UDDER MORPHOLOGY AND EFFECTS ON MILK PRODUCTION AND EASE OF MILKING IN DAIRY SHEEP

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Summary

Mammary morphology is generally accepted as a key factor for machine milkability and its inclusion in dairy sheep improvement programs has been widely recommended (Fernandez et al., 1997; Caja et al., 2000). The anatomical and morphological characteristics of the mammary gland and its importance for milk production, machine milkability and manageability in dairy sheep have become of greater interest from farmers to researchers. The sheep udder is an exocrine epithelial gland mainly constituted by tubulo-alveolar parenchyma with alveoli and well differentiated cisterns. Two anatomical compartments are considered for milk storage: alveolar and cisternal, the large-cisterned animals being more efficient milk producers. The evaluation of external morphology by using udder typology, objective udder measurements and linear scores in practice is also discussed. Recent methodology using ultrasonography has been applied for the study of the mammary gland, providing a satisfactory non invasive method for determination of milk storage characteristics in dairy species. Machine milkability is evaluated by milk fractioning and milk emission curves during milking. Both criteria are discussed and analyzed in sheep breeds of different milk yield. Relationship between morphological and productive traits in dairy sheep is analyzed as a result of anatomical and physiological characteristics. Phenotypic and genetic correlations indicate that selection for milk yield will produce worse udder morphology, resulting in udders which are inadequate for machine milking, especially in highly selected herds. Teat and cistern characteristics appear to be the most limiting factors in machine milkability. Some selection pressure on udder traits in long-term breeding programs needs to be considered and the use of linear udder traits is recommended in practice to improve udder morphology and milkability. Knowledge of the relationship of udder morphology traits with milk production and milking time in U.S. dairy ewes is needed to provide producers with recommendations for culling strategies based on ewe udder traits. The effectiveness of the European scoring systems for dairy-meat breeds cross ewes in U.S. dairy sheep farms is discussed.

Introduction

The current breeding goal for milkability in dairy cows, goats and sheep is focusing on an improvement of the adaptation of these animals to the machine milking process, and its influence on milking time and farm economics. According to Labussiere (1988), even if the main quality of a dairy ewe is its production level, it is essential to be able to extract rapidly the milk retained in the udder, not only with a minimum of manual interventions (udder stimulation, machine stripping and hand stripping), but also at times which are not too restricting and sufficiently spaced to allow the practice of omitting one milking per day (Sunday, end of lactation, etc.).

The interest in the dairy sheep udder has increased in the last few years in which anatomy has been explored in depth (Ruberte et al., 1994b; Caja et al., 1999; Carretero et al., 1999), and a linear scoring system has been developed to select udders with good “milkability” in Spanish and Italian breeds (De la Fuente et al., 1996 and 1999; Carta et al., 1999), as well as the evaluation of its genetic parameters (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 between breeds of different yielding (Rovai et al., 1999; Rovai et al., 2003) or between genetically isolated lines of the same breed (Marie et al., 1999) are under comparison.

Shape and size of the udder and teat have been shown to be related to milk yield (Labussière et al., 1981; Labussière, 1988; Fernández et al., 1995, 1997; Carta et al., 1999; Rovai et al., 1999) and milk flow rate (Marnet et al., 1999; Marie-Etancelin et al., 2002) in Spanish and French dairy breeds. However, the repeatability and heritability of udder morphology traits and their relationships with milk yield and milking time in U.S. dairy ewes are needed so that recommendations can be given to producers on whether or not udder morphology should be considered in culling and selection decisions. A preliminary study of udder traits with U.S. dairy ewes was conducted by McKusick et al. (2000) and continued with a more detailed udder characterization by Rovai et al. (2003).

The American dairy sheep industry started by milking breeds of sheep commonly available in the U.S and selected for lamb and wool production. Strict animal health regulations on the importation of live sheep, ram semen, and sheep embryos was a major obstacle to importations of genetic material from breeds of selected sheep from other countries. However, due to the persistency of producers and some university researchers, a small amount of genetic material in the form of semen and embryos of two dairy sheep breeds (East Friesian of German origin and Lacaune of French origin) was imported into Canada and the U.S. Since the dairy sheep industry is expanding at a very satisfactory rate, the need of care to the economically important traits as high milk yield, milking time, and an ideal udder conformation are crucial to a better milking performance and consequently minor milking labor costs of the future generations.

This paper describes the particularities of the dairy sheep udder and summarizes the current implications of udder morphology on machine milkability with special emphasis on dairy-meat cross ewes under U.S. production conditions.

Mammary gland in the dairy ewe

The mammary gland is an exocrine epithelial gland, exclusive to mammal species, which is quantitatively and qualitatively adapted to the individual growth requirements and behavior of each specie. 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.

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

At birth, the sheep udder shows clearly differentiated cisterns (*Sinus lactiferus*) 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. Moreover an early onset of puberty will bring forward the decrease in mammary development. According to Johnson and Hart (1985) and McCann et al. (1989), a relative low growth rate (50% of high rate) from weaning (wk 4) to the end of rearing period (wk 20) will increase the parenchyma growth and the milk production in the first lactation in non dairy ewe-lambs. No negative effects were observed at the beginning of puberty. Nevertheless a low growth rate before weaning will also negatively affect mammogenesis (McCann et al., 1989). Unfortunately there is no detailed information available on dairy sheep, but Bocquier and Guillouet (1990) reported that the restriction of concentrate in Lacaune ewe-lambs, after they reach approximately 28 to 30 kg, increases milk yield by 10% in the first lactation.

