end of lactation. Yet, this is the period when decisions must be made about removing animals that present a risk of infection.

Variation due to the parity number

Several studies have shown that the somatic cell count increases significantly from the first lactation to the fourth lactation (an average of 20,000 /ml per lactation). However it has not been clearly demonstrated whether the increase in SCC corresponds to an increased level of infection that becomes greater with age.

Variation due to nutrition

No studies exist that have shown a relationship between somatic cell count and level of energy or protein in the ration. However, it seems that there is a correlation between SCC and the level of Vitamin A, and b-carotene on one hand, and Vitamin E and selenium on the other.

Variation between individual animals

There is a definite genetic variation among animals regarding mastitis resistance. In dairy ewes, few results are yet available but many studies are being performed to determine the genetic parameters of resistance to mastitis as described in Chapter 3. According to preliminary results found in dairy sheep, and based on what is known in dairy cows, it could be possible to select animals for resistance to infectious mastitis.

SCC and mastitis

There is no doubt that somatic cell count is an indication of mammary inflammation but the number of somatic cells is under the influence of many factors (infectious and non-infectious). It is therefore necessary to determine the level of SCC for a ewe to be declared infected with relative certainty. Other questions such as the relationship between the SCC in the milk of the bulk tank and the individual SCC are important for strategic planning at the farm level.

Threshold of infection

After reviewing several studies, Bergonier et al. (1997) proposed that three classes be defined to predict the presence of an infection with accuracy greater than 80%.

- **Healthy udder:** If all SCC controls but one are inferior to 500,000 cells/ml.
- **Infected udder (sub-clinical mastitis):** If at least two SCC controls are superior to 1,000,000 cells/ml.
- **Doubtful udder (temporary infection):** In all other cases.

The lower limit between "healthy" and "doubtful" is between 400,000 cells/ml and 500,000 cell/ml. The higher limit between "doubtful" and "infected" is between 800,000 cells/ml and 1,000,000 cells/ml.

Relationship between SCC in milk of bulk tank and individual SCC

Lagriffoul et al. (1998) report that the correlation between bulk tank SCC and individual SCC is 0.86 meaning that an evaluation of the bulk tank SCC could be used to estimate the incidence of udder infection in the flock. Moreover, by considering individual SCC by the quantity of milk that each ewe contributes to the bulk tank, the same authors have been able to establish the proportion of ewes in the flock contributing to the total SCC of the tank (table 1).

The percentage of ewes with high SCC (>1,000,000) increases with the SCC of the tank to the detriment of the percentage of ewes with low SCC (<100,000) while the percentage of ewes with intermediate SCC (>100,000 but <1,000,000) stays relatively constant. Although informative, Lagriffoul et al. (1998) warn that the figures presented in table 1 do not reflect the infection status of the flock.

Table 1. Evolution of the percentage of ewes with less than 500,000 cells/ml according to the SCC of the tank.

Number of somatic cells in the tank	Average SCC in the tank	% of ewes with < 500,000 cells/ml	% of ewes with > 1,000,000 cells/ml
0 to 400,000	257,000	90.1	5.1
400 to 600,000	492,000	83.5	9.2
600 to 800,000	693,000	78.9	12.5
800 to 1,000,000	895,000	74.8	15.5
1,000 to 1,400,000	1,160,000	68.2	20.6
> 1,400,000	1,865,000	56.7	30.9

Lagriffoul et al. 1998

To estimate the incidence of mastitis in the flock, it is necessary to use the regression equation shown in table 2 with the average of all tank SCC taken during the season. Table 3 gives an example using different SCC values.

Though SCC is an excellent tool for detecting sub-clinical mastitis, the repeated controls of SCC at the farm level can be cumbersome and expensive. However, it is indispensable to detect infected ewes, especially when the tank SCC (controlled monthly by state agencies) rises above 500,000 cells/ml. The limit allowed in the United States is 1,000,000 cells/ml but some milk buyers can penalize milk at a much lower level. If controlling SCC is not possible, detection of inflammation can be done with the California Mastitis Test.

- **When the percentage of infected ewes increases, the percentage of healthy ewes decreases, but the percentage of doubtful ewes stays more or less constant.**
- **Although small in number, infected ewes contribute greatly to the elevation of SCC in the tank.**
- **The percentage of infected ewes increases in average of 2.5–3% for each increment of 100,000 cells/ml in the tank.**

Table 2. Prediction of percentage of ewes in different classes of infection according to the average SCC of the tank.

	Regression equation	R^2	test
Healthy	-0.028 X + 89.272	0.699	p<.001
Doubtful	0.004 X + 11.772	0.035	ns
Infected	0.024 X – 1.044	0.845	p<.001

X = SCC in milk of tank/1000 *Lagriffoul et al. 1998*

Table 3. Example of percentage of ewes with infection according to 3 different tank SCC using table 2.

	Average SCC of the tank during the season (10^3cells/ml)		
	270	675	1,100
% healthy udders	81.7	70.4	58.4
% doubtful	12.8	14.4	16.2
% infected udders	5.4	15.2	25.4

California mastitis test

With the California Mastitis Test (CMT), a producer can evaluate the cell content of milk rapidly and cheaply. According to studies reviewed by Bergonier et al. (1994), there is a good relationship between CMT and SCC, especially if a simplified grid is used. CMT gives 87% of right results for the negative values (<250,000 cells/ml) and 92% of right results for positive values (>250,000 cells/ml). As for SCC, CMT has to be performed several times through the lactation to take into account the non-infectious factors of variation, and the rule of the three classes has to be respected.

The California Mastitis Test was developed as a "cow-side" indicator of mastitis. Essentially, it permits early indication of inflammation or poor udder health, and can be used reliably in dairy ewes.

The test is easy to perform. Before putting on the teat cups each udder half is sampled and evaluated separately by squirting milk into a shallow paddle device which contains a special reactive agent. The milk is swirled and the resulting clot formation is subjectively graded to determine the relative amount of inflammation (presumed infection) in the udder half. Results are generally reported as:

- Negative—no jelling seen at all
- Trace—small amount of gel seen when tipped (<250000 cells/ml)
- 1+—significant amount of gel seen when tipped
- 2+—when paddle is swirled, gel tends to clump in the middle
- 3+—mixture completely jelled and clumps in middle when swirled.

Conclusion

Sub-clinical mastitis is mostly due to Coagulase Negative Staphylococci such as *Staphylcoccus epidermis*. Its incidence can be fairly high when the hygienic conditions on a farm are not satisfactory. Reducing mastitis depends principally on good management techniques, good milking procedures, maintenance of milking machine and the elimination of infected animals. The detection of infected animals can be done through SCC or CMT performed several times during the lactation.

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Chapter 9

Milking parlors and equipment

Hand milking can be a very viable option.

Ewes can be milked by hand as they stand on elevated platforms or by machine in parlors with various levels of sophistication. Hand and machine milking share the same goals—keeping the milk clean and emptying the udder as completely and quickly as possible without traumatizing the udder or teats.

The conditions in which cows, goats and sheep are milked in North America are subject to many regulations to ensure that consumers receive the highest quality product. The location of the milking parlor, its design, the materials used for construction, the quality of the water used to clean the milking equipment and many other details need to be respected to qualify for a milk producer's license.

It is very important to milk rapidly in as clean an environment as possible. The area must also be well-lighted and designed for the maximum comfort of both ewes and milkers.

Before starting to build or install any type of milking system, producers should contact the local dairy inspector to learn about existing regulations. For example, in the United States, stanchions cannot be built with porous materials such as wood.

Types of milking parlors

Hand milking (less than 20 ewes)

Hand milking is still very popular in many Mediterranean countries where management systems, labor and energy resources (such as electricity) are quite different than in other countries. A shepherd can hand-milk between 20 to 60 ewes per hour (sometimes more) depending on the breed and the milk yield of the ewes. Until 1950, only about 20 Lacaune ewes per hour could be milked (because the breed is difficult to milk) while 80 ewes per hour was possible in Corsica where local breeds were easy to milk.

Because of the generally small size of the sheep dairy operations in North America, hand milking can be a very viable option. It is simple and does not require sophisticated equipment. But there are other considerations. For example, in a small-scale operation equipped with a milking machine, workers spend more time washing the equipment than actually milking. Hand milking also requires a certain technique that might be hard to acquire or might not appeal to the modern producer. Moreover, it is difficult to get clean milk because of possible contamination caused by external agents.

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

Many sheep dairy producers in the U.S. and Canada have adopted the bucket-and-fixed-stanchion system on an elevated platform because of the modest investment it requires. The stanchion is generally on an elevated platform with 6 or 12 fixed stalls with "cascading" yokes.

The first ewe on the platform goes to the farthest end where a yoke is open. By putting her head through to get to the feed, the animal locks herself in and releases the mechanism that opens the next yoke and so on until the whole platform is occupied. The system works fairly well and is easy to build at low cost. The feed is generally distributed by hand between each group of ewes milked.

The milking is performed in buckets developed for cows or goats. The vacuum in the bucket is provided by a vacuum pump located either next to the bucket (as a wheel barrow system) or in an adjacent room, and the pulsator is fixed on the lid of the bucket, which is also equipped with a filter. Two ewes at a time can be milked with the same bucket.

Some disadvantages arise with bucket milking:

- The vacuum level is not always constant. This can lead to an unusually high incidence of subclinical mastitis reflected by an elevated somatic cell count.
- The pulsators are often old and not adjustable to the required speed for ewes. This limits the stimulation necessary for maximum evacuation of the udder.
- The milk may not cool rapidly enough.
- The buckets can be heavy to haul by hand.
- The speed at which the ewes are milked may not be fast enough to be profitable. One milker can milk only 40 ewes per hour.
- The milking process can lead to bad posture and resulting physical problems for milkers.
- The time involved in cleaning equipment can be substantial.

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

Parlors for larger flocks (more than 120 ewes)

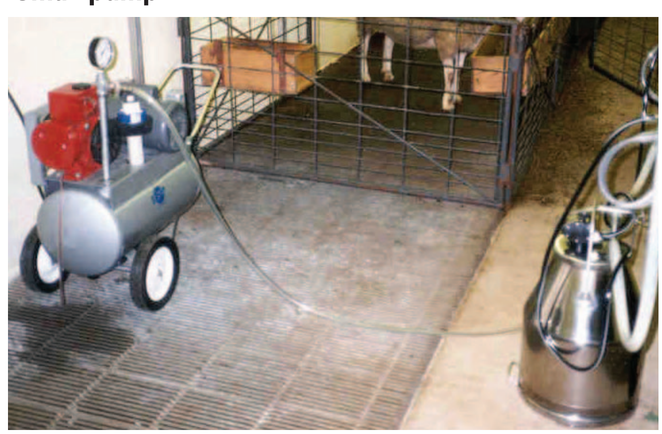
The Casse System

The Casse parlor was born in 1961 in an experimental farm in the Roquefort area of France called Casse farm. This parlor was developed for the Lacaune breed and the special working routine required by the ewes' poor milking ability. The typical milking routine at that time involved:

- Attaching clusters on teats without washing.
- Hand massaging after one minute of milking.
- Machine-stripping and detaching after 180 seconds of milking.
- Re-milking by hand for 10 or 20 seconds.

Homemade six-stall elevated platform

Small pump



Around 1960, only 80 ewes per hour could be milked with this routine by two milkers in a 12-milking-unit, 24-stall parlor. Much progress has been made since then with the development of better equipment and a simplified milking routine without massaging, stripping and re-milking by hand.

The Casse System is a side-by-side parlor developed from the herring-bone parlor, which was in the early stage of development in the latter part of the 1950s. In a Casse parlor, ewes enter and walk to a manger where a concentrate is distributed either manually or automatically; they are locked by their necks in special yokes. The animals go to any headlock they want; the other ewes can move on the platform behind those that are already locked in and eating concentrates (figure 1). When the platform is full, the milker moves the ewes back to the edge of the pit, manually with a crank or automatically with a pneumatic device (figure 2). The throughput is generally 120 ewes/hour with one milker in a typical Casse System (24 ewes/12 milking units).

Six-stall elevated platform

New Casse milking parlors

Today, larger flocks are milked in modern and highly efficient parlors. The new Casse system has fixed stalls instead of movable stanchions (figures 3 and 4). A gate moves on the platform when ewes are entering. It stops at the first place, then an automatic feeder distributes concentrates and the gate opens.

The first ewe enters the first spot equipped with an automatic headlock. When it is locked, the gate moves back to the next spot, the second ewe enters the second headlock and so on.

The gate carries a special curtain that restrains ewes from going to an unoccupied headlock. This new system allows for the possibility of distributing the exact amount of concentrate to each ewe according to her level of production. The movable gate is equipped with a transponder reading the electronic ear tag of the ewe and giving information to the feeder (through an interface system with a computer) about the amount of feed to pour in the individual trough. This system called ADC (automatic distribution of concentrate) solves the logistical problem of properly feeding a large number of ewes that are in different stages of lactation and levels of production. As a general practice, feed was distributed in an amount sufficient to cover the nutritional needs of the highest milking ewes leading to a waste of energy and proteins among ewes not requiring the same amount.

Figure 1. Casse system with ewes entering the platform

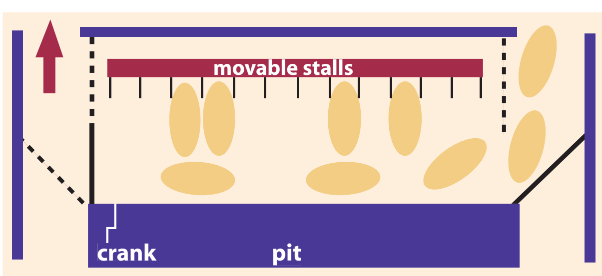
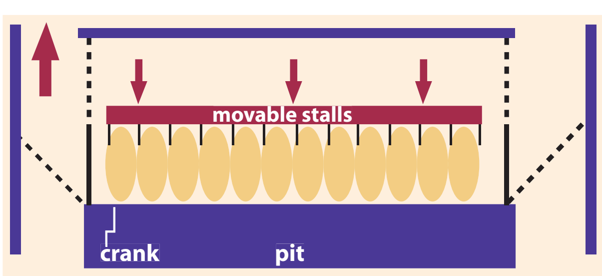


Figure 2. Casse system with ewes ready to be milked



Most of these parlors, now very popular in France, have 2x24 stalls with 24 units and a high line pipeline. Two milkers work in them except when automatic teat cup removal is used; then only one is needed. A dog usually helps ewes entering the platform.

Other popular milking parlors in France are rotary parlors. These generally have 30 units or more (from 30–48 places, sometimes as many as 60) and are used only in big flocks of more than 500–600 ewes with two milkers. Most are now equipped with ACR (automatic cup removal). Table 1 gives a survey of the different styles of milking parlors used in the Roquefort area in 1997.

Table 1. Number of milking parlors used in the Roquefort area in 1997

Type	Number	%
Bucket	10	0.4
Classical Casse	1725	75
New Casse	230	10
Rotary	335	14.6
Total	**2300**	**100**

Other types of parlors

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

Throughputs in different parlors

Today, the most popular milking parlors in France are Casse system, both old and new. These are designed with 2x12 stalls with 6 or 12 milking units and 2x24 stalls with 12 or 24 units. Producers with large flocks need equipment (and especially parlors) with a high degree of efficiency. The main parameter to consider when choosing a new parlor is its potential throughput; that is, the number of animals coming efficiently in and out in a certain amount of time. Many field studies and inquiries are regularly made to give farmers guidelines as they choose their parlors.

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

Figure 3. New Casse parlor with ewes exiting and entering

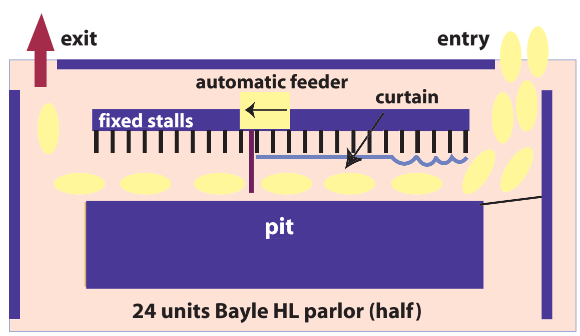
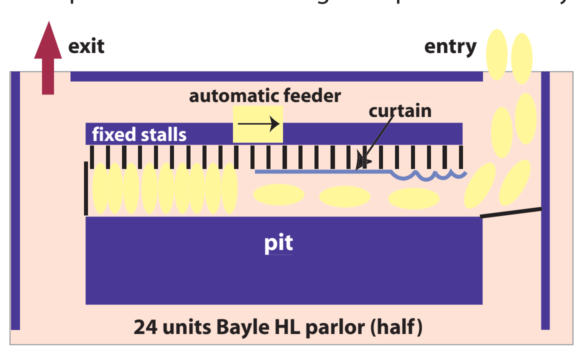


Figure 4. New parlor with ewes taking their place and ready to be milked



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

For small flocks, it is possible to build only one platform to limit costs. The efficiency of such parlors is about 100 to 200 ewes/hour with only one milker (table 3).

Modern Casse parlors are more efficient. Table 4 shows that in a 2x24 place with 24 units, average throughput could be anywhere between 320 and 420 ewes/hour with two milkers. Most of the parlors with 2x24 places and 24 units are now equipped with ACR (Automatic Cluster Removal). In such parlors, one milker can milk between 350 and 400 ewes/hour (table 4).

Finally, rotary parlors with a large number of units are certainly the most efficient parlors, but they are also the most expensive. Producers with more than 500 ewes are the primary users of rotary parlors. Table 5 shows that it is possible to milk 420–650 ewes per hour depending on the number of units, the number of milkers and the daily milk yield of ewes.

Organization of labor

The Casse system is based on the premise that the number of units depends on the time it takes the milker to attach clusters to all ewes, plus miscellaneous and idle time, and come back to the first ewe **without overmilking**. Currently, the average time it takes to milk a Lacaune ewe is about 3 minutes, depending on milk yield (2.5 minutes in mid-lactation and 2 minutes at the end of lactation). **This means that a milker can work effectively with only 12 units.** For parlors with more than 12 units, a second milker or ACR (Automatic Cluster Removal) is needed.

Each milker works in half the pit on one side of the parlor. For example, milker #1 attaches cluster numbers 1–12. Simultaneously milker #2 attaches cluster numbers 13–24. Then returning to the first ewe, the milkers massage the udders in the same order.

Table 2. Average throughput in most popular Casse parlors

number of stalls	number of units	milk line	number of milkers	number of pushers	average throughput
2 x 12	6	Low line	1	0	100–140
2 x 12	12	High line	1	0	180–250
2 x 12	12	Low line	1	1	140–200
2 x 24	24	Low line	2	0	220–300
2 x 25	24	High line	2	1	270–350

Table 3. Average throughput in one-platform Casse parlors

number of stalls	number of units	milk line	number of milkers	throughput
1 x 12	6	High line	1	100–120
1 x 12	6	Low line	1	90–110
1 x 24	12	High line	1	140–200
1 x 24	12	Low line	1	120–180

Table 4. Average throughput in modern Casse parlors

number of stalls	number of units	milk line	number of milkers	number of pushers	average throughput
2 x 24	24	HL	2	0	360–420
2 x 24	24	LL	2	0	320–400
2 x 24	24	HL	1*	1**	350–410

** with ACR, ** the pusher can be a dog*

Table 5. Average throughput in rotary parlors

number of units	number of milkers	number of pushers	average throughput
32	2	1**	420-460
36	3	1**	450-500
48	2-3*	1**	600-650

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

Today, massaging is very rare and not usually necessary thanks to genetic improvements. Therefore, milkers strip ewes only if needed and always detach clusters in the same order. After detaching the cluster from the last ewe, the platform is emptied and milkers swing the milking units to the other side of the pit and repeat the same routine. Then the pusher (which can be a dog) helps ewes enter the empty platform so they are ready when the milkers have finished milking the other side. In these conditions, producers can milk more than 350 ewes per hour with a steady throughput of about 450 ewes/hour.

Importance of good work posture

A person milking a large number of ewes in a very short time, twice a day over 6 to 7 months, must have a good work routine and maintain good posture. Poor posture leads to arm and/or backaches, spinal problems and other troubles that make the task unpleasant. Some general rules of thumb for milkers are:

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

Maintaining good posture and working conditions depends largely on good parlor design. **One of the most important elements is the depth of the pit.** In addition to the rules just mentioned above, a milker must know the average height of the ewes' teats to be milked. For example, in the Lacaune breed, the distance between the floor and the base of the teat is an average 32 cm for ewes with two and more lactations, and 30 cm for ewes during their first lactation. When ewes are standing on the platform ready to be milked, udders must be within easy reach of the milker, taking into account ergonomics and comfortable working angles for body and arms. That means about 10 cm above the level of elbows with a maximum variation of 20 cm. For example, if a milker is 1.7 m tall (5'9"), his elbows are located at about 1 m (3'5") from the floor. Therefore the height of the pit should be .85 m (2'10"). Table 6 gives an idea of the depth of the pit, which should always be calculated in relationship to the height of the milker.

Table 6. Depth of the pit in a milking parlor

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

Figures 5 and 6 give examples of dimensions (in meters) of classic and new Casse parlors.

Figure 5. Parlor with 2x12 places and movable stalls (classic Casse System)

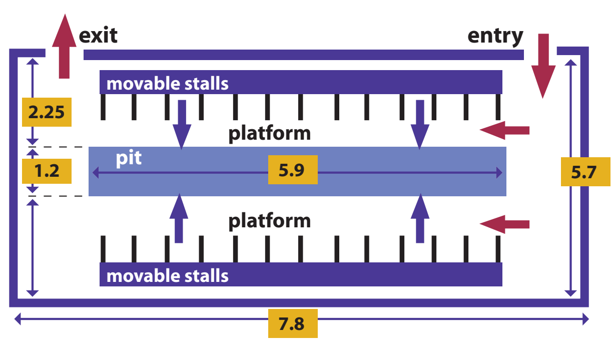
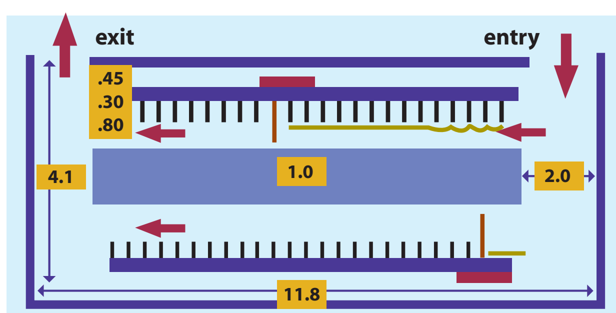


Figure 6. Parlor with 2x24 places and fixed stall (new Casse parlor)



Milking machines

Four parts of the milking machine will be covered:

1. Effective reserve and vacuum pump capacity
2. Size of milk lines
3. Pulsation characteristics
4. Vacuum level

1. Vacuum pump capacity and effective reserve

Vacuum pumps

The vacuum pump should be capable of meeting the operating requirements (milking and cleaning) of all equipment. This is true whether the equipment operates continuously or intermittently.

The vacuum pump should have sufficient capacity **so that the vacuum drop in or near the receiver does not exceed 2 kPa (kilo Pascal) during the course of normal milking. This includes attaching and removing the teat cups and liner slips.**

Capacity should be measured in accordance with ISO 6690: clause 5.3.

Effective reserve

Effective reserve for milking machines for small ruminants should take into account the special milking routines used with these animals. In fact, most farmers do not shut off the vacuum at the cluster or at the liner when they attach or detach clusters from udders so as to maintain high milking rates.

Effective reserve should compensate at least the total air admission of a fully open cluster, evaluated at 600 liters/minute when a milker puts the teat cups on or when a cluster falls off.

The air admitted depends particularly on the type of cluster and the number of milkers. If the clusters are equipped with automatic shut-off valves, the transient air admission is minimized, but may require extra air.

The installation requires a minimum effective reserve determined in accordance with table 7. The extra air leakage is necessary for using ancillary equipment. The manufacturer generally states the maximum air leakage of the cluster equipped with an automatic shut-off device.

The effective reserve shall be measured in accordance with ISP 6690, clause 5.2.

Table 7. Minimum effective reserve (1) for different type of clusters (in litres/minute of free air)

Type of cluster	Number of units	Pipelines	Buckets
Conventional with automatic shut-off or clamp on the long milk tube	n < or = 20	400 + 200 M + 20 n	200 + 100M + 20 n
	n > 20	800 + 200 M + 10 (n-20)	
Automatic shut-off valve	n < or = 20	400 + 50 M + n AL*	200 + 25M + n AL *
	n > 20	500 + 50 M + n(AL - 5) *	
Automatic shut-off valve	n < or = 20	400 + 50 M + 10 n	
+ automatic cluster removal	n > 20	500 + 50 M + 5 n	

(1): Plus addition for ancillary equipment in accordance with clause 17.

AL = extra air leakage at the cluster with automatic shut off valve necessary for working
M = number of milkers, n = number of units

Influence of altitude

For installations at altitudes of less than or equal to 300 meters, an atmospheric pressure of 100 kPa should be assumed for calculating effective reserve.

To fulfill the requirements at altitudes greater than 300 meters, a vacuum pump with increased capacity should be installed.

Air demand for cleaning

Milk and transfer lines are usually cleaned by a mixture of air and cleaning solution transported and agitated by the vacuum difference to achieve effective cleaning by slug speeds of 7 m/s to 10 m/s.

Where washing systems rely on high pump capacity to achieve the air speed necessary to produce slugs for washing this capacity, Q_{clean}, in litres per minute, can be calculated from the following formula:

Q_{clean} = pd2 /4 *v*(p_a -p_w)/ p_a.

Where:

d = internal diameter of the line, in decimetres,

v = air and slug speed in the milk tube, in decimetres per minute,

p_a = actual atmospheric pressure during the test, in kPa,

p_w = vacuum level when washing the plant, in kPa.

Because of the low vacuum milking level, milking installations for small ruminants can be washed at a higher vacuum level to ensure a good cleaning.

To estimate the minimal vacuum pump capacity, effective reserve needs to be calculated from tables 7 and 8.

Example: predicting vacuum pump capacity

If we have:

a. A parlor with 12 units automatic shut-off valve at the liner situated at 300 m above sea level.

b. One milker.

c. Working vacuum level: 38 kPa.

d. Milk pipe diameter: 48 mm.

e. Air admission in the clusters: 10 l/min.

f. Air leakage in the clusters: 20 l/min.

g. Number of pulsators: 6

h. Air consumption for each pulsator: 25 l/min.

i. Vacuum level for cleaning: 50 kPa.

Then:

1. According to table 8 the effective reserve capacity for milking is:

   400 l/min. + 50 l/min. + (12 x 20) l/min. = 690 l/min.

2. The air demand for cleaning at 50 kPa and an altitude of 1000 m should be 386 l/min., which is lower than the effective reserve for milking.

3. The air consumption for the milking units (air admission and pulsators) is:

   (10 x 12) l/min. + (25 x 6) l/min. = 270 l/min.

4. The total air demand during milking is:

   690 l/min. + 270 l/min. = 960 l/min.

5. The total air demand during cleaning is:

   386 l/min. + 270 l/min. = 656 l/min.

6. In this example the capacity for milking is the larger and therefore the base for the pump dimensioning.

7. Leakage into the milk system:

   10 l/min + (2 x 12) l/min. = 34 l/min.

8. Total:

   960 l/min + 34 l/min. = 994 l/min.

9. Regulation loss is 10 % of the manual reserve. The effective reserve was 690 l/min. and is smaller than the manual reserve. Consequently:

   Manual reserve = 690 l/min. x 100/(100-10) = 767 l/min.

   Regulation loss: 767 l/min. x 10/100 = 77 l/min.

   Total: 994 l/min. + 77 l/min. = 1071 l/min.

10. Leakage into the airlines are equal to 5% of the pump capacity; that is, vacuum system leakage: 1071 l/min. x (5/100-5) = 56 l/min.

    Total: 1071 l/min. + 56 l/min. = 1127 l/min.

11. With a pressure drop of 3 kPa between pump and measuring point, the vacuum level at the pump is: 38 kPa + 3 Kpa = 41 kPa.

    Correction for the altitude of 300 m and a vacuum of 41 kPa will give a correction factor of 0.80, that is, for an atmospheric pressure of 100 kPa and a vacuum level of 50 kPa, a nominal pump capacity of: 1127 l/min x 0.80 = 902 l/min.

12. The minimum nominal vacuum pump capacity must therefore be 902 l/min.

2. Size of milk lines

ISO Standards 5707 for cows describes a new method for sizing milk lines.

Stratified or waved milk flow in milk lines should be the normal flow of the milk. Slugged milk flow, which induces vacuum fluctuations in milk lines greater than 2 kPa should be avoided.

Research shows good relationships between large vacuum fluctuations under the teat and higher incidence of mastitis. University of Wisconsin-Madison studies (G. Mein and D. Reinemann) have shown that a vacuum fluctuation of 2 kPa or less in a milk line has no effect on vacuum beneath the teats. These studies gave the maximum milk flow rate to keep vacuum fluctuations no greater than 2 kPa in the milk line.

It is also possible to predict the maximum milk flow rate through the milk line with some information about kinetics of ewes' milk ejection. With a five-second attachment rate and a peak flow of 0.8 l/min and 200 l/min transient air admission, the maximum milk flow rate can be easily predicted (figure 7).

Figure 7. Maximum predicted milk flow rate in milk lines (peak flow : 0.8 l/min)

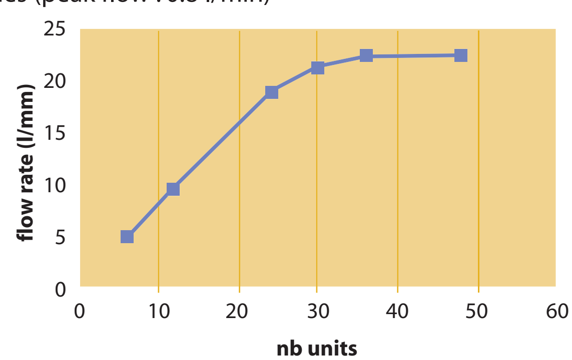


Table 8. Minimum effective reserve for milking, in l/min. of free air: clusters with automatic shut-off valves at the liner (examples)

nb units	Pipeline milking machines — Air leakage at cluster: 20 l/min.		Pipeline milking machines — Air leakage at cluster: 40 l/min.		Bucket milking machines — Air leakage at cluster: 20 l/min.		Bucket milking machines — Air leakage at cluster: 40 l/min.	
	1 milker	2 milkers	1 milker	2 milkers	1 milker	2 milkers	1 milker	2 milkers
2	490	540	530	580	265	290	305	330
3	510	560	570	620	285	310	345	370
4	530	580	610	660	305	330	385	410
5	550	600	650	700	325	350	425	450
6	570	620	690	740	345	370	465	490
7	590	640	730	780	365	390	505	530
8	610	660	770	820	385	410	545	570
9	630	680	810	860	405	430	585	610
10	650	700	850	900	425	450	625	650
11	670	720	890	940	445	470	665	690
12	690	740	930	980	465	490	705	730
13	710	760	970	1020	485	510	745	770
14	730	780	1010	1060	505	530	785	810
15	750	800	1050	1100	525	550	825	850
16	770	820	1090	1140	545	570	865	890
17	790	840	1130	1180	565	590	905	930
18	810	860	1170	1220	585	610	945	970
19	830	880	1210	1260	605	630	985	1010
20	850	900	1250	1300	625	650	1025	1050
21	865	915	1285	1335				
22	880	930	1320	1370				
23	895	945	1355	1405				
24	910	960	1390	1440				
25	925	975	1425	1475				
26	940	990	1460	1510				
27	955	1005	1495	1545				
28	970	1020	1530	1580				
29	985	1035	1565	1615				
30	1000	1050	1600	1650				

Criteria to consider when sizing milk lines in parlors:

- Slope (1% or more if possible)
- Transient air admission (200 l/min)
- Milk line looped or deadlined (looped is better)
- Attachment rate (depending on the milker, milking routine and of the number of milkers : generally 5 seconds with two milkers and 10 seconds with one milker).

Table 9 gives examples of milk line diameters for dairy sheep parlors which could be calculated according to the new method of ISO 5707: (attachment rate: 5 seconds, maximum milk flow rate 0.8 l/min, transient air admission: 200 l/min).

3. Setting of milking machine: Pulsation characteristics

In many countries ewes are milked at a high pulsation rate—from 120 to 180 pulsation/min. French studies showed that ewes milked with a lower pulsation rate have a lower milk production, more strip yield and probably more mastitis problems. Pulsation ratio has not been studied precisely (few results are available) but it seems that 50/50 is the most popular ratio although an inverse ratio 45/55 can also be found.

Table 9. Diameter of milk lines: example of calculations for a 1% slope

nb units/ slope	flow rate (l/min)	diameter
6	4.8	2"
12	9.6	2"
24	19.2	2.5"
30	21.5	2.5"
36	22.8	2.5"
48	22.8	2.5"

This is not a standard. It is only a sample calculation.

4. Vacuum level

Vacuum levels for dairy cows have been decreasing for the 20 last years due to sanitary and mastitis problems. This is also true for dairy sheep. Today, most milking parlors have adopted the following adjusted vacuum levels:

- Low line parlors : 34 to 36 kPa (10 to 10.6 inches Hg)
- High line parlors : 36 to 38 kPa (10.6 to 11.2 inches Hg)

Maintenance of milking machines

Milking machines have a great influence on the speed of milking, the bacteriological quality of the milk and on the udder health as indicated by the occurrence of mastitis or high somatic cell count. It is absolutely necessary that the milking machine be installed properly and maintained regularly.

Cleaning of the milking system

Thorough cleaning of all equipment used during milking is the most important chore in a dairy operation. A good cleaning and disinfecting routine is one that, with a minimum of time, effort and cost, results in visibly clean equipment and milk that consistently meets the buyer's requirement for bacteriological safety.

For bucket and hand-milking equipment, there is no real alternative to washing by hand, although the most laborious part of brushing the clusters can be partially replaced by flush washing.

With a pipeline system, sanitizing before milking and washing afterwards is carried out easily with a cleaning-in-place system. The cleaning protocol will be outlined by the milking machine's manufacturer and should correspond to the regulations of the individual country.

In a pipeline system, all elements should be periodically dismantled (teat cups, liners, milk tubes, claws) and cleaned by hand to remove residue buildups not taken away by chemical solutions. If the total bacteria count of the bulk tank increases significantly it means the milking equipment is heavily contaminated.

Figure 8. Producers should pay particular attention to these check points in the milking system.

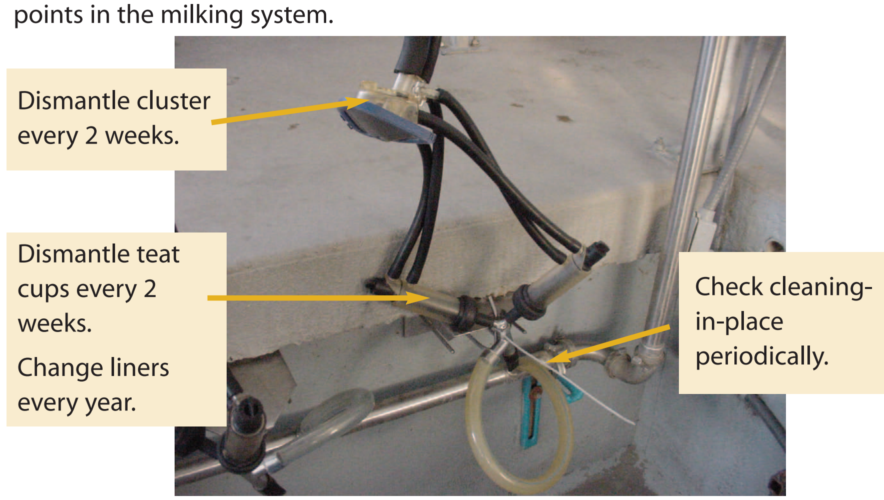
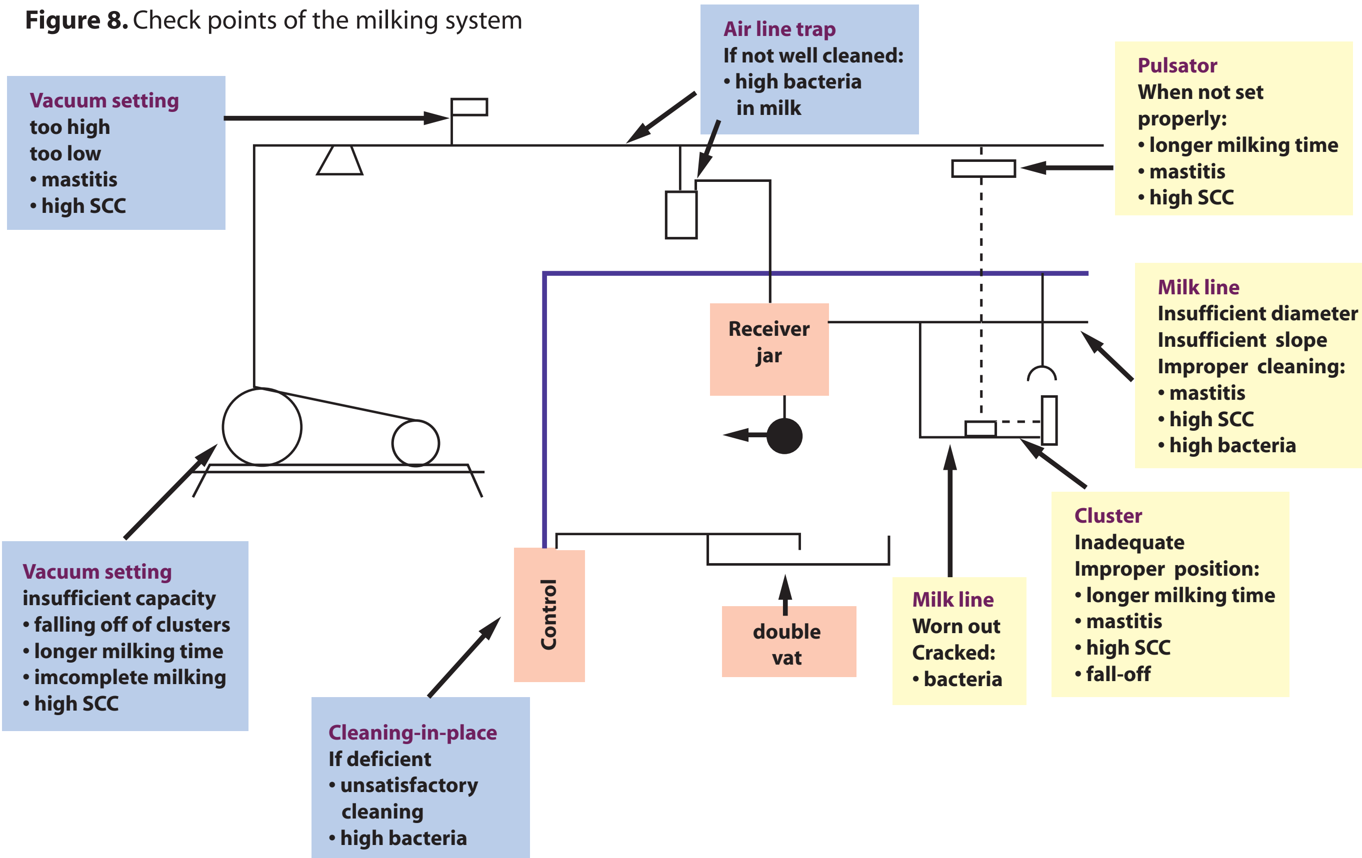


Figure 8. *(continued)*

The whole system should be sanitized before each milking.