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

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

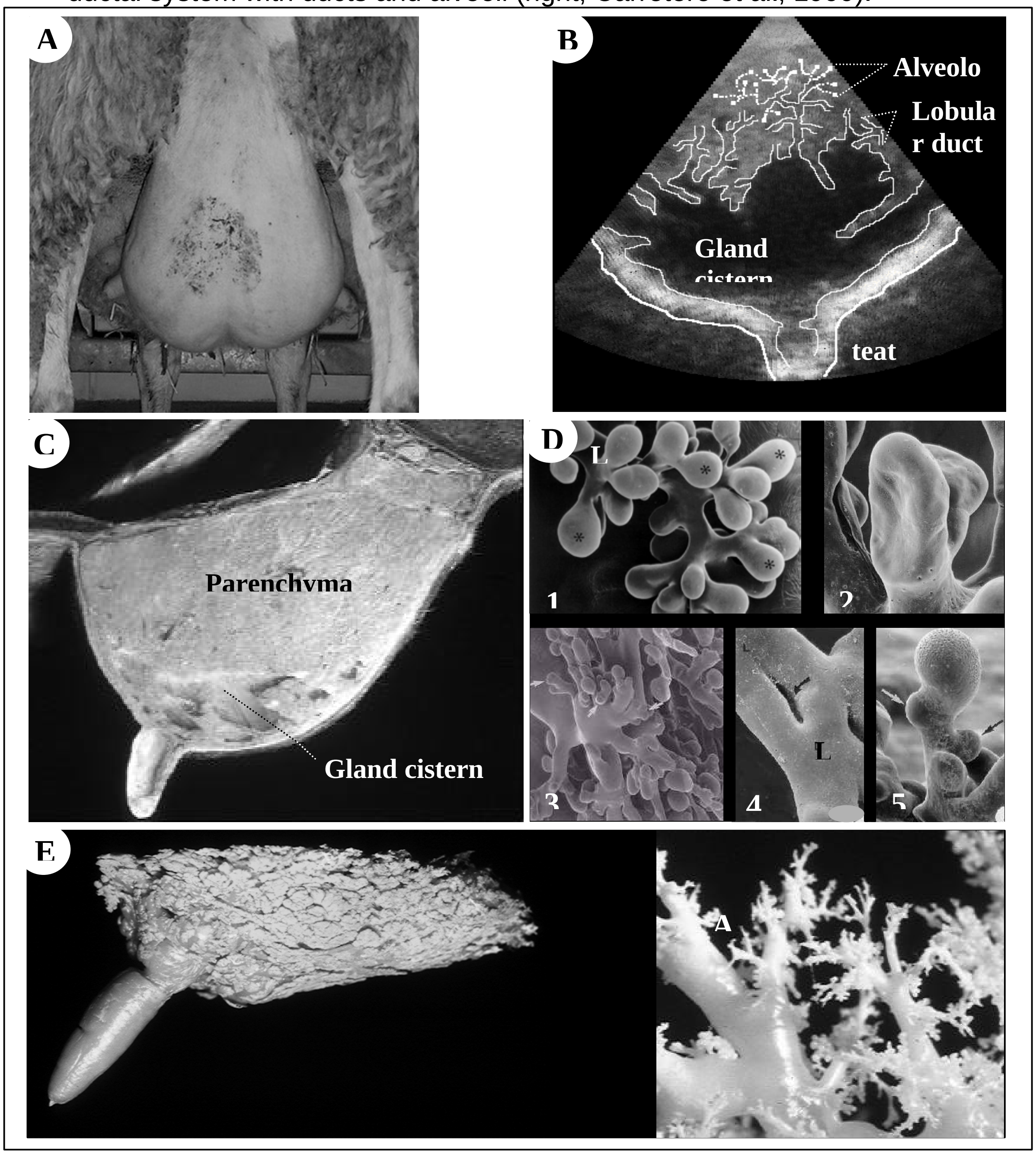
Internal structure of the mammary gland**:** The internal structure of the ewe udder described reveals the presence of two independent mammary glands under a unique skin bag, each of them wrapped by a bag of fibroelastic connective tissue (*Apparatus suspensorius mammarum*) and separated by a clearly defined and intermediate wall of connective tissue (*Ligamentum suspensoris uber*; Turner et al., 1952; Barone, 1978; Tenev and Rusev, 1989; Ruberte et al., 1994b). The strength of this ligament normally produces the presence of an intermmamary groove (*Sulcus intermammarius*) between each gland which plays an important role 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, important for the 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 streakcanal (*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 much branched intralobular ducts and alveoli. The alveolus is the secretory unit of the mammary gland and consists of a bag of a unique layer of specialized cubic epithelial cells (the lactocytes) with an inside cavity (the lumen) in which the milk is stored after secretion.

The mammary gland stores the milk extracellulary and this storage can be explained using a model of two anatomical compartments (Wilde et al., 1996): ‘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, the gland cistern 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).

The external morphology and anatomic ultrastructure of the mammary gland with its canalicular system are shown in detail in the Figure 1.

Figure 1. Dairy sheep mammary gland. A) Dairy ewe udder; B) Cistern ultrasound; C) Sheep udder anatomy; D) Microscopy images from epoxy casts of: 1, lobular duct (L) and alveoli (*), 2, collapsed alveolus, 3, alveoli, 4, intussusceptive growth in a lobular duct, 5, alveolar sprouts; E) 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; Carretero et al., 1999).



Morphology of the mammary gland

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

With this aim an international protocol (M4 FAO project) for dairy sheep udder evaluation in the Mediterranean breeds was performed as an initiative from Prof. Jacques Labussière (Labussière, 1983, 1988). Based on this standardized protocol, the udder of many dairy sheep breeds was systematically studied in relation to machine milking (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).

According to Labussière (1988), the milk production is always correlated to size of the udder, however, voluminous cistern cavities to assure the accumulation of the milk secreted over long milking intervals and teats implanted vertically at the lowest point of the cistern should be also considered to improve the milkability of dairy sheep.

***Udder typology*:** Mammary morphology has been described as an important factor in the machine milkability of dairy ewes (Labussière et al., 1981; Gallego et al., 1983a; Fernández et al., 1995). 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. These typologies were later adapted to the Latxa breed (Arranz et al., 1989) and Hungarian Merino and Pleven (Kukovics and Nagy, 1989). A comparative table of these typologies can be observed in Figure 2. 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 (Figure 2). Typology is recommended as a useful tool for the screening of animals, i.e. in the standardization of machine milking groups or in the choice of ewes at the constitution or acquisition of a flock, and for culling of breeding animals (Gallego et al., 1985; Carta et al., 1999). The evaluation of sheep udders by udder types is easy, quick and repeatable with trained operators (Carta et al., 1999; De la Fuente et al., 1999). However, the inclusion of non-subjective measurements and linear evaluation needs to be considered for the study of machine milkability of the dairy ewes.

The average milk production tend to be superior in Type I udders due probable to the negative relation between milk production and teat insertion (Rovai, 2001). On the other hand, Type IV showed an inferior milk yield due to the unshaped udder presented by the ewes in this category (Gallego *et al*., 1983a; Rovai, 20001). Most of the time, ewes assigned to Type IV refers to animals with mastitis, field accidents, etc.

The udder typology proposed by Gallego et al. (1983a) was evaluated in U.S. ewes of dairy-meat crosses (Table 1) and compared with previous studies on other breeds (Table 2). This system was designed to classify the ewes more adapted to machine milking using teat angle insertion, and is based on check and assigned udders into four categories (Figure 2): **Type I** = horizontal teats; **Type II** = teats at 45 degrees; **Type III** = vertical teats – most desirable ("udder machine"); **Type IV** = misshaped udder. Also the presence or not of the suspensor ligament in the udder (1: yes and 0: no).

Figure 2. Udder scoring method proposed for different dairy sheep breeds (Elaborated by Peris, 1994).

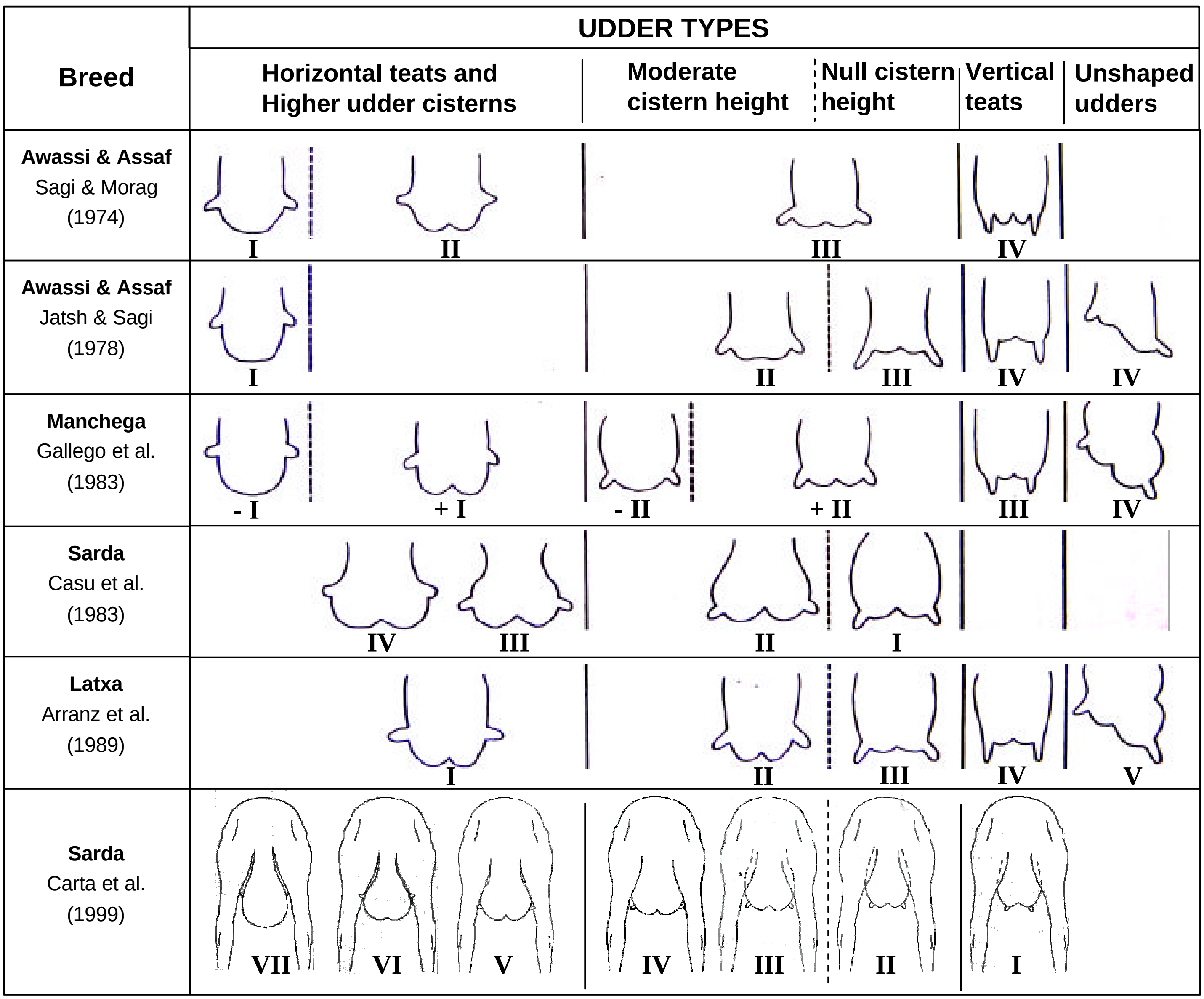


Table 1. Udder typology and the presence or not of the suspensor ligament (IG) in commercial and university U.S. dairy-cross ewe's farms.

Flock [1]	Ewes crosses	Udder type (%)					IG (%)	
		n	I	II	III	IV	1	0
A	**EF** (10 to 50%)	166	**6** (4%)	**123** (74%)	**29** (17%)	**8** (5%)	**166** (100%)	**0**
B	**EF** (10 to 75%)	177	**19** (11%)	**113** (64%)	**32** (18%)	**13** (7%)	**167** (94%)	**10** (6%)
C		194	**27** (14%)	**132** (68%)	**28** (14%)	**7** (4%)	**189** (97%)	**5** (3%)
D[1]	**EF** (75%)	27	**5** (18%)	**21** (78%)	**1** (4%)	**0**	**20** (74%)	**7** (26%)
	EF (50%)	48	**10** (21%)	**36** (75%)	**1** (2%)	**1** (2%)	**38** (79%)	**10** (21%)
	LC (50%)	26	**13** (50%)	**12** (46%)	**1** (4%)	**0**	**26** (100%)	**0**
	EF-LC (¼ EF– ½ LC)	18	**5** (28%)	**13** (72%)	**0**	**0**	**5** (28%)	**13** (72%)

A, B, C are commercial U.S dairy fams, and D is a University farm.
[1] Measurements done at week 11 of lactation.

As shown in Table 1 udders of Type II were more frequent than other types in all flocks. Commercial-D flock also had a high percentage of ewes with udders of Type I which may be the result of the presence of Lacaune ewes. These results are in agreement to Rovai (2001) where comparing 232 ewes of Manchega and Lacaune breeds, found a similar frequency of Type II udders in both breeds, as shown in Table 2. However, Manchega breed showed a higher incidence of Type III (more adapted to machine milking), whereas Lacaune dairy sheep presented a larger percentage of Type I udders, with teats placed more horizontally. The incidence of Type IV, which implies a worse milkability, was very low due the culling of these ewes in this flock.

The frequency of udder types (mainly Type I) tend to increase according to the age of the ewe, although it seems not be affected by the state of lactation (Rovai, 2001). An ideal proposal would be to assess udder morphology during the first lactation, allowing remaining in the herd only those ewes with udders adapted to machine milking.

Table 2. Udder typology from different sheep breeds.

Ewe breeds	Udder type (%)				Authors
	I	II	III	IV	
Manchega	19.2%	56.2%	14.3%	10.3%	Gallego *et al*. 1983a
	11.6%	52.2%	2.9%	33.3%	Fernández (1985)
	8.6%	75.0%	13.6%	2.8%	Rovai, 2001
Lacaune	15.7%	71.6%	8.7%	4.0%	Rovai, 2001
	24.5%	67.9%	7.4%	0.2%	Rovai, 2001[1]

[1] A purebreed Lacaune flock from the experimental research station “Lafage”, Roquefort (France).

Some examples of udders from U.S. dairy-cross ewes are shown in Figure 3. As we can observe the udders can be easy classified into the described udder typology.