Figure 8. Check points of the milking system



New Casse system with automatic take-off and automatic swing-over.

Ewes entering a New Casse parlor.

Ewes taking their places in a New Casse parlor.

Ewes in place in the New Casse 2 x 24 high line pipeline.

One x 12 cascading yokes and elevated platform.

Two x 24 indexing stanchion (Casse system).

Eight-stall cascading yokes and pit.

Two x 24 indexing stanchion (Casse system) low pipeline (Old Chatham, New York).

Twelve-stall cascading yokes and buckets (Olivia Mills, England).

Two x 16 crowding system low line pipeline (Kieffer, Wisconsin).

Two x 24 units high line pipeline (France).

Two x 12 indexing stanchion, 12 milking units, high line pipeline (Spooner Agricultural Research Station).

Cost of milking systems

When building a new parlor, the producer pays for milking machines, the milk room, the sanitary room, the engine room and the bulk tank. Table 11 gives some prices for recently built French milking parlors (translating French prices into U.S. currency). Since no milking parlors (or systems) are built in the U.S. or Canada, most of the equipment needs to be imported, increasing the cost by 50%.

Table 11. Cost of milking parlors (US $)

Equipment	Casse 24p 12u	New Casse 48p 24u	Rotary 36u
Building	21700	28300	31700
Milking system	23300 (34950 imported)	33300 (49950 imported)	65000 (97500 imported)
Automatic cleaning	1700	3300	4200
Self cleaning bulk tank	4700	7700	7700
Total	**$51,400 ($63,050 imported)**	**$72,600 ($89,250 imported)**	**$76,900 ($141,100 imported)**

The cost of the 2 x 12, 6-milking unit (classic Casse System) parlor at the Spooner Research Station (University of Wisconsin–Madison) built in 1996, consisted of the following:

- Building 36′ x 25′ (without labor) $14,500
- Stanchion and feed hopper $ 4,800*
- Milking equipment $10,200
- Feed delivery system to parlor $5,000
- Cleaning in place system $1,500
- 4HP air compressor $329
- 210 gallon bulk tank (used) and hook up $1,000
- 80 gallon water heater $480
- Miscellaneous items $500

TOTAL **$ 38,309**

** The real cost of stanchion and feed hopper is closer to $ 15,000 when purchased directly from an equipment dealer.*

Figure 9. Maintenance schedule of the milking system

	Milking machine	Milk tank
Before each milking	Sanitizing with a chlorine solution	Sanitizing with a chlorine solution
After each milking or emptying	Thorough cleaning according to dealer specification	• Pre-rinsing with cold water • Cleaning with hot water and detergent with an adequate brush • Rinsing with acid
Every day	Checking admittance of air in the clusters	
Every week	Cleaning of the outside of the clusters	Control of temperature
Every two weeks	Dismantling and cleaning by hand of all elements	Cleaning of air lines
Every 6 months	Cleaning of the clean-in-place system and control of the integrity of milking liners.	
Once a year	Conrol of the integrity of the whole system by a technician Analysis of water	Control by a technician
Every two years	Replacement of milking liners and all milk lines	

Conclusion

This chapter describes in detail several milking systems and discusses various milking rates. This is significant because a producer chooses a system based on the number of ewes to be milked and the number of milkers.

The greater the number of ewes the more efficient the system has to be so that the producer does not spend all day in the milking parlor. Of course, the overall cost of the system is a determining factor; often a producer must compromise between efficiency and cost. However, by decreasing the efficiency of the operation the producer might never achieve the production and profit goals set beforehand.

The choice of the milking system has to be a realistic compromise between efficiency and cost. No compromise can be made on the quality of the milking equipment (pulsator, regulator, clusters, liners). Only equipment specifically designed to milk sheep should be used.

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Chapter 10

General management of dairy ewes

Important decisions made before, during and after milking will affect the whole operation.

Managing dairy ewes is very similar to managing most other ewes, but milking adds tasks not involved in a meat and wool operation. The number of ewes milked twice a day for 5–7 months will have a tremendous impact on the producer's workload. Moreover, with respect to milking, the producer is forced to rethink certain aspects of management, and to reorganize and reprioritize the work routine. Some aspects of animal health need to be reviewed since many treatments with available medications cannot be performed concurrently with milking. Therefore, important decisions made before, during and after milking will affect the whole operation.

Choosing the milking season

Individual farms must determine the best milking season according to feed resources, the availability of labor (family or hired help), the sale of milk or cheese, the goals of the producer (total or supplemental income) and the breed's sexual season.

Milking throughout the year

Producers who process their milk into cheese or yogurt and sell to markets such as distributors, restaurants or upscale retail stores should consider milking throughout the year. These markets generally require a steady supply of products. Given the limitations of dairy ewes in terms of lactation length and the rapid decline of milk production throughout lactation, meeting the same level of production (quantity and quality) day after day poses constraints that are not easily resolved without using frozen milk.

Managing a year-round milking operation works by splitting the flock into six different groups that come into production in two-month intervals. On any given day, the producer has roughly the same number of ewes at milking with an equal number in early, mid- and late lactation. The fat and protein content of the milk in the bulk tank should stay fairly constant, allowing for the manufacture of a consistent product.

There may be seasonal variation in milk production and content due to differences in dry matter intake as a result of the way ewes are fed (for example, pasture vs. complete confinement). An example of possible management systems is given in table 1.

Each of the six units has to be kept separated and treated as a different flock. Since each unit will always lamb at the same time of year, replacement ewe lambs should be kept from each unit or from the unit immediately preceding. Units that will be bred in the spring (April or June) should have more ewes to compensate for lower fertility at this time of the year.

A management system with only two units, one lambing in February and the other in September, would be much simpler in terms of production but the change that takes place in milk composition affects the cheesemaking process.

Seasonal milking

Seasonal milking is the most popular system with lambing concentrated over a few weeks and the majority of ewes milking at more or less the same time. In this type of system ewe lambs generally lamb one or two months later than older ewes. Lambing and milking can occur in winter or in spring according to the objectives of the producer: maximum milk production at higher cost, or lower input with maximized green forage consumption. Producers should evaluate all considerations before making a choice.

Generally speaking, a January lambing, corresponding to a February milking start, is more apt to sustain a 5–6 month milking period than a spring lambing because most lactation occurs during cooler temperatures. This better favors the animal's feed intake and comfort. However, the highest feed demand (at the end of gestation and early lactation) occurs in winter and requires an ample supply of expensive stored feed.

- Winter lambing (and milking) makes more efficient use of hired labor while spring lambing (and milking) is better for family labor.
- Dry matter intake greatly influences milk yield. High-producing ewes arriving at peak yield while on pasture need to have their diets supplemented by either concentrate or high quality dry forage.
- High summer temperatures decrease ewes' appetites, reducing the feed intake and therefore the milk yield.
- Milk produced in summer has poorer cheese making performance. It seems that warm temperatures do not affect the composition of milk as much as the length of days.

Do not plan for ewes to reach their peak of production during the hot summer months.

Breeding of ewes

Manipulation of the ewe's reproductive cycle might be of interest if the sheep dairy producer plans to:

1. Synchronize estrus of ewes so that a sufficient number can be put at milking on the same day. If lambing is spread out over time, milking of the first ewes to lamb might be delayed, creating a significant loss in milk income.
2. Breed out-of-season for milking all year or just in the fall.

Table 1. Possible management system for year-round milking

	Breeding	Lambing	Milking	Dry off	Breeding
Unit 1	August	January	February	June–July	August
Unit 2	October	March	April	Aug–Sept	October
Unit 3	December	May	June	Oct–Nov	December
Unit 4	February	July	August	Dec–Jan	February
Unit 5	April*	September	October	Feb–March	April*
Unit 6	June*	November	December	April–May	June*

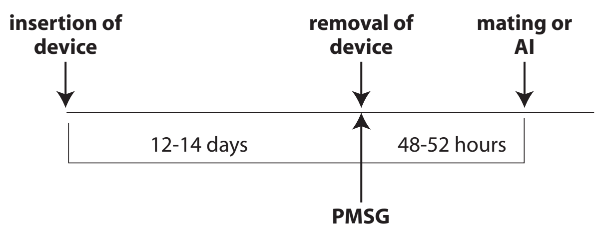
** Difficult months for breeding*

Synchronization

Synchronization of estrus can be followed by natural mating (one ram for ten ewes) or by artificial insemination with fresh or frozen semen.

The technique of synchronization extends the luteal phase (with the help of progestagen) until all corpora lutea (progesterone-secreting cells) have regressed and disappeared from the surface of the ovaries. A new estrus cycle with ovulation occurs at the end of the treatment.

The progestagen is slowly administered to the ewes over a period of 12–14 days via an implant, a vaginal pessary or a vaginal CIDR. At the removal of the device an injection of PMSG (pregnant mare serum gonadotropine) is injected to the ewes to regulate ovulation. Estrus appears 48 hours later.



Treatment with melatonin and manipulation of light

Sheep from mild climates present seasonal variations of breeding activity that can be controlled by annual photoperiodic changes. Melatonin is a substance secreted by the pineal gland during the short-length days that stimulates sexual activity. In practical applications, melatonin can be delivered either in feed or via an implant. Treatment with melatonin alone advances the sexual season by $1\frac{1}{2}$ months. A melatonin treatment before the summer solstice does not appear to be efficient. For good control of out-of-season breeding, melatonin treatment should follow a light treatment.

By artificially manipulating the length of days (by use of artificial lighting in the barn) it is possible to create short days during the natural long days, thus favoring the synthesis of melatonin. Chemineau et al. (1993) showed that a "long day" light treatment is necessary before a melatonin treatment to establish the ovulatory cycle and maximum expression of estrus behavior. Light treatments are difficult and expensive because they require completely enclosed barns. However, Chemineau et al. (1993) defined protocols that can be used either in closed barns or open sheds (figure 1).

Habituating new ewes to the parlor

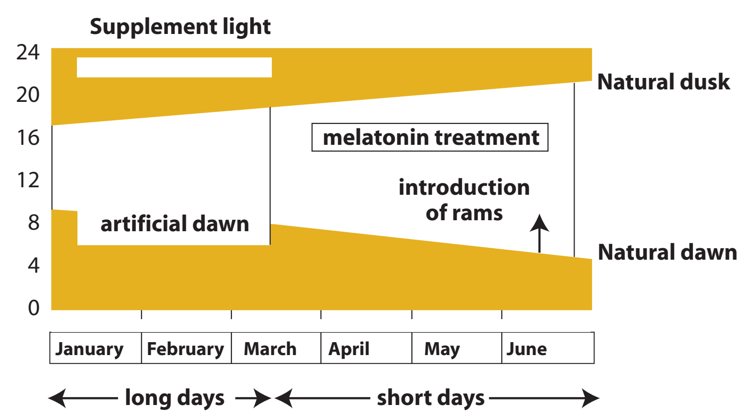
Training new ewes or ewe lambs to come willingly to the parlor can be stressful for the animals and is best done before the ewes lactate. If training of the ewes is conducted simultaneously with the weaning of lambs, expect a drop of 30–40% in milk production (Labussière, 1988).

Out of season breeding

The ram effect

When ewes are in estrus and isolated from the rams for at least 30 days, they ovulate when the rams are reintroduced. Isolation from sight and smell of the rams is recommended. A success rate of 60–65% is reported in the literature (Pearce and Oldham, 1984). Success is improved when the ram effect is accompanied by synchronization of estrus. However, the ram effect used for out-of-season breeding permits the induction of only one period of ovulation; that is, the sexual cycle is not maintained. The ram effect seems to have little or no effect on ewe lambs.

Figure 1. Photoperiodic treatment in an open barn where extra light is given as an artificial dawn and two hours of supplementary light 16 to 18 hours later for more than 60 days, followed by a melatonin treatment. Breeding with males managed the same way is done 70 hours after the onset of the melatonin treatment (Chemineau et al., 1993).



Training of the ewes is best executed 4–5 weeks after the end of breeding. At this time the resulting stress will not affect embryonic development and the ewes will remember the feed in the parlor later at milking. The training consists mostly of habituating the ewes to come willingly and without fear into the milking parlor, and is usually completed within a week. At the beginning of the milking period, training will consist mostly in the milking per se without significant negative effects on milk production.

Preparing the ewes for lactation

Rearing of ewe lambs

In chapter 6, it was explained that the udder's future milk capacity can be impaired by excessive growth of the stroma (mainly adipose and connective tissues) in comparison to the parenchyma (tubulo-alveolar epithelium). This critical development occurs in sheep before puberty between two and four months of age.

An excessive growth rate at this period favors the development of stroma over parenchyma. Therefore, a relatively low growth rate (50% of high growth rate) from weaning at 4–20 weeks of age will increase the parenchyma growth and the milk production in the first lactation. However, producers have to realize that sufficient growth of ewe lambs has to be attained for successful breeding at 7–8 months. Milk and lamb production of ewe lambs at one year is a very important economic component of the operation. A compromise would have to be reached between maximum milk production of ewe lambs and age at first milking.

Feeding

As with non-dairy ewes, the month preceding lambing is critical in preparing for milk production. Nutrients given to ewes must support not only the rapidly developing feti but also mammogenesis (development of secretory tissues in the mammary gland). Ninety-five percent of the development of the mammary gland takes place during the last third of gestation. Significant undernutrition during this period can greatly reduce mammogenesis (Treacher, 1970).

Bizelis et al. (2000a, 2000b) found that dairy ewes receiving only 90% of their maintenance requirements during late pregnancy had much smaller udders and significantly lower milk production, even though they were put on an adequate free choice diet in early lactation. Dairy ewes in late pregnancy can be fed the same as any other ewes at the same stage of production. Producers should refer to chapter 4 on general nutrition of sheep.

Shearing

Shearing ewes before lambing is a common practice in any sheep operation. It provides a cleaner environment at lambing time, gives the animals more room and makes lambing easier to supervise. In a dairy operation, shearing before milking is a must because milking must be performed in a clean environment. Sanitary collection of milk is nearly impossible when ewes are in full fleece. **It is imperative that ewes be shorn before milking starts.** A second shearing might be necessary in the middle of lactation.

Weaning of lambs

In dairy ewes, 25% of the total milk yield for the entire lactation is produced during the first month (Folman et al., 1966; Ricordeau and Denamur, 1962). This is mainly due to the fact that milk production increases from parturition to about 24 days in lactation when peak milk production is reached.

To complicate matters, ruminants have the highest probability of mastitis during the first 45 days post-partum (Hamman, 2000). Therefore, early lactation management is critical to udder health and profit margins.

A wide variety of weaning systems exists for dairy ewes that allow either optimum lamb growth, commercial milk production, or a combination of the two (Folman et al., 1966; Gargouri et al., 1993; Papachristoforou, 1990).

The weaning system that favors lamb growth is the **30-day exclusive suckling system (DY30)** where ewes are not machine-milked during the first month of lactation and the lambs are weaned at about one month of age. This is the most common system used throughout the world and in North America.

The system that favors maximum commercial yield is the **day one system (DY1)** where lambs are removed from their dams within 24 hours after birth and raised on artificial milk replacers or with part of the milk collected from the ewes; the ewes are machine-milked twice daily for the entire lactation. This system is particularly common in Northern Europe with the East Friesian breed (Flamant and Ricordeau, 1969).

Finally, a weaning system that attempts to find a compromise between acceptable lamb growth and commercial milk production is **the mixed system (MIX)**. The MIX system allows for lambs to suckle their dams for 8–12 hours per day, after which they are separated for the night, and the ewes are machine milked the following morning (McKusick et al., 2001[a]). Lambs are weaned at 28–30 days and the ewes are exclusively machine-milked twice a day. The three systems have been evaluated at the Spooner Agricultural Research Station (University of Wisconsin-Madison).

The weaning system most appropriate in terms of maintaining maximum milk production potential during the first 30 days of lactation is the MIX system. This allows for frequent udder evacuation during the day (lambs suckling) and one large evacuation every morning (machine milking).

Because the MIX system permits the sale of at least some commercial milk during the first 30 days of lactation and requires no artificial rearing of the lambs, it is more advantageous compared to both traditional 30-day weaning and the DY1 system (McKusick et al., 2001[a]). The DY1 system is probably the least efficient in maintaining maximum milk production potential due to the fact that the udder is being emptied only twice per day. The traditional DY30 system relies uniquely on the lamb to maintain milk production during early lactation. It is only when milk requirements of the lambs are greatest that maximum milk production is met in DY30 ewes.

The DY30 system is not appropriate for ewes that rear only one lamb.

Lambs separated from their dams for the once a day milking (MIX).

Although we see marked differences between the three weaning systems during the first 30 days of lactation in terms of milk production potential, they disappear after about 45 days in lactation (figure 2). This is to say that DY1, DY30 and MIX ewes have similar milk yield and lactation lengths from seven weeks onward.

Milk composition and quality

In addition to the significant differences in milk production observed for the three weaning systems, there are also marked differences in milk fat content (figure 3) and somatic cell count (figure 4) during the first 30 days of lactation. **Compared to DY1 ewes, the commercial milk (total milk extracted with the machine) of MIX ewes has significantly less milk fat content for as long as the ewes remain in contact with their lambs. This lower fat content can have a serious negative effect on the milk's value.**

The reason for lower fat content is probably due to failure of the milk ejection reflex during machine milking of MIX ewes, but could also result from problems associated with stress, milk fat storage and/or fat synthesis in the udder when the ewes are separated from their lambs in the evening.

Oxytocin is a hormone released from the brain of mammals as a result of teat and udder stimulation, usually at the time of suckling (Ely and Peterson, 1941). Oxytocin is an integral part of milk ejection (see chapter 6). During machine milking, if there is no release of oxytocin combined with other factors, milk remains in the alveoli along with large quantities of fat. This results in incomplete udder evacuation as well as a less rich commercial milk.

Figure 2. Average daily commercial milk yield per ewe for 3 weaning systems.

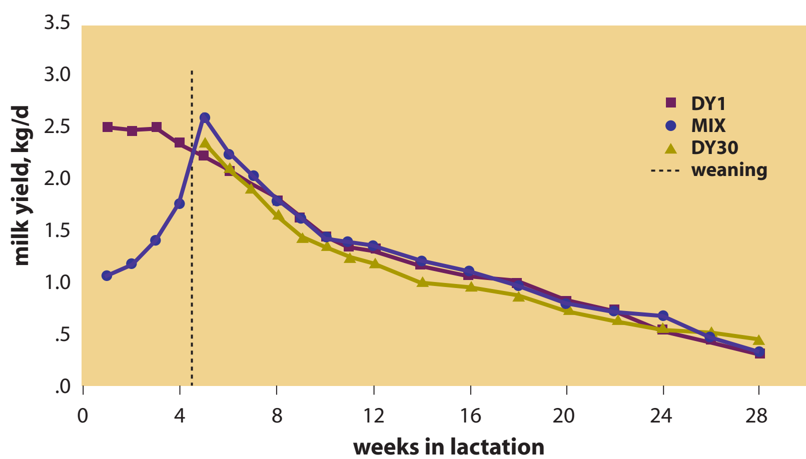
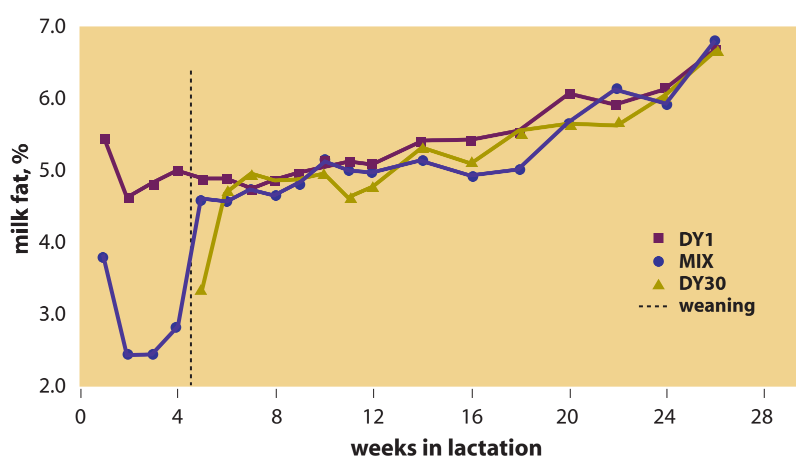


Figure 3. Percentage of milk fat for 3 weaning systems.



Somatic cell count (SCC) is often used in monitoring udder health in dairy animals. Although the probability of infection is higher as the number of SCC increases (Billon and Decremoux, 1998), it should be noted that SCC is not a direct indicator of infection, but rather of inflammation.

Weaning systems can have marked effects on SCC in dairy ewes. Observations at the Spooner Agricultural Research Station indicate that MIX ewes maintain significantly lower SCC during the first 30 days of lactation than DY1 ewes. This seems to be related to more frequent udder evacuation when milk production is the highest in lactation. When the udder is heavily distended and under high intramammary pressures, the small junctions between cells in the mammary gland begin to open. This permits an influx of SCC (white blood cells and other cell types) into the mammary gland (Stelwagen et al., 1997). Furthermore, if the mammary gland does get infected (via entry of bacteria through the teat canal), more frequent evacuation of the udder decreases the chance of those bacteria from colonizing the udder and establishing infection. DY30 ewes tend to have significantly higher SCC compared to both MIX and DY1 ewes around the time of weaning and during mid-lactation. It is, however, difficult to say whether or not any of the weaning systems are beneficial in reducing the mastitis incidence in dairy ewes.

Milk protein percentage (figure 5) was similar over the whole lactation between MIX ewes and DY1 ewes. It was highest during early lactation, decreased through mid-lactation, and then increased for the remainder of the lactation.

Choosing a weaning system is not easy when all factors are adequately considered. The maximum amount of milk is obtained with the DY1 system because about 25–30% of all milk is produced during the first 30 days, but this system calls for the artificial rearing of lambs (see chapter 11). The MIX system is the most economical, but the percentage of fat in the milk is reduced while lambs are suckling, lowering the quality and value of the milk. The DY30 system is economical but does not favor maximum milk production and should not be used with ewes suckling only one lamb.

Figure 4. Log-transformed Somatic Cell Count (SCC) for 3 weaning systems.

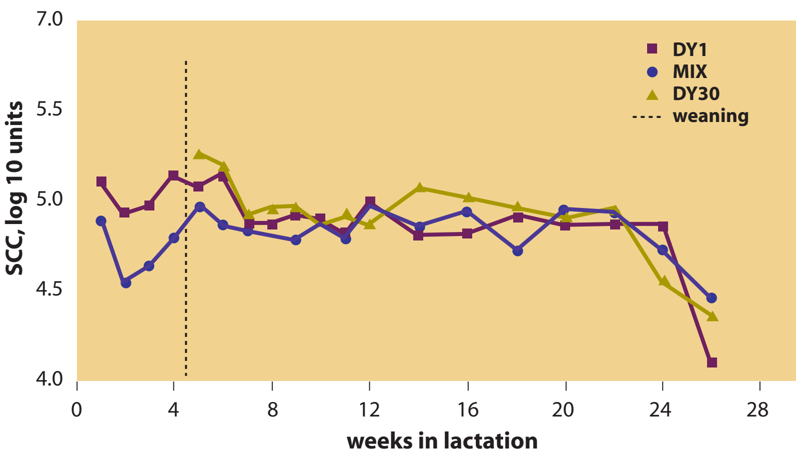
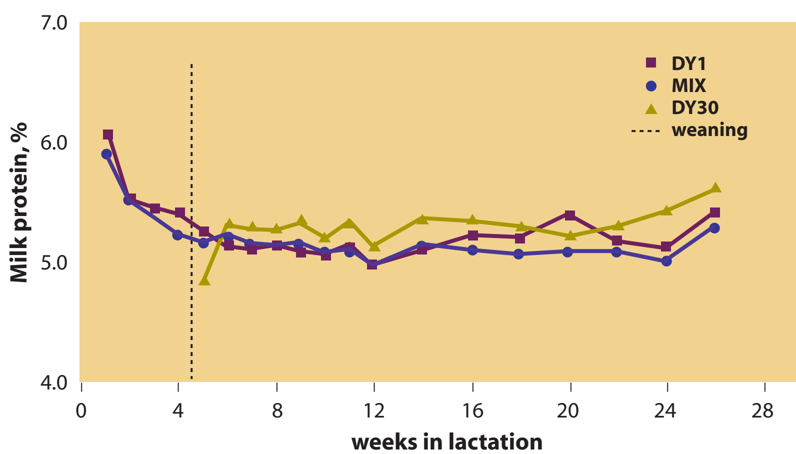


Figure 5. Percentage of milk protein for 3 weaning systems.



Milking frequency

In looking at different weaning systems, it has been shown that for a dairy ewe to maintain her maximum milk production potential, the udder must be frequently and completely evacuated, especially in early lactation when milk production is highest.

The effect of milking frequency on daily milk production, fat percentage and protein percentage has been studied at the Spooner Agricultural Research Station (de Bie et al., 2000). Two groups of DY1 ewes (ewes exclusively milked beginning 24 hours after lambing) with equal initial production were milked either two or three times a day. Overall milk production (table 2) was increased by 15% during the first 30 days of lactation but the response to an increase in milking frequency varied according to the percentage of East Friesian breeding. Ewes with between 25–50% East Friesian breeding produced 30% more milk when milked three times a day while ewes of 25% East Friesian breeding did not respond at all.

The percentage of milk fat was significantly reduced in ewes milked three times a day, while protein percentage was less sensitive to changes in the frequency of milking.

In conclusion, more milk was obtained by milking a third time, but the response varied greatly according to the ewes' genotype. The variable response was probably due to the ewes' genetic potential to produce milk and to the storage capacity of their udders. For a given level of milk production, the more milk the ewe stores in the cistern, the less often she has to be milked. The economic interest of involving more labor and cost in a third milking, even for a short period of time, cannot be ascertained at this point. More research is needed to determine the exact reason why some ewes respond better than others to higher milking frequencies.

Interval between milkings

One can think about the inside of the udder as having two compartments. One compartment is responsible for producing and secreting milk (the alveoli), and the other is responsible for storing milk (the cistern).

In ewes, a dynamic relationship exists between these two compartments that greatly affects milk yield. Immediately following evacuation of the udder, either by suckling or the machine, the pressure within the udder (intramammary pressure) decreases significantly (Labussière, 1993). The removal of milk combined with the drop in pressure allows newly secreted milk to accumulate naturally in the udder. The alveoli begin to stretch as they accumulate newly secreted milk, and eventually they spontaneously contract in response to the tension within the alveoli. Milk then flows into a long system of small ducts, eventually traveling through a system of larger ducts, to finally arrive in the cistern. The whole process is repeated.

Eventually, because of the large volume of milk that accumulates in the cistern, the intramammary pressure of the cistern becomes great enough to slow down the flow of milk from the small and large ducts. Milk begins to distend the alveoli because it can no longer be expelled into the small ducts. In response to the increased pressure within the alveoli, the neighboring secretory cells begin to shut down milk production.

Table 2. Daily milk production (Liters/ewe) during the first 30 days of lactation of ewes milked twice (2TM) or three times a day (3TM).

Group	%EF	N	Total 30day	Week 7
2TM	All	72	82.6 ±2.8 a	2.1 ±.09 a
3TM	All	53	95.2 ±2.3 b	2.1 ±.09 a
2TM	25%	20	88.3 ±5.0 a	2.3 ±.15 a
3TM	25%	16	89.1 ±5.1a	2.0 ±.15 a
2TM	37.5%	12	70.4 ±4.9 a	1.7 ±.16 a
3TM	37.5%	9	95.8 ±6.6 b	2.0 ±.16 a
2TM	50%	40	89.3 ±4.0 a	2.3 ±.12 a
3TM	50%	28	100.7 ±5.1 b	2.3 ±.12 b

[a,b] For each group, means with a different letter differ significantly (P< .05)
de Bie et al., 2000

For a dairy ewe to maintain her maximum milk production potential, frequent and complete evacuation of the udder is essential, especially in early lactation when milk production is highest.

Additionally, the feedback inhibitor lactation hormone (FIL) concentration increases when large volumes of milk remain in the alveoli. This hormone essentially tells the secretory cells that there is too much milk being produced and that milk synthesis should be slowed down. Thus, when the interval between milkings (or sucklings) surpasses around 16 hours, and cisternal milk storage capacity has been reached, milk secretion may be hampered (Davis et al., 1998). Prolonged periods of milk stasis in the udder, particularly at dry-off, are some of the factors that initiate apoptosis, or "programmed cell death."

The interval between milkings should not be more than 16 hours. Producers milking only once a day, especially in early lactation, should expect a reduction in daily milk yield and lactation length.

Oxytocin, a hormone produced by the brain, influences the release of milk from the alveoli to the cistern during suckling or milking. Without oxytocin, milking is incomplete and the milk has a lower fat content. In nature, suckling is the normal stimulus for the release of oxytocin. During milking the stimulation is achieved just prior to milking (noise in milk room, the start of the vacuum pump) and at milking with the attachment of the teat cups to the teats.

Another important factor conditioning ewes to the machine milking is the time of day. Ewes are creatures of habit and are time sensitive.

It is important that once a milking routine has been established, it should be respected as much as possible from one day to the next.

Since it appears that a milking interval of 16 hours could be appropriate for dairy ewes because of their increased cisternal storage capacity. McKusick et al. (2001)[b] looked at the possibility of milking only 3 times in 48 hours (6 am, 10 pm, 2 pm) instead of 4 times starting in mid-lactation (90 days) to the end. The authors concluded that milking every 16 hours apears to be a reasonable compromise to normal twice-daily milking routines for dairy ewes, and does not result in any deleterious effects on milk yield, milk composition, somatic cell count or lactation length. A longer milking interval results in a significant reduction in labor and time spent in the milking parlor.

Milking procedures

The milking procedure should allow for recovery of the maximum amount of milk possible, in the shortest amount of time, with the least amount of human intervention and without causing harm to the ewe or udder. Time is essential because sheep dairying generally involves many animals. With an efficient milking system, high throughput of animals through the milking parlor can be achieved (300–350 per hour) as long as milking procedures stay simple and ewes have uniform milk flow and udder conformation.

Washing the udder

It is a normal practice to start milking ewes without washing the udder. The time taken to **properly** wash and dry the udder increases tremendously the time of milking. Moreover, if washing is carried out as a group (generally a group of 12 ewes at a time), stimulation of the ewes can result in premature release of oxytocin.

It has been shown that contamination of the milk by external bacteria is greater with improper washing than with no washing at all. The general recommendation is not to wash the udder but to make all possible efforts to keep the ewes clean. **Fresh, abundant bedding should be provided daily to ewes in confinement.** Muddy pastures or muddy roads should be avoided as much as possible. If management practices do not allow for ewes to be maintained in a sufficiently clean environment, udder washing may be necessary.

California Mastitis Test

The California Mastitis Test (CMT) gives an early indication of inflammation or poor udder health, and can be used reliably in dairy ewes. The test is easy to perform, but can significantly increase milking time.

Before putting on the teat cups, each udder half is sampled and evaluated separately by squirting milk into a shallow paddle device that contains a special reactive agent. The milk is swirled and the resulting clot formation is subjectively graded to determine the relative amount of inflammation (presumed infection) in the udder half. CMT score actually has a good correlation with somatic cell count; it is important because it provides an early indication of mastitis that can be confirmed with further veterinary diagnostics.

The California Mastitis Test should be done when:

- the somatic cell count in the milk of the bulk tank is abnormally high. Problem ewes must then be detected and removed from the flock.
- the quality of some ewes' milk appears doubtful. Just a few ewes with high somatic cell count are enough to rapidly elevate the count in the bulk tank.

Stripping

The udder's size, shape and form are determined genetically (Fernández et al., 1997), and play an important role in storing and recovering milk (Labussière, 1988). In general, ewes with large udders produce more milk than ewes with small udders. Ewes with taller cisterns (that is, more udder volume below the teat canal exit) take significantly longer to milk than ewes with shorter cisterns (McKusick et al., 1999).

During milking the udders of ewes with tall cisterns often have to be lifted and massaged during milking to allow for all the milk to drain from the udder. This is called **stripping**. This process takes time and therefore reduces the milking machine's efficiency. Because the volume of milk gained by stripping is lower than the volume of milk recovered by the machine (machine milk yield), it has been proposed that machine stripping be eliminated, especially in ewes with low stripping percentages, to gain in overall parlor throughput time.

At the Spooner Agricultural Research Station an experiment was conducted to see if stripping could be eliminated (McKusick, 2003). Commercial milk yield for non-stripped ewes was only 15% less than for stripped ewes (average stripping percentage is 22%). Furthermore, machine milk yield for non-stripped ewes increased and was significantly higher than stripped ewes during the experiment. These results imply that ewes become habituated to stripping, and that elimination of the process could result in relatively more milk recovered by the machine. Therefore, stripped yield might be overestimated and could be closer to what has been found in France in ewes with excellent udder conformation (11 to 15%).

In some cases, stripping could be eliminated because the small amount of milk gained during stripping is not worth the labor input to extract it.

Speed of milking

Another experiment at the Spooner Station looked at machine milking efficiency (volume of machine milk recuperated / the total time required to milk the ewe). The experiment permitted the identification of five types of ewes (McKusick, 2000).

1. The "fast milker"— a ewe that attains milk flow almost immediately after the teat cups have been placed on the udder. She achieves one or two very high peak milk flow rates (1.5 to 2 liters/minute) and has usually emptied her udder in 60 seconds. If the ewe has correct teat placement, she typically has only 5–10% stripping volume. This is the type of ewe that should be kept and replacements chosen from.
2. The "average milker"—a ewe that, in one milking, during mid- to late gestation gives approximately 1 liter of milk in 2 minutes. She gives 80% of her milk in the first 1.5 minutes and then requires about 30 seconds for stripping to remove the rest of the milk (20% of the total yield). If the stripping yield is due to habituation to massage, the machine yield will increase and stripping can be omitted. This type of ewe is adequate for milking and will not significantly decrease the speed of milking.
3. The "slow milker"—a ewe that generally requires a great deal of manual intervention in the parlor. Milk begins to flow 20–30 seconds after the teat cups have been placed on the udder. Peak milk flow rates rarely exceed 0.5–0.6 liter/minute. Milking procedure times often exceed 4 minutes, and the milker has a tendency to spend significant amounts of time in udder massage and stripping. One slow milker in each batch of ewes is enough to greatly slow parlor throughput time. Moreover, because of the time spent on a particular ewe, overmilking can occur in other ewes, increasing the chance of mammary infection. **The slow milker should be removed from the flock.**
4. The "poor udder conformation/teat placement ewe"—a ewe with a large amount of udder volume located beneath the teat canal exit. This is often seen in older ewes with relaxed medial suspensory ligaments. Milk flow rates and milk yields might be acceptable; however, stripping percentages are high (30 to 40%) which significantly increase milking procedure time. The age at which ewes' udders attain significant loss of conformation due to stretching of

the middle suspensory ligament has to be determined. **Select ewes with profound intramammary grooves since deeper grooves imply stronger ligaments.**

5. The "no milk-ejection ewe"—a ewe that does not release her alveolar milk fraction during milking. This is principally due to a lack of oxytocin release, implying that the ewe does not possess any dairy characteristics. Cud-chewing during milking has been correlated to oxytocin release which usually occurs 30–45 seconds after the teat cups have been placed on the ewe. Stripping these ewes sometimes results in enough stimulation for milk ejection; however, this is a very inefficient way to extract milk. **A ewe that never chews her cud in the parlor should be removed.**

Speed of milking or number of ewes milked per hour can be increased significantly by removing "problem" ewes. These ewes can lead to overmilking others, which may lead to an increase of udder inflammation.

Post dipping increases milking time but appears to be a necessary precaution.