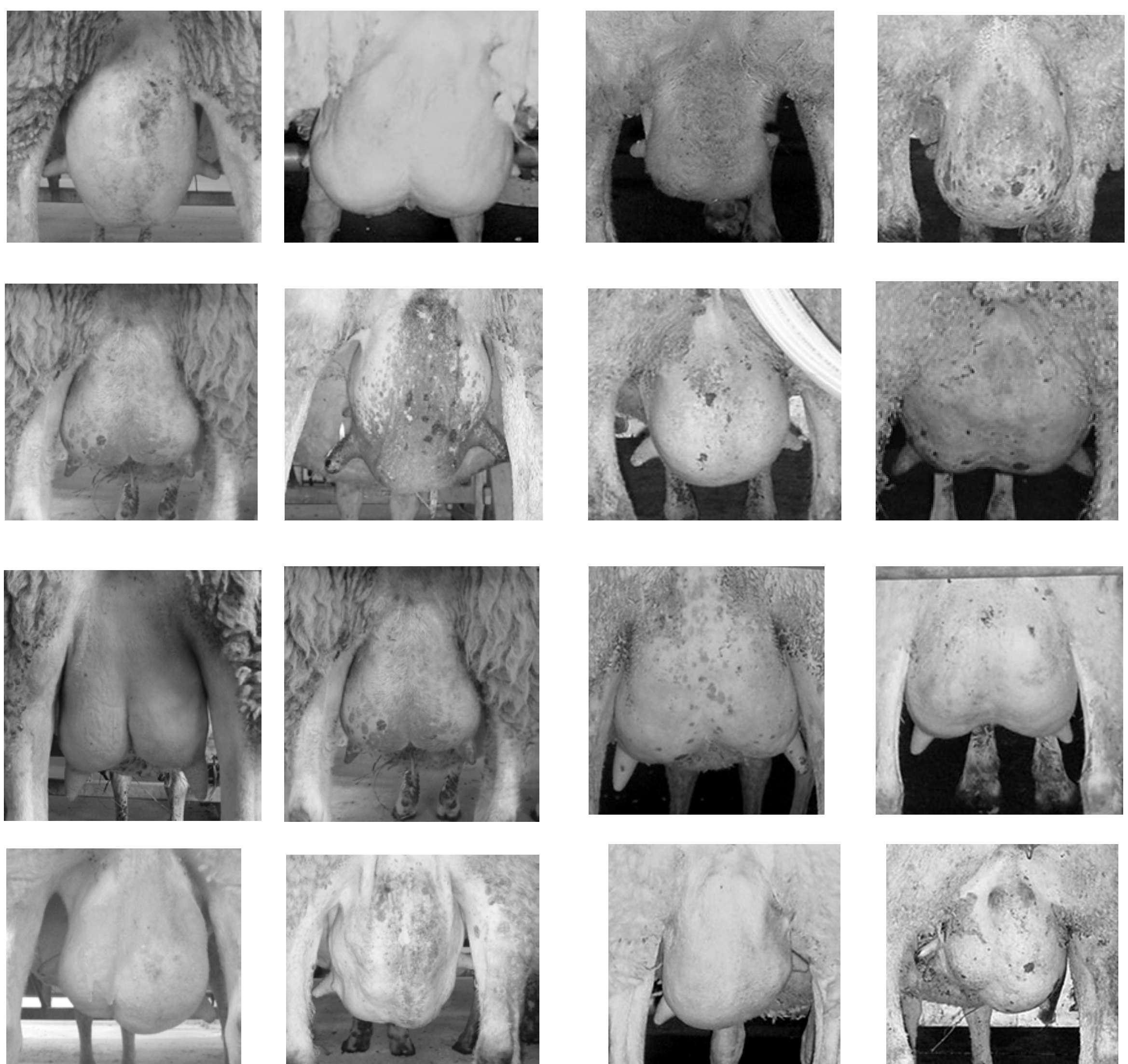
Figure 3. *Examples of types of udder from commercial and university U.S. dairy-cross ewe’s farms classified according the typology proposed by Gallego et al. (1983a).*

Type 1

Type 2

Type 3

Type 4



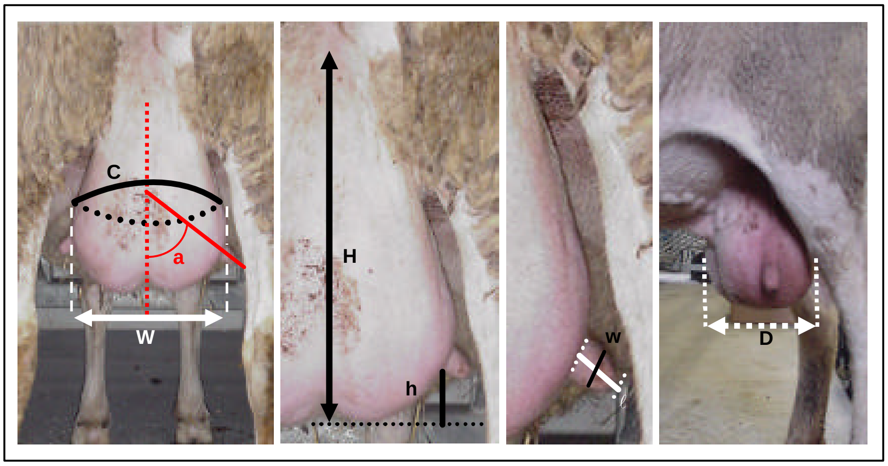
Udder measurements: The use of objective measurements for the characterization of the dairy sheep udder and its relations with other productive traits has been undertaken by different authors. The importance of the mammary traits on milk yield and milking routine has been studied in the dairy ewe since the development of machine milking, and its evaluation during lactation can be significant for obtaining a positive genetic response in the milkability of dairy ewes. Until now, the mammary traits have not been considered as a primary objective in dairy sheep selection. Nevertheless, these traits determine several aspects of the machine milking and manageability (time of milking, falling off of the clusters, difficulty of lambs to find the teats,...).

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; Rovai, 2001).

Udder size (depth, width, length, and circumference), teat size (length and width), teat angle, and cistern height used to be measured *in vivo* using a ruler and protractor as shown in Figure 4. The main traits which can be grouped and explain an important amount of the variability of the mammary morphological traits are: 1) *Udder size*: height, depth and width; 2) *Teat size*: length and width; 3) *Teat insertion angle and cistern height*.

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.

Figure 4. Mammary traits, rear and lateral view.



C: udder circumference, **a**: teat angle, **W**: udder width, **H**: udder depth,
h: cistern height, **l** and **w**: length and width of the teat and **D**: udder depth.

Udder shape and size is related to milk yield and milking time in specialized dairy sheep breeds in Europe (Gallego et al., 1983a; Fernández et al., 1983 and 1995; Rovai, 2001). The comparison of main udder measurements among dairy-meat cross ewes under U.S. production conditions was also studied, and are in accordance with previous studies on different breeds of ewes. Table 3 shows that milk yield and udder traits were different between U.S. dairy cross ewes.

Milk yield was highest in East Friesian-Lacaune ewes, increased with age of ewe, and decreased through lactation. Lacaune ewes had the shortest teats and the highest teat insertion. Cistern height and udder size were larger in Lacaune and East Friesian-Lacaune ewes than in the other two breed groups and corresponded with their greater milk production. Udder size and teat size increased with parity number, reaching their maximum in ewes of three or more lactations. Udder size decreased through lactation while teat angle and cistern height increased.

In general, the stage of lactation produced significant effects on all udder traits in accordance with previous studies on udder morphology. Udder traits increased according to parity and maximum was observed on third and more parity ewes, however, age effects only showed a tendency in teat angle and cistern height.

Table 3. Mean values of udder traits and effects of breed in U.S. dairy-cross ewes (Rovai et al., 2003).

Traits		Ewe crosses			
		EF (½ EF)	**EE** (¾ EF)	**LC** (½ LC)	**EF-LC** (¼EF-½LC)
Ewes	*n*	49	27	26	18
Milk yield	liters	1.2 [a]	1.3 [a]	1.2 [a]	1.6 [b]
Udder size					
depth	cm	8.7 [a]	8.8 [a]	9.1 [a]	10.3 [b]
width	cm	13.5 [a]	13.8 [a]	14.0 [ab]	14.7 [b]
length	cm	21.2 [a]	21.2 [a]	21.8 [ab]	23.1 [b]
circumference	cm	42.2 [a]	42.5 [a]	43.4 [a]	46.7 [b]
Teat size					
length	cm	3.4 [a]	3.3 [a]	3.0 [b]	3.4 [a]
width	cm	1.5 [a]	1.5 [a]	1.4 [b]	1.5 [a]
Teat angle	degrees	51 [c]	48 [a]	59 [b]	54 [c]
Cistern height	cm	3.3 [a]	3.0 [a]	3.8 [b]	4.0 [b]

[a,b,c] Within sheep group per trait, values with a different superscript are different ($P < 0.05$).

These results agree with those obtained previously in different breeds (Labussière, 1988; Fernández et al., 1983, 1995; Casu et al., 1983; Gallego et al., 1983a; Labussière et al., 1983; Fernández et al., 1989a, 1995; Rovai, 2001) although teat angle was affected by stage of lactation in other references.

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 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 decrease; and, as udder height increases, cistern height and teat angle also increase.

When morphological traits are related to milk yield the greatest effects are observed for udder width and height and commonly tendencies are only observed for the remaining traits (Gallego et al., 1983a; Labussière et al., 1983; Fernández et al., 1989a, 1995; McKusick et al., 1999; Rovai et al., 2003). Big volume and cisterned udders produce more milk. Main effects of teat traits are related to milk fat (McKusick et al., 1999) and milk emission during milking (Fernández et al., 1989a; Marie et al., 1999).

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

- Teat dimensions (length) and placement (angle)
- Udder height and width
- Cisterns height

Analysing the results on Table 3 we can also observe that the different cross-breeds ewes present enough differences in udder morphology to be grouped according to udder type, making the possibility of establishing a universal udder classification valid for all breeds almost impossible.

Linear scores**:** The main drawback of the udder typologies is their use for the estimation of the genetic value of breeding animals and when genetic and environment effects need to be break 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 based on 9-point scale per trait as shown in Table 4 (De la Fuente et al., 1995).

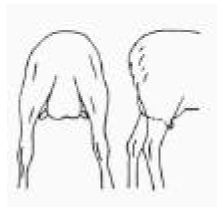
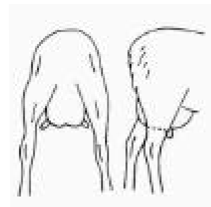
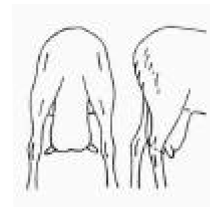
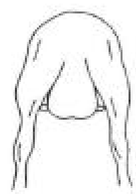
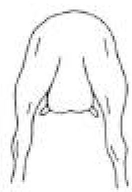
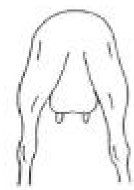
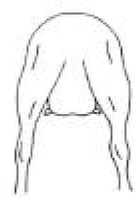
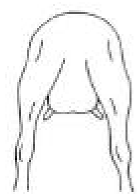
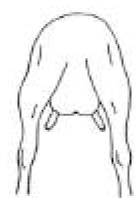
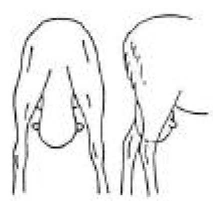
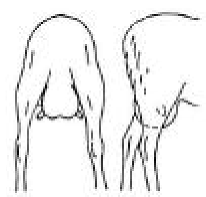
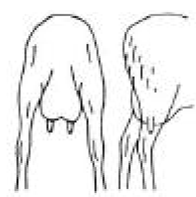
The system is based on the following udder traits: **udder depth** (from the perineal insertion to the bottom of the udder cistern), **teat angle** (teat insertion angle with the vertical), and **teat length** (from the gland insertion to the tip), and also includes an expanded typology to evaluate the whole udder shape, in accordance with the previously described optimal criteria for udder types. Each udder trait is evaluated independently by using extreme biological standards.

The desirable value is in some cases the highest score (i.e. teat angle: vertical teats that scored 9 will reduce cluster drops and will make easier the milk drainage) or the average score in others (i.e. teat length: medium size teats scored 5 and agree with a uniform cluster length). In udder height, given its positive relationship with milk production an average score will also be preferable. This linear methodology has been used in Spain for the evaluation of different flocks (27 flocks and 10,040 ewes) of Churra, Manchega and Latxa dairy ewes (De la Fuente et al., 1999), partially in France for Lacaune breed (Marie et al., 1999), and in U.S. for the evaluation of the machine milking ability of East Frisien and Lacaune crossbred ewes (Rovai et al., 2003).

The linear udder scoring systems evaluated in U.S. included flocks of dairy-meat ewe crosses from three commercial dairy sheep farms and one university farm, as shown in Table 5. Percentage of East Friesian breeding had no effect on udder trait scores in the commercial farms. However, Lacaune ewes from University farm had the most horizontal teats. As we can observe in Table 5, Lacaune crosses tended to have udders less suited to machine milking compared to East Friesien crosses; as assessed by the European scoring systems.

Udder depth score increased significantly as parity number increased in all farms, reaching the maximum values in third and greater lactations. Udder depth score decreased through lactation in the commercial farms, and remained constant in the University flock. Ewes in later stages of lactation tended to have more horizontal teats and faulty udders than ewes in earlier stages of lactation. Within all genotypes and farms, positive and significant correlations were observed between udder depth scores and milk yield (0.20 to 0.46). High correlations were observed also between udder shape and teat angle scores (0.80 to 0.93), and also between udder depth score and milk production.