Post dipping

The teat sphincter, a ring-like structure at the end of the teat composed of smooth muscle fibers, allows milk to flow from the teat canal during suckling or milking by relaxing and opening under the influence of suckling or milking stimuli. Soon after milking or suckling the sphincter closes and keeps the milk from flowing. The closing of the sphincter, however, is not immediate and there is a chance that environmental (mainly Coagulase-Negative Staphylococci) bacteria can find their way through the teat canal and infect the udder.

When lambs suckle, the frequent emptying of the udder limits invasion by bacteria. With exclusive machine milking, however, the long period between two milkings favors the multiplication of bacteria and increases the chance of udder inflammation. Dipping the end of the teat with an antibacterial agent immediately after milking reduces the risk of contamination before the teat sphincter is completely closed.

In conclusion, the amount of time spent by the producer in the milking parlor is directly linked to milking procedures.

- Washing the udder is not necessary if ewes are kept in a clean environment.
- Detection of high somatic cell count ewes should be done periodically but not systematically.
- Stripping of some ewes should be omitted so as not to habituate ewes to massages.
- Post-dipping is essential to reduce udder infection.
- Problem ewes (slow milker, poor udder conformation, high SCC) should be removed from the milking herd.

Dry off

Dry off is a natural process that actually begins just after peak lactation (three or four weeks after lambing) and gradually continues for as long as the ewe remains in milk. The cells in the udder that secrete milk undergo a process called "programmed cell death" and are not "renewed" until the following lactation.

Dairy ewes lactate between 4–7 months. The decline of milk production is estimated to be 15–20% per month after reaching peak production. A small population of ewes within the flock will continue to consistently produce a little bit of milk long after the rest of the flock has been dried off. It will be up to the producer to decide whether or not it is worth his or her time to keep milking these ewes. According to data from the Spooner Station it appears that when milk production falls below 0.5 liter per day, it is no longer economical to continue milking. However, other economic reasons such as a higher milk price due to a higher fat content might push a producer to keep milking.

When a producer decides to stop milking because of low production, it is best to switch to once-a-day milking for 8–10 days, followed by one milking every other day for another 8–10 days.

Drying off should always be accompanied by a drastic reduction in the quantity and quality of feed.

Intramammary administration of antibiotics at drying off is effective in cows (Dossing, 1994) and in goats (Mecier et al, 1998). Most studies found that dry period antibiotic therapy is an efficient method to control sub-clinical infections and to decrease milk somatic cell count in subsequent lactation, especially on animals with high milk yield or high somatic cell count at the end of lactation. In dairy ewes Longo et al. (1994) found a cure rate of close to 95% in ewes treated with spiramycin and neomycin after dry-off with only a 3.1% infection rate during the dry period. Intramammary treatments after dry-off must be performed with extreme care and scrupulous hygiene.

Treatment while milking

Milk intended for human consumption (fluid or processed) should be free of any drug. The Food and Drug Administration (FDA) is responsible for approving and enforcing the use of drugs in animals to ensure that food obtained from treated animals does not contain illegal drug residues.

Such residues are detected during regular tests conducted by state or federal public agencies at milk and cheese manufacturing plants. If illegal drug residues are found, the milk cannot be processed (reducing financial returns to the producer) and more frequent testing of the producer's milk will follow. Producers caught repeatedly with illegal drug residues in their marketed milk will have their milk producer's license revoked. Therefore, dairy sheep producers need to be aware of treatments that can be legally performed to avoid leaving illegal drug residues in milk.

Antibiotics

Antibiotics are the most common illegal drug residues found in milk. Many antibiotics available in the United States are not approved for use in sheep. The use of antibiotics in farm animals requires a veterinarian-client-patient relationship, and in the case of dairy ewes, occasionally permits the use of drugs labeled for other species to be used under veterinary supervision.

The use of antibiotics is becoming increasingly controversial and prophylactic methods are preferred. Mastitis is reduced by a properly functioning milk machine (check for inappropriate or unstable vacuum levels, faults in milking machine pulsation, teat cup slippage), good milking management (avoiding over- and undermilking), correct udder hygiene (post-dipping), correct hygienic bedding (abundant and fresh bedding on a daily basis), and correct flock management (culling of high SCC ewes, which necessitates the control of individual SCC on regular intervals and culling of all ewes showing hardness or nodules in the udder after dry off).

Each drug approved by the FDA has a withdrawal period, specific for the approved species that must be respected before any tissue from the treated animal can be sold for human consumption. Because of the lack of approved drugs for sheep, drugs approved in cattle are often administered to sheep. However, the withdrawal times may not have been accurately established for sheep.

A good example of this situation is presented in the study performed by Roncada et al., (2000). Following intramammary administration of dicloxacillin in cows and in sheep, the authors found that residues were undetectable after 48 hours in cows but only after 72 hours in ewes of low milk production and 84 hours in ewes of high milk production. This presents problems, especially for dairy sheep producers, and **it is recommended that a veterinarian be consulted prior to the use of any medication in dairy ewes**. Many of the common drugs and antibiotics used by lamb and wool producers, are not allowed in dairy sheep, simply because the withdrawal time is not appropriate for the sale of milk (it is not uncommon for many antibiotics to leave residues in animal tissues for up to one month).

Antibiotics are commonly added to livestock feed to enhance growth and protect animals from possible infection. When buying commercial feed, a dairy producer should pay particular attention to the composition of the feed.

As a general rule, antibiotics should not be used in lactating dairy ewes. In case of acute mastitis, the ewe should be immediately removed from the milking group, treated, and not allowed back in the milking parlor.

Oxytocin

As previously noted, oxytocin is a hormone produced by the brain and released at milking (or suckling) as an integral part of the milk ejection reflex. During the transition from suckling to exclusive machine milking, it takes a few days for the ewe to get enough stimuli from the milking process to release oxytocin. Therefore complete evacuation of the udder at this time is impossible and yet necessary for the normal continuation of lactation.

To remedy this problem, producers could rely on oxytocin injections for one or two milkings to ensure that the udder empties adequately. Oxytocin , does not pose a drug residue problem at this time. Oxytocin injections should be limited to only one or two milkings because there is a risk that the ewe will not properly adapt to normal machine milking due to the animal's becoming habituated to it. Finally, extended use of high doses of oxytocin can actually decrease milk yield.

Anthelmintics

Due mainly to intensive management practices, dairy ewes are extremely susceptible to parasite infection and require treatment with anthelmintics ("de-wormers"). There are two times during the year when parasite infection is important: during the spring ("spring rise"), when the combination of increasing ambient temperature and lush pasture growth are ideal for parasite development; and in the fall, just before the first frost when parasites already inside the animal go into a period of hibernation or "arrested development."

To complicate matters, dairy sheep should not be de-wormed during lactation when milk is being sold for human consumption. Therefore, strategic de-worming schedules need to be implemented according to a producer's management system. Some anthelmintics can be administered during gestation (consult your veterinarian), just prior to the first frost, which kills parasites before they have a chance to start the "arrested development" phase. This greatly reduces the parasite load in the flock the following spring. Depending on a producer's management system, dewormers can be administered a second time in the spring, approximately a month prior to sale of milk for human consumption (that is, a month prior to lambing for ewes that will be exclusively milked in early lactation, or at lambing for ewes that will be exclusively suckled in early lactation). Many de-wormers used in sheep have officially been approved only for use in other species, therefore it is always important to consult your veterinarian before using any anthelmintic or other drug in the flock.

As a rule, anthelmintics should not be administered to dairy ewes during the milking season. Control of parasite load should be performed through careful rotational grazing practices.

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Chapter 11

Artificial rearing of lambs

Many producers are reluctant to raise lambs artificially.

Introduction

Chapter 10 explained that the maximum milk production occurs when ewes are milked twice a day after removing their lambs 24 hours after birth. It has also been demonstrated that high producing ewes suckling only one lamb during the first 30 days of lactation will have a lower milk production and that 25–30% of the total milk production takes place during the first 30 days of lactation.

But in a previous study, McKusick et al. (1999) showed that when all lambs born (2.3 lambs per ewe) were raised on milk replacer and all ewes were put at milking 24 hours after lambing, the total financial return was only 6%–7% more than the traditional system of letting the lambs suckle their dams for 30 days.

A weaning management plan combining the two systems appears to be a better solution for the time being to realize maximum milk production and the highest profit. Therefore, in a dairy sheep operation it is desirable that a certain percentage of lambs be raised artificially either with part of the milk collected during milking or with lamb milk replacer.

Many producers are reluctant to raise lambs artificially for several reasons: the increased workload, the number of lambs that do poorly, a high mortality rate and the expense. In many cases those reasons are valid, but they are often linked to poor management and organization.

The Spooner Agricultural Research Station (University of Wisconsin-Madison) developed a simple, low-cost lamb rearing system that provides ease of management, promotes good lamb growth and reduces lamb mortality to a minimum.

Materials needed

Lambs should feed themselves on a free-choice basis to minimize labor and maximize the amount of milk consumed, promoting maximum growth. The self-feeding is done with the use of a "lamb bar" system consisting of rubber nipples connected to the source of milk by plastic tubing. The mixed milk replacer is put in containers placed in a regular cooler. The cooler's function is to control the temperature of the milk. The amount of material needed to successfully raise lambs artificially depends on the number of lambs the producer is planning to raise. However, the best plan is to keep it as simple as possible.

For approximately 100 lambs, you will need:

- Two or three used plastic baby bottles and used nipples in which the hole has been slightly enlarged. It is not necessary to purchase fancy bottles and fancy nipples.
- One heat lamp.
- Three coolers: one that holds 20 liters (20 quarts), two that hold 55 liters (55 quarts).

- One cake pan small enough to fit inside the small cooler and 4–5cm deep.
- One plastic dishpan fitting inside a bigger cooler and about 14 cm deep
- Two 8-liter (2-gallon) plastic pails.
- One dozen nipples (lamb bar). Nipples with a valve system should not be used because of cleaning difficulties.
- Clear plastic tubing to carry the milk from the source to the nipple. The tube is cut to desired length. The outside diameter of the tube should fit tightly inside the base of the nipple.
- Three panels of 120 cm x 90 cm to which a sheet of tin is attached. The tin is perforated with four holes to receive the nipples.
- Enough panels to build four pens.
- Cleaning equipment: brush, bottle-brush, tube brushes.
- Several deep-freeze plastic containers to store frozen colostrum.

For a large number of lambs, one or several automatic milk mixing machines might prove indispensable. They work well and save labor.

Products used

Colostrum

Since a certain amount of maternal instinct needs to be triggered in the ewes to be milked, lambs are not removed from their mothers until 24 hours after birth, giving them sufficient time to consume colostrum directly. On their second day lambs will receive the colostrum collected at milking.

The milk (or colostrum) produced during the first 3 days following parturition is unsuitable for human consumption or cheese making. Do not make this milk available commercially.

Some diseases, such as Ovine Pleuri Pneumonia (OPP) also known as "Hard Bag," is transmitted directly from the dams to their progeny through the colostrum. The disease can be eradicated within a flock by rearing the lambs on milk replacer and not allowing them to suckle their mothers. In this event, cow colostrum can be used efficiently. Collect cow colostrum on a dairy farm ahead of lambing time and freeze it in 16-oz. plastic containers. This colostrum can be thawed when needed.

Milk

Milk from the ewes

Part of the milk collected from the ewes at milking can be distributed to the lambs raised artificially. However, it is recommended that lamb milk replacer should be used because it is generally medicated, therefore protecting the lambs against possible infection.

Lamb milk replacer

Use only high quality lamb milk replacer. Some people might achieve relative success with a few lambs using goat or cow's milk, but these cannot be used on a large number of lambs. The fat content of sheep's milk is much higher than cow's or goat's milk and the lactose content is lower. Modern lamb milk replacers are made to meet the lambs' exact requirements. By using milk replacers according to the label, it is rare to see scours in young lambs. Moreover, modern lamb milk replacers are easy to mix and stay in suspension for long periods of time.

In a simple system, milk powder is mixed with water (one part dry powder to two parts water) with a hand beater. Fresh milk is made several times during the day. When . Automatic milk mixing machines mixe only a small amount of milk at a time, therefore providing fresh milk to the lambs at all time.

Starter feed

A starter feed (19% CP) is provided to the lambs at a very early age. The starter feed used at the Spooner Research Station has the following composition:

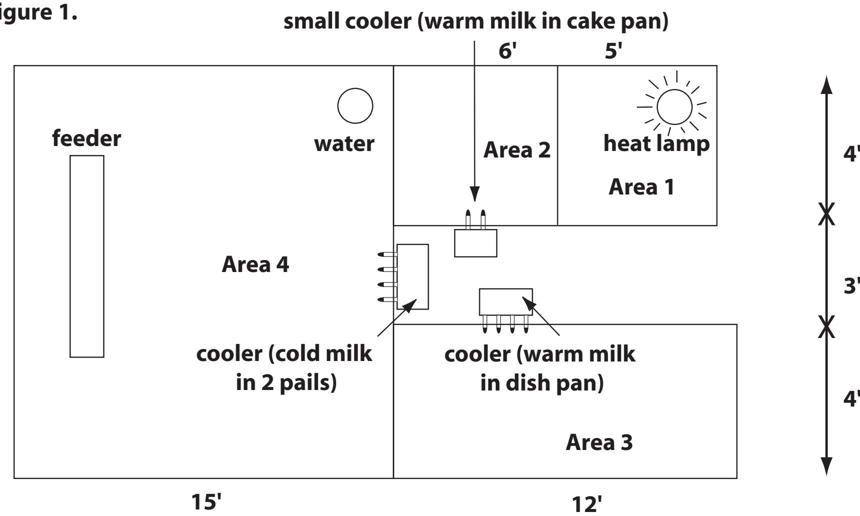
Rolled shelled corn	47.8%
Rolled oats (can be replaced by rolled corn)	12.5%
Premix with Bovatec	16.5%
Soybean meal	17.2%
Molasses	5.0%
Sheep mineral	.5%
Ammonium chloride	5%
	100%

Set up

Four pens are set up: a small pen in which newborns are trained to the baby bottle, a slightly bigger pen in which lambs are trained to the lamb bar, an intermediate pen and a graduate pen (figure 1). All pens are set up in a heated area, which, in the middle of winter stays at 2˚C to 5˚C. Pens are bedded with straw.

It is very important that the rearing area be well-ventilated and without any drafts.

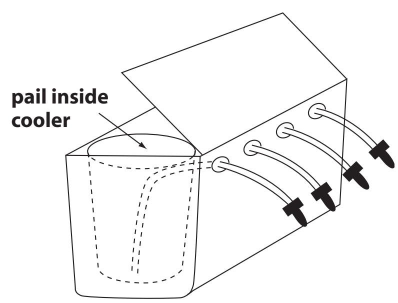
Figure 1.

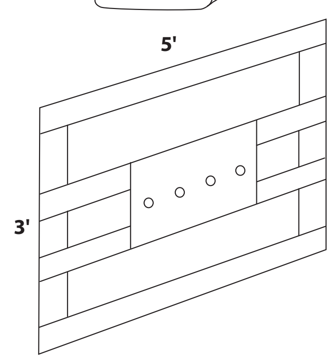


- *Bottle lamb pen (Area 1)*: After a lamb is chosen to be raised on milk replacer, it is placed in a small pen (150 cm x 120 cm) with a heat lamp in a corner. In this pen, lambs receive an adequate supply of colostrum (at least two feedings) and are trained to eat willingly from the baby bottle. Lambs are fed approximately every 4–5 hours. This phase lasts generally 24 hours. The time spent with the lamb in this pen depends on its behavior, which varies greatly between individuals. In this pen, a heat lamp is provided for the comfort of the very young lamb.
- *First lamb bar pen (Area 2)*: As soon as the lamb takes the bottle greedily, it is put into a slightly larger pen (180 cm x 120 cm) in which a lamb bar has been set up using the smaller cooler, the cake pan, two tubes and two nipples. No more than seven or eight lambs are put in this pen at the same time. The cake pan is placed inside the cooler resting in a block placed in the bottom of the cooler. Therefore the level of milk is kept high enough for lambs to receive the milk without sucking very hard. Warm milk is put in the cake pan. In wintertime, the milk is kept warm by placing a jug full of hot water in the bottom of the cooler. In this pen, lambs are trained to find the milk by themselves. The first two or three feedings, lambs are brought to the nipple and held until the milk comes. It helps to let the lambs get slightly hungry before the first feeding. Some lambs understand the principle of the surrogate mother right away; others are a little bit more reluctant, but all can feed themselves adequately in 48 hours. It is important to observe the lambs from a distance and take note of the ones eating well by themselves. Those lambs can be put in the intermediate pen.
- *Intermediate pen (Area 3)*: This pen is bigger (360 cm x 150 cm), where 15 lambs can be put together. A four-nipple lamb bar is set up with a bigger cooler. A plastic dishpan filled with warm milk is placed inside the cooler that is raised on a block to keep the level of milk high enough for easier sucking. At this point, no jug of hot water is placed in the cooler. It does not matter if the milk is allowed to cool. When lambs are doing well in this pen they are advanced to the graduate pen.

There should be one nipple for every five lambs in the training and intermediate pen and one for every 10 lambs in the graduate pen.

Cooler with 1/2" holes for plastic tubing. Nipples adapt to holes in tin in panel.





3' x 5' panel with tin insert, in which holes (9/16") are drilled for nipples.

General set up of the lamb rearing operation at the Spooner Ag Research Station (UW-Madison).

One-day-old lambs.

Older lambs in larger area.

Nipple attachment to panels.

Milk in a cake pan in the training pen.

Milk in a dish pan in the intermediate pen.

Milk buckets in the graduate pen.

Bottle feeding one-day-old lamb.

Training lamb on the lamb bar.

Lambs eating on their own.

Feeding machine.

Feeding machine.

- *Graduate pen (Area 4):* this is a much larger pen (450 cm x 360 cm) where up to 30 lambs are together. A four-nipple lamb bar is set up. The cooler is big enough to hold two 8-liter (2-gallon) plastic pails filled with cold milk. Lambs do very well on cold milk and it keeps them from eating too much at one time. In this pen, a starter feed is put at the disposition of the lambs. At this stage, lambs are no longer a source of intense work. It is enough to bring them fresh milk at regular intervals and watch them grow.

Lambs are vaccinated with C, D & T as soon as they are 10 days old.

Daily routine

1. In the early morning, completely dismantle **all lamb bars. Wash all elements thoroughly with detergent, brushes, and hot water**. This is an essential step since cleanliness is the most important factor in keeping the lambs healthy.
2. Set up the lamb bars again. Mix fresh (either warm or cold, according to pen).
3. Put fresh bedding in all pens. Feed is put in pen four. Some lambs move from pens three to four.
4. Lambs in pen one are fed milk in the bottles. Some of the lambs will move to pen two.
5. Lambs in pen two are trained at the lamb bar. Some lambs are moved to pen three.
6. New lambs are put in pen one.
7. During the day, the levels of milk in the coolers are checked regularly and more milk is mixed when needed.

Weaning

Lambs are weaned **abruptly** anywhere from 17 to 45 days with an average of 28.9 days. Small lambs are always weaned at an older age than regular lambs. As a rule of thumb, lambs are weaned when they are close to three times their birth weight.

The Spooner Research Station average of 28.9 days for age-at-weaning is somewhat high (25 days would be better), although many lambs are weaned much earlier.

Age in days	% of lambs
15 to 19 days	1.7%
20 to 24 days	20.5%
25 to 29 days	38.7%
30 to 34 days	22.4%
35 to 39 days	8.7%
40 to 50 days	7.9%

Generally, the smaller the lamb is at birth, the older it is at weaning because of a slower growth rate. At weaning, lambs are removed from the nursery area. For the next two or three days, lambs bleat ferociously and lose some of their bloom. But soon the amount of starter feed consumed increases and a very decent growth rate is achieved. For the next few weeks, a high protein ration is essential.

The first lambs of the season are always the most difficult to wean since no experienced lambs are around to share their expertise. Thereafter, lambs that are added to the already weaned group wean easier with less stress.

At weaning, lambs are given a booster of the C, D & T vaccine.

Performance of lambs raised on milk replacer

Between 1989 and 2003, a total of 2214 lambs have been raised on milk replacer at the Spooner Research Station. All information pertaining to these lambs are presented in the following two tables. Table 1 gives the performance of lambs according to the year of lambing, the type of birth, and sex. Since the Spooner Research Station deals with many different genotypes of lambs, table 2 gives the same type of data according to the breeds of sire of the lambs.

Both tables reflect very good performances of lambs raised on milk replacer. Mortality before weaning varies greatly between breeds of lambs (from 0% to 10%) and growth between birth and weaning is good to excellent although McKusick et al. (1999) reported a somewhat slower growth rate after weaning of East Friesian crossbred lambs when compared to the same type of lambs that suckled their mother for the first 30 days. Very small lambs at birth (2.0 to2.5 kg.) do not do quite as well and it takes longer to wean them. However, most lambs grow well after weaning with a gain of 300–330 g/day.

Economics of raising lambs on milk replacer

The apparent high cost of raising lambs on milk replacer is the main reason for the reluctance of sheep producers to start an artificial rearing system. A brief analysis of the expenses and income from the milk collected follows.

Expenses—example

Milk replacer

For the 2214 lambs raised on milk replacer between 1989 and 2003, an average of 8.2 kg. of milk powder was used per lamb. The average price of milk varies according to quality, brand, quantity purchased and retailer.In large quantities the price can be as low as US$ 1.94/kg but can also be a s high as US$ 3/kg when purchased one bag at a time. In this study the price is US$ 2/kg. Therefore, the cost of milk per lamb is $16.40.

Labor

During the first three days, one lamb gets approximately 10 minutes of personal attention per day. Thereafter, the time spent per lamb up to weaning is very minimal, consisting mainly of cleaning equipment, making milk, and giving creep feed.

- First three days 10 min./day
- Remaining 25 days 2 min./day
- Total 1 hr. 20 min.

x $8/hr.=$10.60

Table 1. Performance of lambs raised on milk replacer according to the type of birth, and sex.

	No.	Birth wt.	Wean wt.	Wean age (days)	ADG birth weaning	ADG wean sale	Mortality before weaning
All lambs	2214	4.6	13.0	29	286	324	3.9%
Type of birth							
1	287	5.8	14.8	29	313	332	5.2%
2	932	5.0	13.9	29	306	326	4.8%
3	768	4.1	11.8	29	266	320	2.6%
4	197	3.5	10.7	30	243	329	3.0%
5	24	3.0	9.6	33	203	297	4.3%
6-7	6	2.6	9.2	36	203	104	0%
Sex F	1097	4.5	12.6	30	278	291	3.7%
Sex M	1117	4.8	13.3	29	294	341	4.1%

*partial results

Table 2. Performance of lambs raised on milk replacer according to genotype.

	No.	Birth wt.	Wean wt.	Wean age (days)	ADG birth weaning	ADG wean sale	Mortality before weaning
All lambs	2214	4.6	13.0	29	286	324	3.9%
Breeds of sires							
Hamp-Suffolk	964	5.0	13.8	29	307	328	1.8%
Dorset	140	3.5	10.6	31	240	333	2.2%
Finnsheep	38	4.3	11.7	26	286	352	0%
Romanov	55	3.6	10.0	28	228	303	0%
Targhee	32	5.1	12.5	27	275	324	0%
Texel	150	4.3	11.6	29	265	300	2.7%
East Friesian	487	4.6	12.7	30	276	319	5.6%
Lacaune	348	4.5	13.1	31	277	332	10.4%

Investment

At total of $150 has been invested in equipment (coolers, pails, etc.). After ten years of use, the coolers are still suitable for further use. The total cost of investment per lamb is $0.15.

Supplies

A few supplies are needed, such as:

Nipples	10/year @ $1.10	$0.10/lamb
Brushes		$0.12/lamb
Detergent		$0.12/lamb

Summary of costs

Milk replacer	$16.40
Labor	$10.60
Investment	$.15
Supplies	$.34
Total cost	$27.50

Therefore, the total cost of raising lambs on milk replacer in 2003 from birth to weaning is $27.50

Income

The income derived from the sale of milk collected during the first month of lactation depends on the level of production of the ewe. The expected level of production can be obtained by taking 30% of the total milk production at the previous milking season.

From this income, it is necessary to subtract the cost of labor of milking this ewe twice a day for 30 days, that is, $11.50 (see chapter 12). The results are best expressed in a table (table 3) according to the expected level of production of a ewe for the first 30 days and the number of lambs born and artificially reared.

Table 3 shows that, for the best financial return, a ewe having given birth to 3 lambs should raise her own lambs rather than being milked twice a day unless she is a very goodl animal able to give 80 liters and more during the first month of lactation. On the other hand an animal having given birth to only one lamb should be milked and her lamb raised artificially even if she is an average animal giving only 50 liters of milk in the first month of lactation. Below an expected level of production of 50 liters it is best to have the ewe raise her lamb(s). The break even point is very much dependent on the price of the milk sold and the cost of milk replacer.

Conclusion

With ewes producing more and more milk it becomes difficult to keep the traditional weaning system without suffering a significant loss in financial return. The milking at 24 hours after lambing of the best milking ewes and of the ewes producing only one lamb becomes necessary forcing producers to rear artificially a certain percentage of lambs born on the farm. Lambs can be successfully raised artificially with good management practices and good working organization. The most important considerations are:

- Making sure lambs receive enough colostrum.
- A high level of cleanliness.
- A well-ventilated rearing area with no draft.
- Providing fresh milk to the lambs at all times.

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Table 3. Potential return in US dollars during the first month of lactation according to the level of milk production and the number of lamb born and raised artificially (cost of milk powder US$2/kg, price of milk sold US$1.4/liter)

Number	Expected level of production in the first 30 days (in liters)					
of lambs	50	60	70	80	90	100
1	+$31	+$45	+$59	+$73	+$87	+$101
2	-$3.5	+$17.5	+$31	+$45.	+$59.5	+$73.5
3	-$24	-$10	-$+41	-$+18	+$32	+$46

Chapter 12

Economics of raising dairy sheep

For most producers, the appeal of the lifestyle is the main motivation for beginning a dairy sheep operation.

Yves M. Berger

As in any enterprise, milking sheep and selling the milk (or processed products) is all about making a profit. Berger (1999) in a comparison between a dairy sheep operation and a meat/wool operation has shown that milking ewes can double a producer's return. Of course, the financial return varies according to the producer's reasons for starting a dairy sheep business (practical and/or philosophical)—reasons that will influence the type of operation.

No matter what the type of operation, it needs to be profitable while still respecting the principles of sustainability. There are practically as many types of operations as there are producers, but in North America most sheep dairy enterprises are small-scale family businesses (up to 300 ewes) designed either to provide a supplemental income or a full-time occupation to at least one member of the household, or to make sheep dairying the main source of income.

For most producers (and families), a certain way of life is the main motivation for beginning a dairy sheep operation. More often than not, those involved are fairly new to the sheep business, able to look at a sheep operation from a fresh perspective, and understand that there is much to gain by cultivating more products from their sheep.

However, milking is not for everyone. It involves many constraints that a producer must master before entering the business. In addition, plans to sell and market the product and for some type of financial analysis must be part of the overall operation.

What to consider before starting a sheep dairy operation

Labor resources

Sheep farming is a labor-intensive operation requiring a substantial number of hours per day. Milking can easily double or triple the time involved for an inexperienced or ill-equipped producer and the intense work can be overwhelming. Lambing, rearing lambs, weaning and milking, handling and/or processing milk often coincide at the beginning of the season. Depending on the number of animals, the workload can be too much for one person to perform efficiently. Later in the season, when things calm down, milking still must be performed everyday, twice a day—*without fail*—for the next 5 to 7 months.

If milk processing is also being done, cheese (or other products) need to be made on a regular basis. Entering the dairy business is, therefore, a long-term commitment to be taken seriously by *all members of the family,* because at times it will require that all members be involved in the operation.

In a larger (but still family size) operation, hiring supplemental labor might be necessary and will need to be considered in the financial plan.

A disciplined work routine and thorough understanding of the milking ewe are indispensable to get the best production in the best possible conditions. Dairy ewes are creatures of habit and changes in their routine create stress that affects milk production.

Forage resources

In contrast, to meat-only production systems where ewes' lactation is often cut short when their lambs are weaned, dairy sheep have a longer production period during which they need feed with high nutritional value. Feed reserves in terms of preserved forage, green forage and grain supplement must be calculated to cover the whole lactation.

A short supply of high quality feed will have a negative effect on the overall milk yield of the flock and therefore on its profitability.

In many cases it is cheaper and simpler to purchase feed than to produce it on the farm. By not having to produce the feed, the producer can put more effort on caring for and milking the animals.

The season chosen for milking will affect the overall cost of production. Winter milking favors milk production and length of lactation but relies on a greater consumption of expensive preserved forage. Spring milking relies more on cheaper green forage to the detriment of milk yield because of generally higher temperatures in July and August when ewes are still in mid-lactation. Deciding when to milk depends on forage availability and cost, the producer's ability to grow high quality pastures, and on the demand for milk or processed products.

If feed resources are based on hay, corn, soybean meal and pasture, approximate quantities of each feed are shown in table 1 according to the system used.

Table 1. Quantity of feed needed by a dairy ewe during a year.

	Complete confinement year round	Semi-confinement winter lambing	Semi-confinement spring lambing
Alfalfa hay (kg)	730	410	350
Corn (kg)	148	120	80
Soybean meal (kg)	20	18	12
Pasture	-	4 month high quality 2 months low quality	6 month high quality

Choosing a milking system

The parlor

The different milking systems available are described in chapter 9.

The most important point to consider in choosing a system is the speed at which milking can be performed in the best possible conditions for both the animals and the milker.

As a general rule, milking, cleaning and handling milk should be completed in no more than two hours—whatever the number of ewes involved. If it takes longer, the milker, as described by Olivia Mills (1995) "gets tired, gets fed up, gets hungry, gets bad-tempered, gets problems." Therefore, throughput of the ewes in the parlor is of the utmost importance.

The tables in chapter 9 can help producers decide on a system according to the number of ewes being milked. However, the number of ewes milked per hour shown in these tables has been calculated for Lacaune ewes which give milk more rapidly than East Friesian ewes (Bruckmaier et al., 1997). Lacaunes are also milked using a simpler milking procedure that does not include stripping. With the type of ewes actually milked in North America, the parlor throughput will be generally less than reported in the literature.

The more ewes that are milked, the more sophisticated the system becomes and consequently, the more expensive it becomes. Good planning can help reduce expenses, but an initial investment of $170 per ewe in the U.S. is not farfetched. Installing a system for 300 ewes if it will take 10 years to build a herd this size is not advisable.

The milking machine

The quality of the equipment and its suitability for dairy sheep is also very important. The incidence of mastitis and/or high somatic cell count in the milk, as well as the total milk yield, is directly linked to the milking machine. Sufficient vacuum reserve, constant vacuum level throughout the system, correct pulsation rate, correctly sized teat cup liners, and ease of cleaning all ensure complete evacuation of the udder, promoting udder health and a long lactation.

There can be no possible compromise on the quality of the equipment. A producer should not indulge in makeshift equipment that is not especially designed for milking sheep.

Marketing

Marketing the milk should be a main priority for anyone considering sheep dairying. The "how" and "where" of selling the products (milk, cheese, yogurt) should be settled before other decisions are made. The market for domestic sheep dairy products is in its infancy and the products are not yet accessible everywhere. Options to consider are selling fluid milk to a cheese plant (family or industrial) or processing the milk on the farm and selling the products (cheese, yogurt, ice cream, soap, etc.) directly to the consumer.

Sale of fluid milk

Selling fluid milk to an industrial cheese maker is certainly the most straightforward way to distribute the product. The dairy sheep producer can then concentrate on producing high quality milk without the burden of marketing more individual products.

However, there are several constraints to note. Cheese makers, even small ones, generally use equipment that allows for processing a significant amount of milk. Keeping just each day's production (most equipment will hold about three days' worth) in the cooling tank is not efficient. **In fact, an isolated sheep dairy producer will find it difficult to sell fresh fluid milk to a professional cheese maker because a single producer cannot deliver sufficient quantity.** To solve this problem, several producers in the area near a processing plant need to pool their milk.

The problem is made more complicated by the uneven seasonal production in which the daily quantity of milk produced is determined by the number of ewes lambing on the same day or week. An individual producer's volume is low at the beginning of the milking season and reaches a peak when all ewes are at milking. The volume then decreases rapidly. Thus, delivering fresh milk during the peak of production could be considered but is almost impossible at both ends of the production period.

To help alleviate this problem, producers can freeze milk that cannot be delivered on the day of production. Many excellent cheeses and yogurts can be made from frozen milk if it is frozen correctly.

Freezing milk correctly calls for very low temperatures (see chapter 1) that only commercial freezers can reach. Home chest freezers do not have the capacity to freeze milk rapidly enough. Freezing too slowly leads to processing problems later because milk proteins degrade.

When planning to sell milk it is essential to include the purchase and operating cost of a commercial freezer in the financial plan. Freezing the milk will increase its cost of production.

Farmstead products

Because of the many constraints linked to the sale of fluid milk and fluctuations in buyers' willingness to purchase it, many producers choose to develop their own finished product and sell directly to consumers—individuals, restaurants or specialized stores and markets.

The process can be very rewarding as long as one understands that:

- It requires a very high quality and original product. Average or inconsistent goods might sell once but will not bring repeat buyers. It might take years and much trial and error before arriving at the perfect product. Income could be markedly reduced during this process.
- It requires many hours of work to market the product. Visits to potential consumers, farmers' markets, store promotions, etc. are time-consuming. Generally it will take a full-time person to care for and market the cheeses. There is simply not enough time for the same person to also feed, milk and care for the animals.
- It requires some initial investment such as cheese room equipment, pasteurizer, cold room and aging rooms. In the case of yogurt making, the investment could be fairly substantial.

In some areas (such as Wisconsin), selling cheese other than directly from the farm requires completing an 18-month apprenticeship and test to get a cheese maker's license. A license is also required to pasteurize milk.

Producers in the same area should consider collaborating to reduce cost and labor. Milk marketing, cheese making and/or cheese aging cooperatives already exist in North America. Potential sheep dairy producers should contact them for information (see Appendix A: Useful Addresses).

Potential financial return of a dairy sheep operation: An example

It is important for a producer to have a precise idea of the operation's potential financial return so as to be able to adopt techniques that allow for a better return.

It is impossible to describe all possible types of operations because, as already mentioned, there are practically as many types of operations as there are producers. Nevertheless, the example here can help establish a framework, keeping in mind that it does not consider the interactions that might exist in a real situation. The figures presented are merely an example and are not based on the real conditions, resources, management skills and philosophy of the operation.

Example

Background

The operation consists of a flock of 300 East Friesian crossbred ewes milked in a 2 x 12 Casse parlor with 12 milking units, high line, cooling tank and commercial freezer. All the milk produced is frozen and sold to a cheese plant at the price of $ 1.32 per liter. All feed is purchased outside the farm, but improved pastures are grazed for 6 months of the year.

Lambing occurs in February, with a start of milking 30 days after lambing. This is a conservative weaning system that does not maximize milk production (see chapter 10, "Weaning of Lambs"). Lambs are weaned at 30 days and raised on high-energy ration to a slaughter weight of 55 kg. The price of live lamb is $1.54 a kilogram. This operation seeks an average return per ewe with moderately high cost of production.

Animal parameters

The prolificacy of East Friesian crossbred ewes is 220% with a fertility of 95%, an annual mortality rate of 3% and a culling rate at milking of 3%. The total number of lambs produced is 627 with a mortality rate of 13% between birth and sale at 55 kg. A total of only 220 adult ewes will be available for milking.

Sixty ewe lambs are kept for replacement, 20 are sold for breeding as are 4 ram lambs. Ewe lambs are bred at 7–8 months of age with a success rate of 95%. Because of some ewe lambs not adapting to milking, only 50 ewe lambs will be available for milking.

Milk production of adult ewes is 200 liters in a milking period of 180 days, while the milk production of ewe lambs is 130 liters in 110 days. The flock average is therefore 187 liters/animal milked.

Feed

Ewes are fed alfalfa hay (1.8 kg before lambing, 2.8 kg after lambing), shelled corn (0.45 kg/day before lambing) and a 16%CP concentrate during milking (0.9kg/day). As soon as possible, ewes are put on improved pastures such as Kura clover-grass mix. The cost of pasture is evaluated at $2 per ewe per month.

Lambs consume an average of 47 kg of a creep ration (21% CP) and 122 kg of a finish ration (13%CP) and are sold in June–July when the market is generally at its highest point.

Equipment

The total investment for the milking system including the commercial freezer is $50,000. Other equipment for general sheep management is evaluated at $15,000 and the buildings at $30,000. Initial investment for livestock is $50,000.

Labor

Labor is provided by one person working full-time and one part-time person working 900 hours and paid $8/hour. The hired labor is included as an expense while the possible salary of the manager of the operation is represented by the return to labor and management.