Table 4. Linear scores for the evaluation of main udder morphological traits in dairy sheep (De la Fuente et al., 1999).

Morphological trait	Score (1 to 9)		
	1 (Shallow)	5 (Average)	9 (Deep)
Udder depth or height			
	1 (Horizontal)	5 (45 degrees)	9 (Vertical)
Teat angle			
	1 (Short)	5 (Average)	9 (Long)
Teat length			
	1 (Faulty)	5 (Average)	9 (Ideal)
Udder shape			

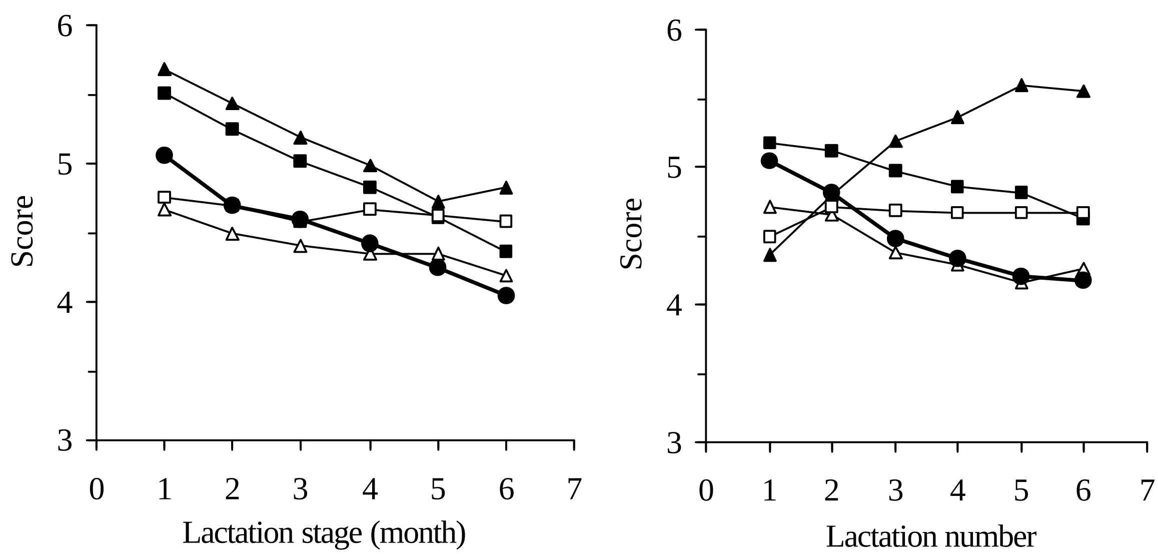
The results obtained for Spanish breeds, according to lactation stage and parity effects, are shown in Figure 5. In regard to lactation stage, all linear scores decreased as lactation progressed, udder height and udder attachment being the traits which showed the greatest decrease during lactation, while teat size was only slightly modified. This evolution agrees with the loss of udder volume and milk yield but indicates a deterioration of udder morphology for machine milking as indicated by udder shape. Only udder height was improved. Regarding lactation number, udder height increased dramatically in the first lactations, while other traits decreased and teat size was steadily constant. As a consequence, udder shape deteriorated and its score decreased rapidly from first to third lactation and stabilized thereafter.

Table 5. Linear udder scores in U.S. dairy-cross ewes farms (Rovai et al., 2003).

Flock	Farm	Ewe crosses	*n*	Traits		
				Udder depth	***Teat angle***	***Udder shape***
A	commercial	**EF** (10 to 50%)	177	4.4	4.9	5.0
B	commercial	**EF** (10 to 75%)	166	4.6	5.3	5.5
C	commercial		197	3.8	5.2	5.1
D	university	**EF** (50 or 75%)	120	5.1[a]	4.3[a]	3.8
		LC (50%)		5.3[a]	3.3[b]	3.1
		EF-LC (¼ EF– ½ LC)		6.0[b]	3.9[a]	3.7

[a,b] Within farm C, values with a different superscript are different ($P < .05$).

Figure 5. Evolution of linear scores of main udder traits in Spanish dairy sheep: ? , udder height; ¦ , udder attachment; ?, teat angle; ?, teat length; and, ?, udder shape (elaborated from De la Fuente et al., 1999).



The values of linear scores calculated by Fernández et al. (1997) in the Churra dairy breed (Table 6) were sufficiently repeatable (r= 0.48 to 0.64) and showed intermediate heritability values (h^2=0.16 to 0.24) as reported in cattle. Coefficients of variation ranged between 18 and 37%. The authors indicate that a single scoring per lactation would be sufficient in practice.

Table 6. Genetic parameters of linear udder traits in dairy sheep (Fernández et al., 1997).

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

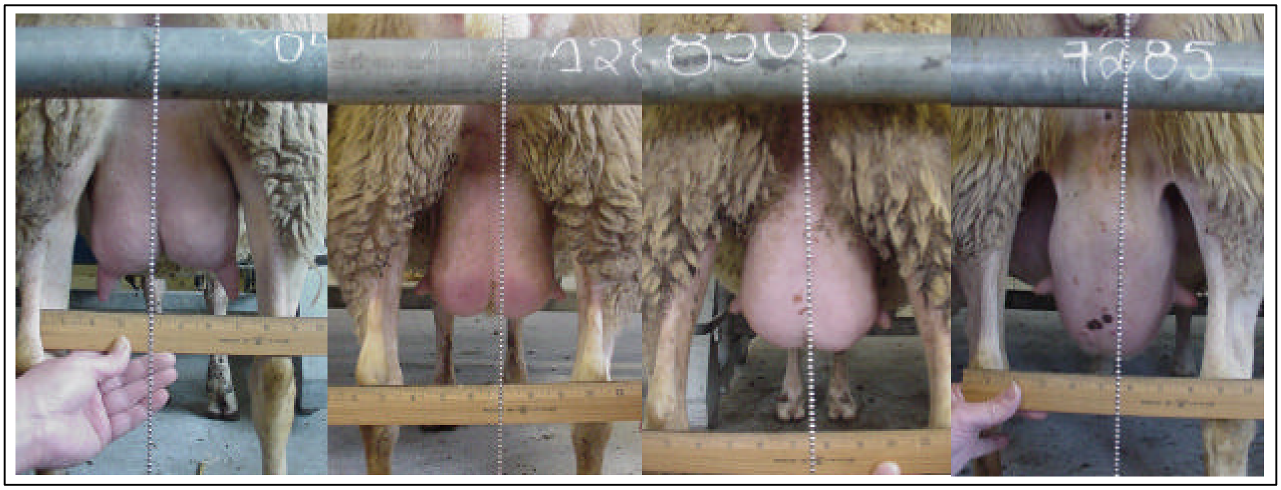
Udder shape, equivalent to a typology of expanded categories (nine), was highly repeatable and heritable, indicating its utility as a single trait for dairy sheep selection. Nevertheless udder shape showed high and positive genetic correlation with udder attachment (r= 0.55) and teat placement (r= 0.96),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

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

Use of digital pictures to study udder morphology. Practical application of the digital system for evaluation of mammary morphology may provide an easy and accurate method to study ewe udders. Advantages of the digital picture method are that pictures can be taken faster than the *in vivo* measurements at the farm, analyzed at our convenience, and it can provide a permanent record for future use.

To evaluate the effectiveness of this method the relationship between udder traits measured *in vivo* and from digital photographs were studied on 120 U.S. dairy-cross ewes from a University farm (Rovai et al., 2003). Digital pictures were taken in the milking parlor of the rear udder of each ewe at the time of the *in vivo* measurements (objective measurements and linear score system). A ruler, at each picture taken, was held parallel to the ground in the same vertical plane as the back of the udder and a few cm below the bottom of the udder to serve as a calibration device for measurements on the digital pictures (Figure 6). Likewise a plumb bob was suspended vertically in back and in the middle of the udder while taking each picture to give a true vertical line as a reference for measuring teat angle. Measurements from the digital pictures were obtained using the public domain software, Image Tool from Texas University, available on the Internet.

Figure 6. Examples of udder digital pictures.



Comparisons of the in vivo and digital measurements are presented in Table 7. In general, udder traits *in vivo* did differ neither statically nor substantially from the digital pictures measurements. Teat length was the only trait that differed between methods; perhaps due to folding at the teat udder junction, which is not visible in the measurements taken from the pictures.

Table 7 **.**Udder measurements taken *in vivo* and from digital pictures.

Traits		Measurements	
		in vivo	picture
Udder measurements			
Udder depth	cm	21.8	19.3
Udder width	cm	13.9	12.9
Teat length	cm	3.3^{a}	2.2^{b}
Teat angle	degrees	52.6	52.8
Udder linear score			
Udder depth	1-9	5.4	5.3
Udder shape	1-9	3.6	3.6
Teat length	1-9	5.3	5.6
Teat angle	1-9	3.9	3.8

All digital measurements were significantly correlated with those measured in vivo. Phenotypic correlations between the methods (direct udder measurements and linear udder score) were: 0.73 for udder height, 0.67 for udder width, 0.47 for teat length, 0.88 for teat angle, 0.68 for teat size score, 0.79 for teat angle score, 0.88 for udder height score, and 0.89 for udder shape score. The major ewe udder traits that can be viewed from the rear can be accurately measured from digital photographs of the rear udder.

Ultrasonography and milk production capacity**:** Size of the cisterns is related to morphology and yielding capacity of the udder, varying markedly with time from last miking. Apparently, 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). Machine milkability can be modified by cistern features, however, there is a low relationship founded between cistern size and milk yield (Gallego et al., 1983; Labussière et al., 1981; Fernandez et al., 1995), due probably to the method used on its valuation. Cistern is a non visible internal udder structure, and its size together with all other udder traits have been measured externally using a ruler and protractor. Recent literatures described the use of ultrasound technique for estimating the size of udder cisterns.

Ultrasonography has been used as a non invasive method to study the internal structure of the mammary gland in cows (Bruckmaier and Blum, 1992; Bruckmaier et al., 1994; Ayadi et al., 2003a), sheep (Caja et al., 1999; Nuda et al., 2000; Rovai et al., 2000; Rovai et al., 2003) and goats (Salama et al., 2004) and to measure the milk storage capacity within the udder (Ayadi et al., 2004; Caja et al., 2004). The principle structures of the mammary gland, as cistern area and teat cistern, can easily be determined by the position and frequency of the transducer used for its exploration. In dairy sheep, a specific method for mammography was proposed by Ruberte et al. (1994a), being the transducer applied directed from the portion of the proximal intermammary groove, between localizations areas of superficial inguinal lymph nodes, towards the teat. 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.

Differences in cisternal area according to dairy species and dairy sheep breed are summarized in Figure 7.

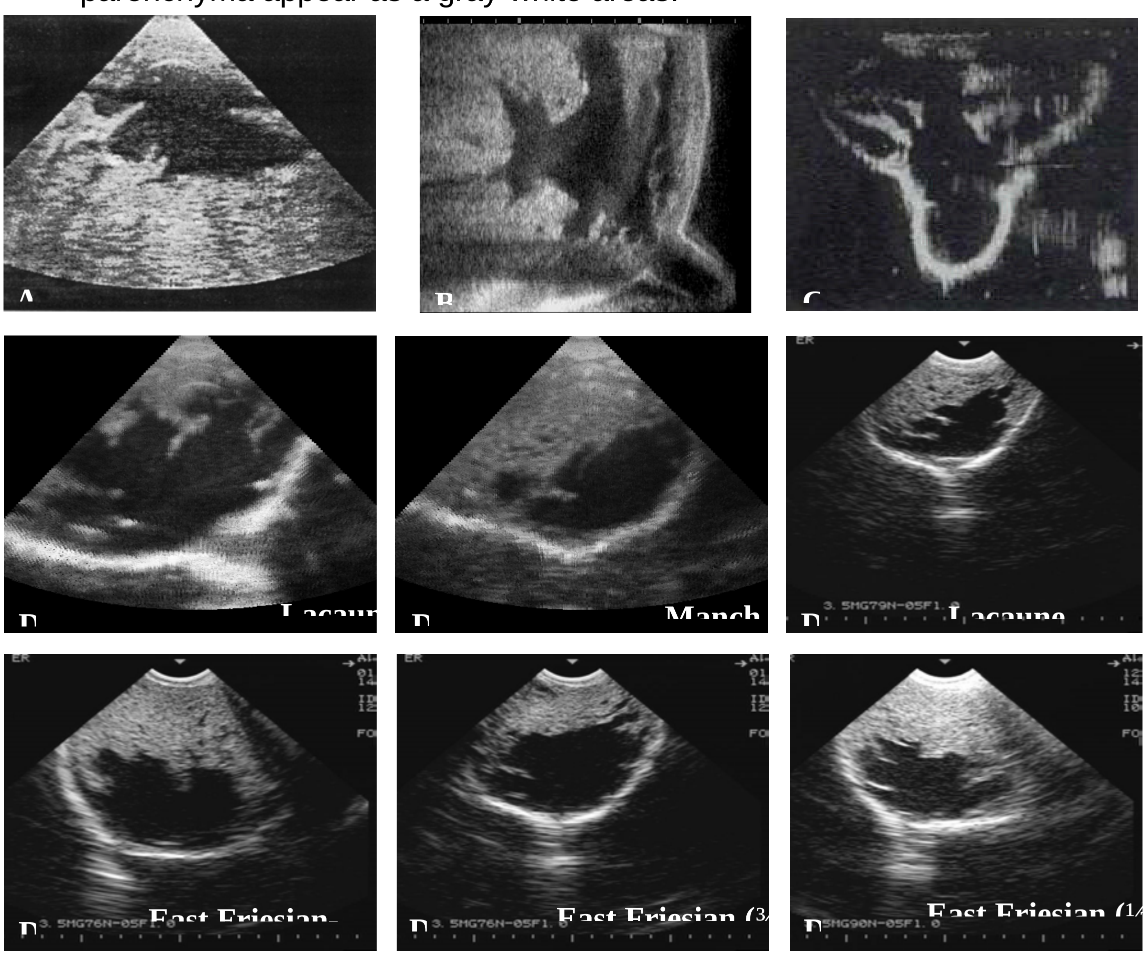
The differences in cistern capacity according to the productive level of two different dairy breeds were evaluated by Rovai et al. (2002). In this study, Lacaune ewes showed a larger area of the mammary cistern and also a larger amount of cisternal milk when compared to Manchega ewes (24cm^2 and 275ml vs. 14cm^2 and 149ml, respectively). Lactation number did not affect cisternal area. However, this area, as well as the amount of stored milk, decreased through the lactation in both breeds.