Income-expense report

	number	unit	price ($)	total
Receipts				
Slaughter lambs	406	55kg	1.54	38,962
Sale of ewe lambs	20		200.00	4,000
Sale of ram lambs	5		500.00	250
Sale of culled ewes	50		75.00	3,750
Sale of older rams	2		500.00	1,000
Wool	300	4kg	22.00	264
Milk	270	187.1	1.40	70,686
Total receipts				**121,162**
Variable expenses				
Ewe feed				
pasture	300	6mo	2.00	3,600
3 month hay 1.8kg	300	160kg	.08	3,840
3 month hay 2.8kg	270	250kg	.10	6,750
1 month corn .45kg	300	16kg	.13	624
3 month 16%CP .90kg	270	82kg	.15	3,321
2 month 16%CP .45kg	270	28kg	.15	1,134
Total				**19,269**
Lamb feed				
Creep feed 21%CP	545	47kg	.20	5,123
Finish ration 13% CP	545	122 kg	.14	9,309
Hay replacement ewes	60	300kg	.11	1,980
Total				**16,412**
Other feed				
Salt and minerals				970
Milk replacer				1000
Total				1970
Total feed				**37,651**

Income-expense report, *continued*

	total
Livestock expenses	
Shearing	600
Marketing-trucking of lambs	1,300
Vet-Med	1,500
Supplies	
sheep	1,000
milking	1,500
Bedding	1,800
Utilities	
electricity freezer	2,500
other	1,000
Machine operation cost	1,500
Ram cost	2,000
Hired labor $8/hour	7,200
Maintenance and repairs	1,500
Operating loan interest	2,000
Dairy cooperative cost (.21 cts/liter of milk)	6,065
Total livestock expenses	**36,003**
TOTAL VARIABLE EXPENSES	**73,654**
Fixed expenses	
Sheep equipment 8% of US$ 15,000	1,200
Livestock 4% of $50,000	2,000
Building 7% of $30,000	2,100
Milking equipment 8% of $50,000	4,000
Pickup truck	2,000
Property taxes	2,000
Insurance	2,000
Total fixed expenses	**15,300**
Returns	
Total income	**121,162**
Less variable expenses	73,654
RETURN TO LABOR AND CAPITAL	**47,508**
Less fixed expenses	15,300
RETURN TO LABOR AND MANAGEMENT	**32,208**
	$107/ewe

This is a relatively high return to labor and management. The operator working an average of 2500 hours a year could expect an hourly rate of roughly $13. Milk accounts for 50% of the total receipt. With a high cost of production the return will greatly depend on the total milk production of the ewes and on the sale price of milk. Table 2 shows the expected return according to the average milk production of the flock and the price of milk.

In this type of system, excellent management of the dairy ewes is essential to ensure a high return. It would be unreasonable, however, to expect a high milk yield during the first year of production (table 3).

Cost of milk production

In the example, the ewe feed cost represents more than 31% of the variable expenses. It is possible to reduce this amount without affecting the total milk production. Marie et al. (1998) have shown that high-producing ewes have better feed efficiency than lower-producing ewes. Therefore, with higher-producing ewes, the ewe feed cost/receipt from milk ratio would be greatly improved. Other means of reducing the overall cost of production can be found by relying on low input systems—generally at the expense of volume.

Since the cost of milk production is the difference between receipts from the sale of milk and expenses incurred solely for its production, it should roughly be similar in many types of operation. Expenses from milk production cut across all expense categories.

In any situation, however, it is best to prioritize expenses, choose what can be cut or reduced without affecting the performance of the animals or of the operator, and to never compromise on the animals' welfare.

Ewe feed

Not all ewe feed is required for the animals to produce milk. Feed costs at the end of gestation and early lactation are the same for meat-only and dairy operations. The difference lies in a longer, high-quality feeding period that involves concentrates and pasture. In the example, one-third of the ewes' feed expenses can be attributed to milking ($6,423).

Lamb feed

In a dairy operation, lambs are weaned at 30 days or earlier which translates into a higher consumption of expansive creep feed (+ 20 kg/lamb) and of finish ration (+32kg/lamb) for a total of $4,621. Lambs weaned at an early age need to receive a high protein ration and cannot be put on forage. The extra cost cannot easily be decreased.

Supplies

Supplies for milking such as detergent, acid, brushes, liners, milk tubes, milk filters and lab costs for milk analysis are estimated at $1,500.

Utilities

The single most expensive item is the operating cost of the commercial-grade freezer, estimated at $2,500 for the milking season.

Table 2. Expected returns according to the price of milk and milk yield.

Price of milk in $/liter	Average milk yield of the flock in liters					
	140	160	180	200	220	240
1.00	-263	4,003	8,269	12,535	16,801	21,067
1.20	9,297	12,643	17,989	23,335	28,681	34,027
1.40	14,857	21,283	27,709	34,135	40,561	46,987

Table 3. Evolution of milk production at the Spooner Research Station between 1996 and 2003.

	1996	1997	1998	1999	2000	2001	2002	2003
Age of ewes (years)	Ewe lambs	Ewe lambs +2	Ewe lambs +2 +3	Ewe lambs +2+3+4	All ages	All ages	All ages	All ages
# of ewes milked (min. and max.)	23-130	49-193	12-225	18-215	27-267	30-261	16-326	20-293
Date started milking	4/2/96	3/18/97	2/11/98	2/13/99	2/11/00	2/13/01	1/18/02	1/14/03
Date stopped milking	9/11/96	9/14/97	9/8/98	9/16/99	8/31/00	9/19/01	9/27/02	9/16/03
Total production (liters)	10,000	23,903	36,550	43,257	59,661	50,254	64,559	70,389

Berger, 2000

The steady increase in milk production shown in table 3 is due to more mature ewes in production, better genetics and above all better management of the milking ewes (introduction of the DYI weaning system).

Machine operation cost

Half of the machine operation cost ($750) can be imputed to milking.

Labor

With an efficient system, milking 270 ewes should not take more than 4–5 hours a day as an average over the 160-day season. Considering that the producer's salary should be at least $13/hour, the cost of labor for milking is $10,400. Moreover, about three-fourths of the hired labor cost is attributable to the dairy operation ($5,400). The total labor cost for the milking and extra care of 270 ewes is therefore $15,800.

Operating loan

Half of the operating loan cost ($1000) is imputable to milking.

Milking system

The cost of amortization of the milking system ($4,000) is imputable to milking.

The total cost of production of the 50,490 liters of milk in the system described above is $34,844 or 0.69/liter. The difference between the cost of production and the sale price of milk represents the deficit or the profit of the dairy operation in the sheep enterprise. The cost of production varies greatly according to the average milk yield of the flock as shown in table 4.

Since the average milk yield of the flock depends on the performance of each individual ewe and on the number of ewes that stay healthy and in lactation, the cost of production is directly linked to the management skill of the operator.

Table 4. Cost of producing a liter of milk based on the average milk yield

Average milk yield of the flock in liters					
140	160	180	200	220	240
$.97/l	$.85/l	$0.75/l	$0.68/l	$0.62/l	$0.56/ll

Table 5. Comparison costs of producing Cheddar cheese from cow, goat and sheep milk (38% moisture, 54.6-55.1% FDB)

	Cow[a]	Goat[a]	Sheep[a]
Raw milk costs/100kg	28.05	48.4	140
Cheese mfg. costs/100kg of milk[b]	7.7	7.7	7.7
Credit for excess cream	(.64)	—	—
Credit for whey cream	(.42)	—	—
Credit for whey solids	(1.1)	—	—
Total cost/100kg of milk processed	33.59	56.1	147.7
Kg of cheese/100kg milk[c]	10.34	10.72	18.79
Cost per kg of cheese	3.24	5.23	7.86

[a]Milk composition assumed to be: cow, fat = 3.95%, protein = 3.33 %; goat, fat = 3.9%, protein = 3.3%; sheep, fat = 6.9%, protein = 5.7%

[b]Small processors cost of $.77/kg production cost for Cheddar

[c] Assuming 93% fat recovery, 96% casein recovery and a solids recovery factor of 1.09

Cost of cheese production

The economic potential for marketing sheep cheese products in the U.S. will depend on the cost of producing those cheeses. With sheep's milk, the increased solids and increased cheese yield will impact favorably on production costs. However, the initial cost of the milk will be the greatest factor affecting the cost of producing cheeses.

At the actual price (2003) of $1.40/liter in the U.S., milk cost per kilogram of cheese is very comparable to that of goat's milk. The other significant cost of producing cheese involves manufacturing. Table 5 shows a comparison of costs of producing a Cheddar-type cheese from cow's, goat's and sheep's milk. Currently, goat and sheep's milk processors do not have established markets for whey and processors are losing potential revenue from those components.

Cheddar cheese is produced most efficiently from milk with a casein:fat ratio of .70. With a casein:fat ratio of .60 in sheep's milk, the processor would lose some of the excess fat in the whey unless some separation of cream took place prior to cheese making. If the processor tries to maximize the cheese yield by designing a high moisture cheese that uses the casein:fat ration of .60, the estimated cost of production of that cheese would be as shown in table 6. The cost of producing this sheep cheese is slightly lower than the Cheddar-type primarily due to more efficient use of the protein and fat in sheep milk.

In a farm situation, the manufacturing cost might be somewhat higher because of smaller volumes and less efficient equipment. Add the costs of expenses related to the preparation of the cheese (curing, aging, etc.) and expenses related to marketing, as well as the profit of the producer. The final retail price of the cheese could be fairly high. To command such a high price, the product must be the highest quality in terms of taste, character, texture and consistency.

Domestic cheese producers face the challenge of producing cheese for which consumers are willing to pay more than they pay for subsidized imported sheep cheeses, such as Peccorino.

Domestic processors must develop unique products that are not in direct competition with commodity cheeses or imported sheep cheese.

Table 6. Comparison cost of producing a Manchego-type cheese from cow and sheep milk (45% moisture, 54.4% FDB)

	Cow[a]	Sheep[a]
Raw milk costs/100kg	28.05	140
Cheese mfg. costs/100kg of milk[b]	15.73	15.73
Added cream cost	.79	
Credit for whey cream	(.73)	—
Credit for whey solids	(1.56)	—
Total cost/100kg of milk processed	42.28	155.73
Kg of cheese/100kg milk[c]	12.96	20.74
Cost per kg of cheese	3.26	7.50

[a] Milk composition assumed to be: cow, fat = 3.95%, protein = 3.33 %; sheep, fat = 6.9%, protein = 5.7%

[b] Small processors cost of $1.21/kg production cost for Cheddar

[c] Assuming 90% fat recovery, 96% casein recovery and a solids recovery factor of 1.12

Conclusion

Sheep dairying can provide a decent return to a producer with good management skills if certain conditions exist:

- A well-thought-out financial plan
- A readily available market
- A long-term commitment
- Good control of production costs
- Ewes with good milking ability
- An understanding of the importance of a good milking system
- Membership in a group, association, or cooperative that supports the marketing of the milk and aids in solving in technical problems.

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Appendix A

Resources

Milking equipment

DeLaval, Inc.
11100 N. Congress Ave
Kansas City, MO 64153-1296
Phone: 816-891-7700
www.delaval.com

Westfalia Surge
1880 Country Farm Drive
Naperville, IL 60563
Phone: 877-973-2479
Fax: 630-369-9875
www.westfaliasurge.com

The Schlueter Company
3410 Bell street
Janesville, WI 53545
Phone: 608-755-5444
Fax: 608-755-5440
www.schlueter.com

The Coburn Company
P.O. Box 147
Whitewater, WI 53190
Phone: 1-800-776-7042
www.coburnco.com

Milk testing

DHIA
National Dairy Herd Improvement Association
Suite #102, 3021 E. Dublin Granville Road
Columbus, OH 43231
Phone: 614-890-3630
Fax: 614-890-3667
dhia@dhia.org
www.dhia.org

Performance recording software

EWE BYTE Sheep Management System
P.O. Box 375
Fergus
Ontario N1M 3E2
Canada
Phone: 519-787-0593
Fax: 519-787-2675
ewebyte@sentex.net
www.ovc.uoguelph.ca/associations/ewebyte/ewebyte.htm

Importation of germplasm and artificial insemination

USDA-APHIS (importation regulations, importation permits)
USDA-APHIS
Veterinary Services-National Center for Import/Export
4700 River Road Unit 40
Riverdale, MD 20737
Phone: 301-734-3277
Fax: 301-734-4704
www.aphis.usda.gov/vs/import_export.htm

Small ruminant genetics
R.R. 3
Markdale
Ontario N0C 1H0
Canada
wooldrift@bmts.com
www.srgenetics.com

Super Sire Limited (source of semen, embryos, artificial insemination)
4000 University Rd.
Hopland, CA 95449
Phone/fax: 707-744-1538
mdally@pacific.net

GENELEX (source of Lacaune from France)
Upra-Lacaune
Route de Moyrazès
12033 Rodez Cedex 9, France
Phone: (33) 565 73 78 14
Fax: (33) 565 73 78 15
upra.lacaune@worldonline.fr

BRITBREED Ltd.
Dr. James Mylne, Director
1 Airfield Farm
Cousland, Dalkieth
Midlothian EH22 2PE
Scotland
Phone: 01875 320727
Fax: 01875 320734
www.britbreed.co.uk

Associations

Dairy Sheep Association of North America
Carol Delaney, Secretary
University of Vermont
570 Main St., 200B Terrill Hall
Burlington, VT 05405
Phone: 802-656-0915
Fax: 802-656-8196
carol.delaney@uvm.edu
www.dsana.org

Wisconsin Sheep Dairy Cooperative
N 50768 County road D
Strum, WI 54770
Phone: 715-695-3617
kieftl@win.bright.net
www.sheepmilk.biz

Ontario Dairy Sheep Association
Wooldrift farm
RR3
Markdale, Ontario NOC 1HO
Canada
Phone: 519-538-2844
Fax: 519-538-1478
wooldrift@bmts.com

Vermont Shepherd
875 Patch Road
Putney, VT 05346
Phone: 802-387-4473
Fax: 802-387-2041
vtsheprd@sover.net
www.vermontshepherd.com

The British Sheep Dairying Association
BSDA Secretary
The Sheep Centre
Malvern, Worcestershire WR13 6PH
ENGLAND
Phone: +44(0)1684 892 661
Fax: +44(0)1684 892 663
bsda@btopenworld.com
www.sheepdairying.com

Research—Extension

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W6646 Highway 70
Spooner, WI 54801
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ymberger@facstaff.wisc.edu

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Madison, WI 53706
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cheeseout@aae.wisc.edu
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Journals, books, resource materials

Journal of the Dairy Sheep Association of North America
Pat Elliot, Editor
23246 Clark Mountain Road
Rapidan, VA 22733
Fax: 540-854-6443
pelliott@ns.gemlink.com

Sheep Dairy News
Secretary, British Sheep Dairying Association
The Sheep Centre
Malvern, Worcestershire WR13 6PH
ENGLAND
Phone: +44(0)1684 892 661
Fax: +44(0)1684 892 663
bsda@btopenworld.com
www.sheepdairying.com

Practical Sheep Dairying (out of print)
Author: Olivia Mills
Publisher: HarperCollins
ISBN: 0722507313

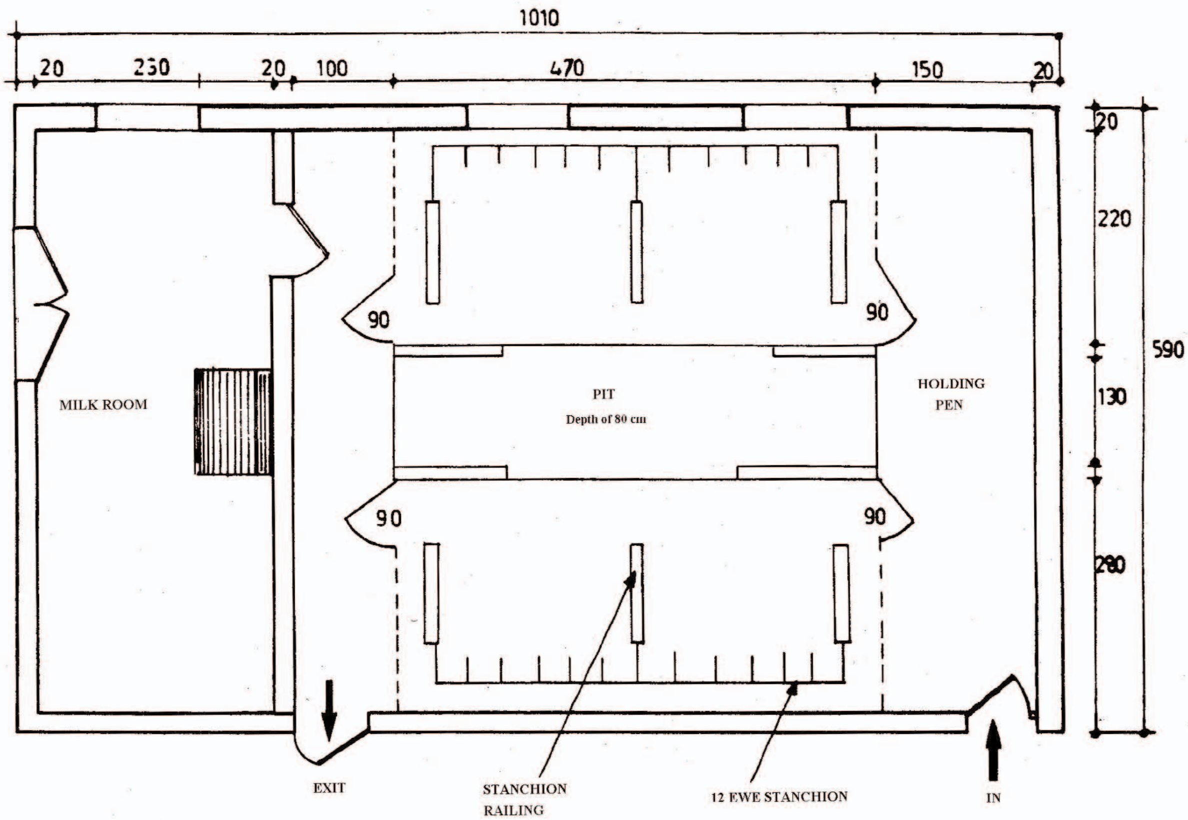
Past Proceedings of The Great Lakes Dairy Sheep Symposia
The Great Lakes Dairy Sheep Symposium has been held annually since 1995 in the U.S. and Canada. Past proceedings can be viewed at: www.uwex.edu/ces/animalscience/sheep.

Appendix B

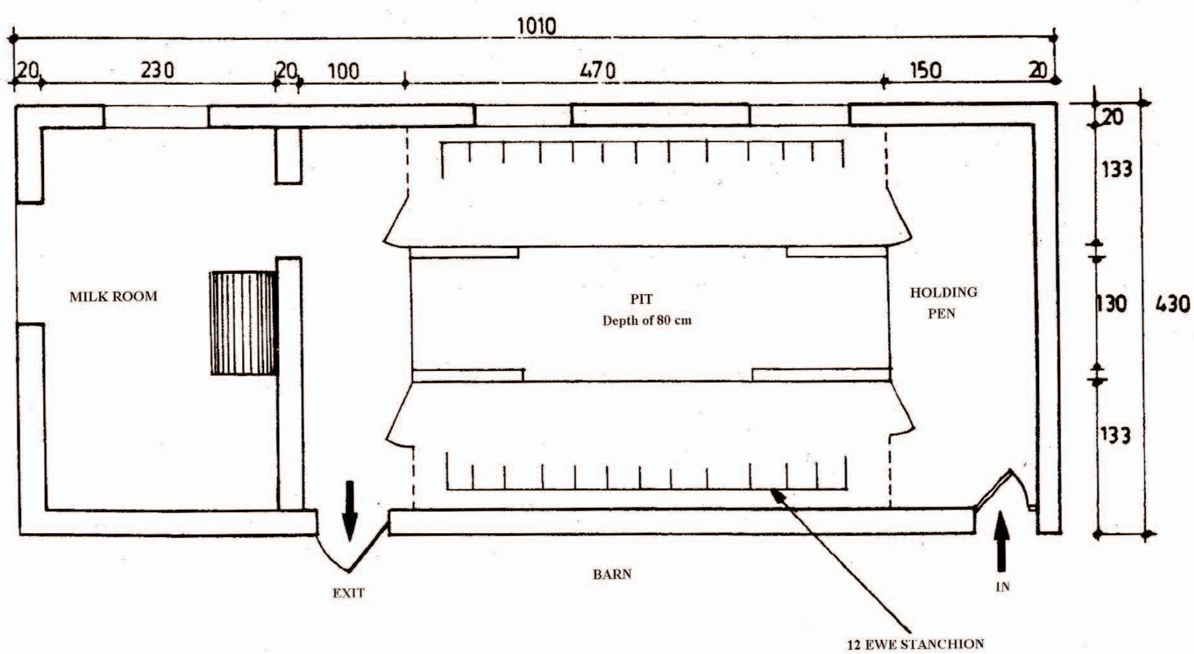
Floor plans of milking parlors & barn designs

Lacaune ewes in a typical barn in the Roquefort area

Floor plans of milking parlors.

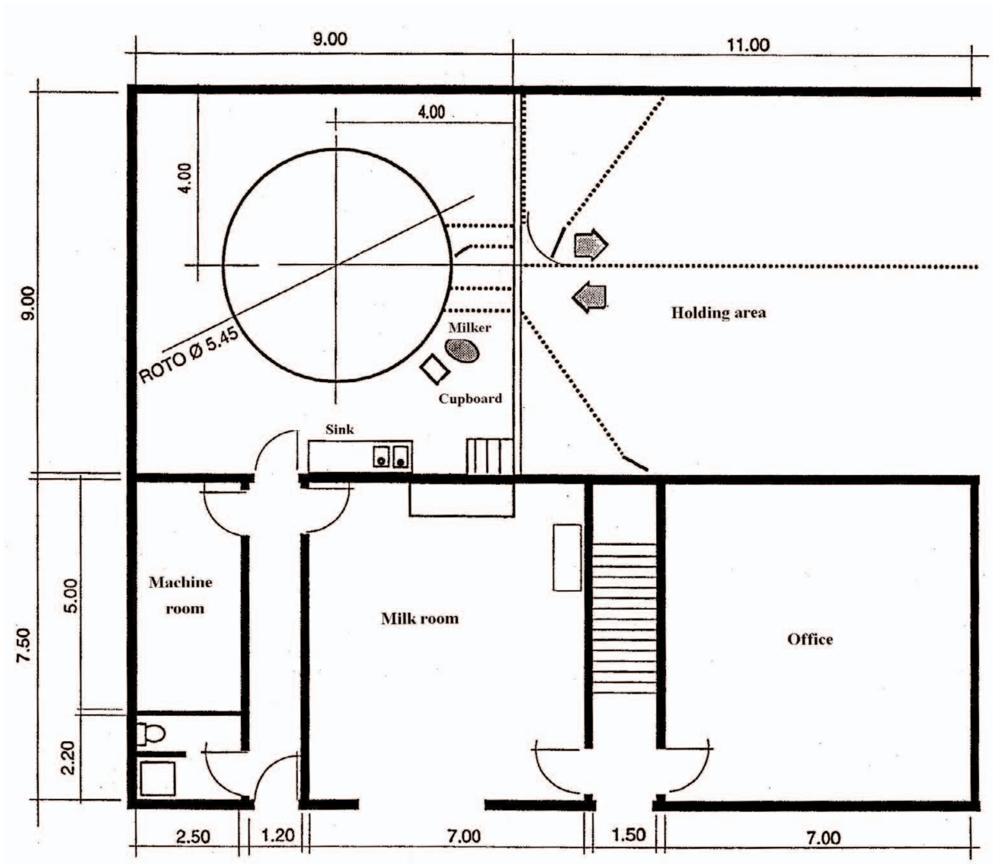


Milking parlor 2 x 12 ewes, mobile stanchion

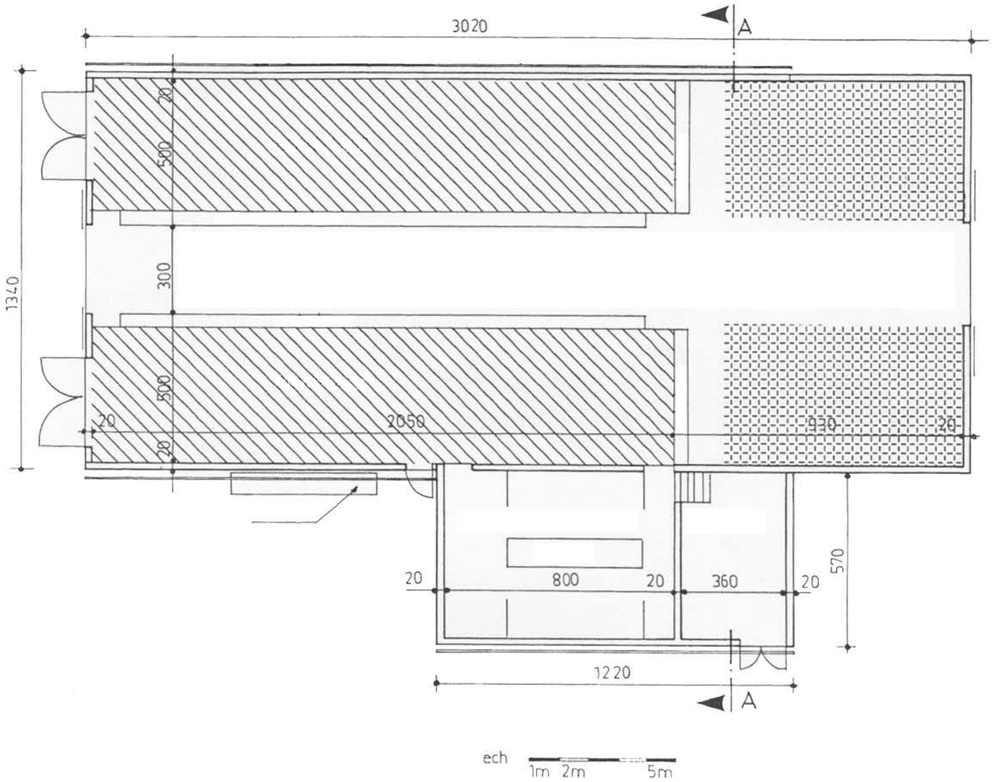


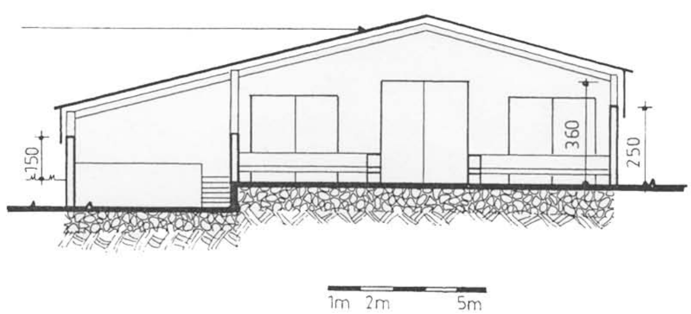
Milking parlor 2 x 12 ewes, Fix stanchion

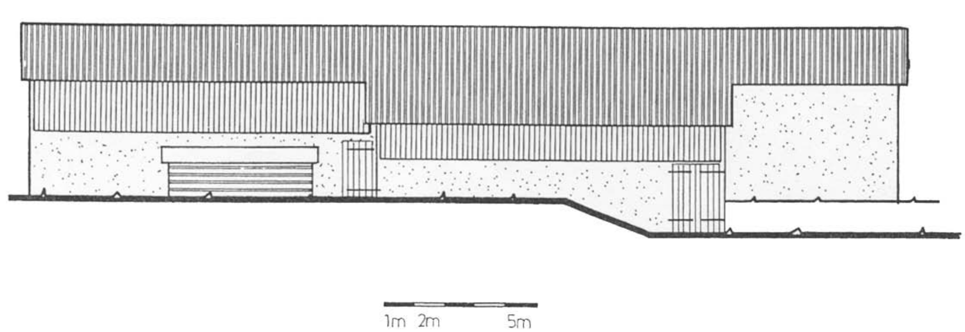
Floor plans of milking parlors.



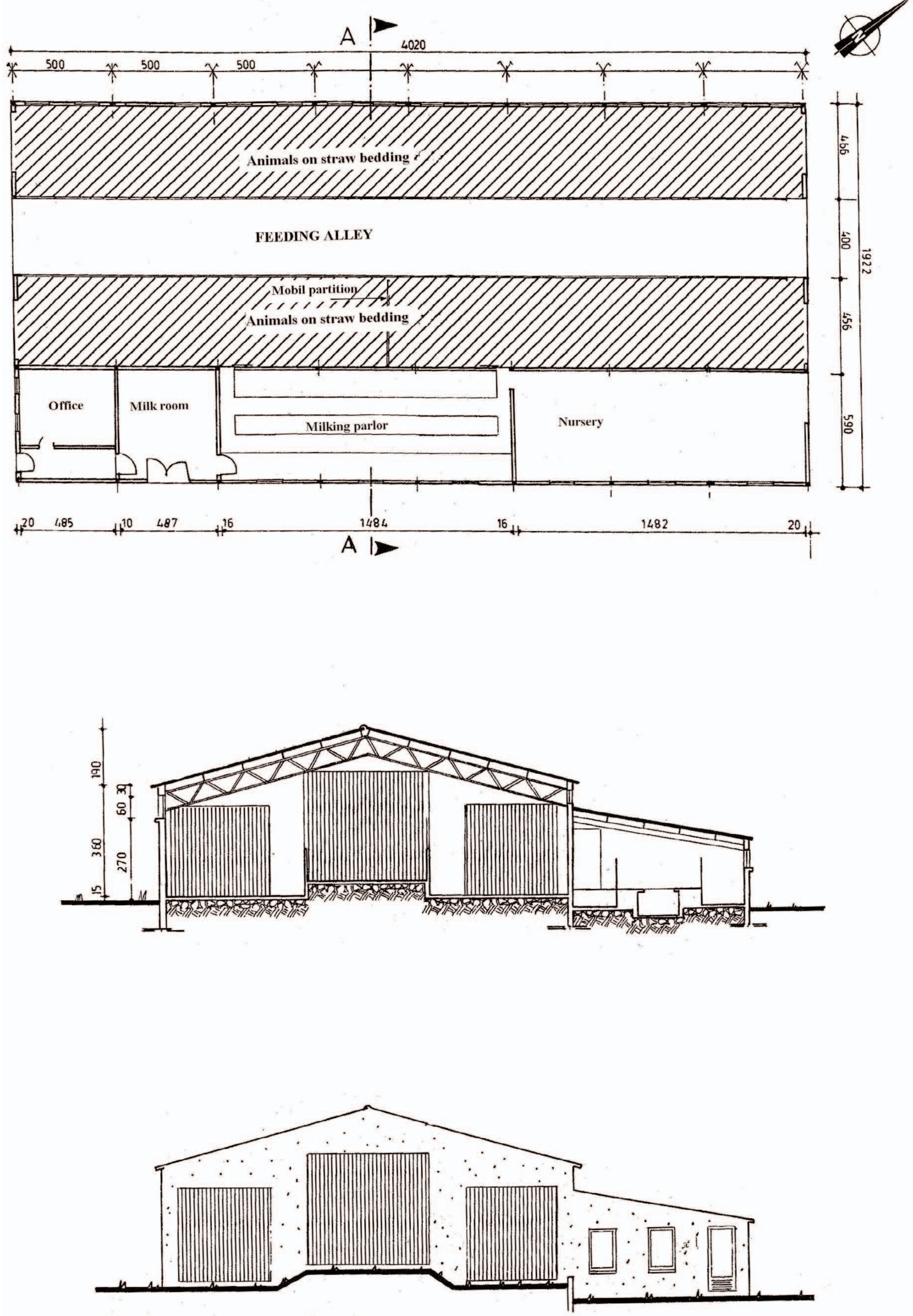
Barn for 150 ewes.



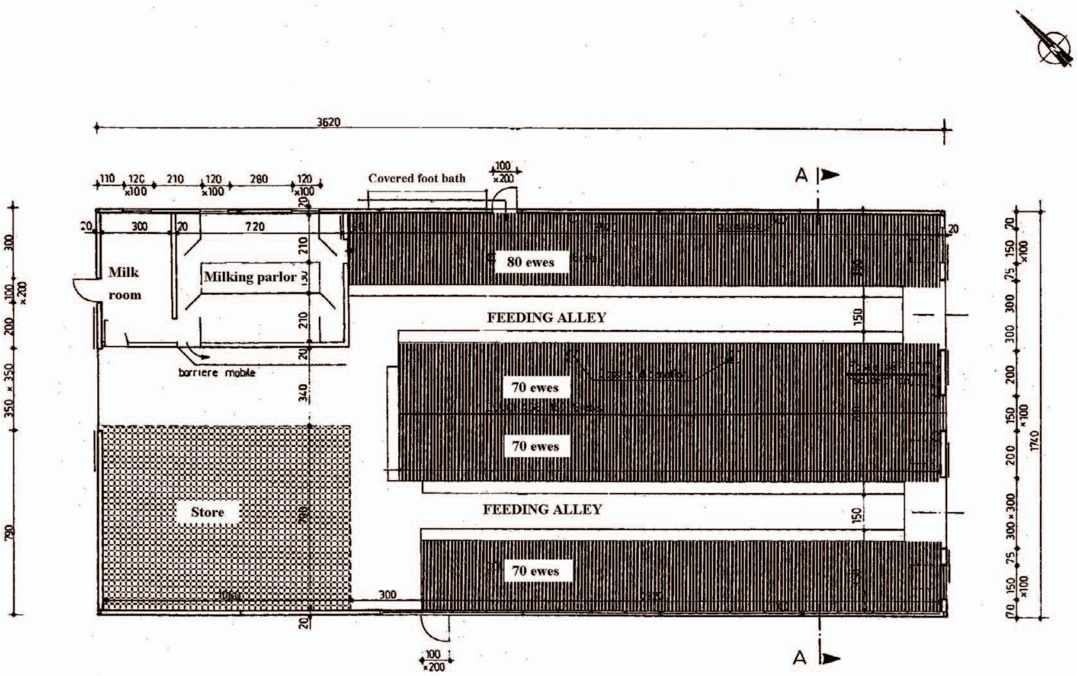


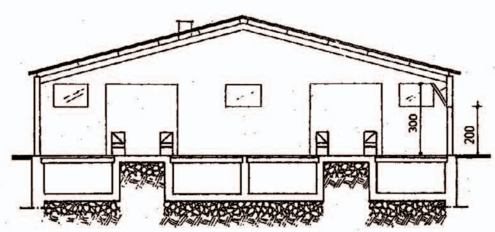


Barn for 250 ewes.

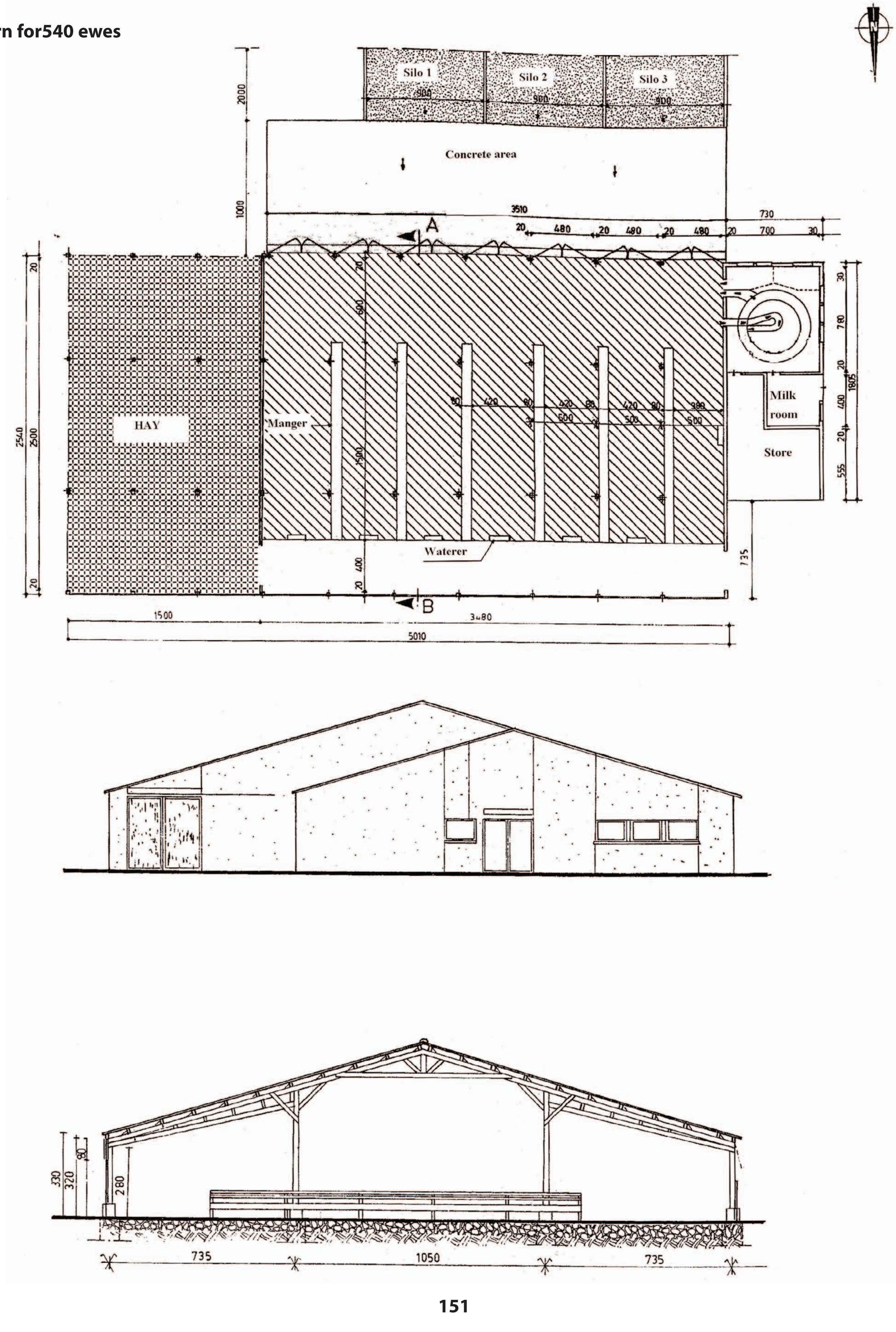


Barn for 300 ewes





Barn for540 ewes



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