The interbreed differences on cistern storage capacity was also studied among dairy-meat cross ewes under U.S. production conditions (Rovai et al., 2003). Cistern area was different between ewe crosses as shown in Table 8. East Friesian (¾ crosses) and East Friesian-Lacaune dairy ewes had greater cistern area than ewes of the other two breeds (East Friesian, ½ crosses; Lacaune ewes). Cistern area and as well as milk yield in this study, decreased through lactation and increased with parity.

In general, cisternal areas and cisternal milk shows high dependency. The correlation coefficient was reported between cisternal areas and cisternal milk, and also with milk production, udder size measurements, and, in a lower extent, with teat measurements.

The observed better milkability of Lacaune ewes can be explained by the progress in breeding for improving milk production which also provided animals with quiet temperament at the milking parlor, more spontaneous milk ejection reflex and improvement of the dairy sheep management without the need of a previous udder preparation as used for dairy cows.

Figure 7. Cistern ultrasound scans in dairy cows (**A,** Ayadi, 2000; **B**, Rovai et al. 2004), dairy goats (**C**; Bruckmaier y Blum, 1992), and different breeds of dairy ewe (**D**). Udder cisterns filled with milk appear as dark areas, and the glandular parenchyma appear as a gray-white areas.



The use of cistern ultrasonography in dairy cows showed that losses in total milk yield is negatively related with cisternal milk volume (r=-0.77) and cisternal size (r=-0.70), meaning smaller losses in big udders in response to omitting one milking weekly (Ayadi et al., 2003). Recent studies also suggest that udder anatomy (mainly size of mammary cisterns) in terms of to milk storage may be an important factor in determining reduced yield associated with extended milking intervals in dairy species (Knight and Debwhurst, 1994; Stelwagen et al., 1996; Davis et al., 1998; Ayadi et al., 2003; Salama et al., 2003). Regarding this subject, the omission of one or more milkings per week in dairy ewes as shown in dairy goats (p.e. Sunday afternoon) would provide an important improvement in the quality of life of farmers, especially in small or family based dairy farms.

Table 8. Cistern area by ultrasonography, average milk production, and relation between scan area and cistern milk according to dairy species and the ultrasound scanner used (AMP, average milk production; Area, cistern area).

Dairy species	AMP	Area (cm^2)	Cistern milk×Area	Array scanner (MHz)		Authors
Dairy cows						
Simmental×Red Holstein	26 kg/d	28	-	5.0	linear	Bruckmaier et al., 1992[1]
Holstein	20 l/d	3-41	0.84-0.88	5.0	sectorial	Ayadi et al., 2003
Buffalo						
Murrah	50-320[2]	26-70	0.87	6.0	linear	Thomas et al., 2004
Dairy goats						
Swiss Saanen	3.5 kg/d	16	-	5.0	linear	Bruckmaier et al., 1992[1]
Murciano-granadina	1.12 l/d	13-28	0.72	5.0	sectorial	Salama et al., 2004
Dairy sheep						
East Friesian	3.2 kg/d	19	-	5.0	linear	Bruckmaier et al., 1992[1]
East Friesian crossbred						
EF (½ EF)	1.2 l/d	27	0.71	3.5	sectorial	Rovai et al.[4]
EE (¾ EF)	1.3 l/d	30	0.76	3.5	sectorial	Rovai et al.[4]
EF-LC (¼EF-½LC)	1.6 l/d	32	0.73	3.5	sectorial	Rovai et al.[4]
Lacaune crossbred						
LC (½ LC)	1.2 l/d	24	0.64	3.5	sectorial	Rovai et al.[4]
Lacaune	1.7 l/d	24	0.50[3]	5.0	sectorial	Rovai et al., 2001
Manchega	0.9 l/d	13	0.82	5.0	sectorial	Rovai et al., 2001
Sarda	92 to 156[2]	19	0.82	3.5	linear	Nudda et al., 2000
Meat Sheep	1.62 l/d	5.6	0.90	5.0	sectorial	Caja et al., 1999

[1] Five animals from each group to study the effect of exogenous oxytocin on gland and teat cistern. Values shown correspond to the gland cistern before oxytocin treatment.
[2] These values correspond to the cisternal yield (ml).
[3] The lower value of correlation for Lacaune ewes can be probably explained by the capacity limitations of visualization using a 5MHz ultrasound transducer.
[4] Unpublished data.

Machine milkability in the dairy ewe

Milk fractions collected during milking, residual milk (e.g., obtained after oxytocin injection) and milk flow curves during machine milking have been used to evaluate machine milkability in dairy sheep (Labussière, 1988; Bruckmaier et al., 1997a; Marie-Etancelin et al., 2002; Rovai et al., 2002; Díaz et al., 2004). The methodology proposed in the M4 FAO Project (Labussière, 1983) is normally used as the standardized method for both criteria.

***Milk partitioning in the udder*:** Milk partitioning between cisternal and alveolar compartments may influence milk secretion and milk yield response to altered milking frequencies (Knight et al., 1994b; Ayadi et al., 2003a; Salama et al., 2004). Large differences between species and breeds exist with regard to the proportion of total milk that can be stored within the cisternal compartment (Bruckmaier et al., 1992; Ayadi et al., 2003a; Salama et al., 2004). In sheep, high variation in cisternal milk has been reported with values ranging from less than 30% for meat breeds (Caja et al., 1999) to more than 50% for dairy breeds (Nuda et al., 2000; Rovai et al., 2000; McKusick et al., 2002), showing that selection for milk yield resulted in larger cisternal udders to accommodate the greater milk volumes.

Nevertheless cisternal milk volume can be increased in some breeds by spontaneous liberation of endogenous oxytocin as a consequence of milking conditioned behavior or during udder manipulation. This can be avoided by using oxytocin antagonists to temporarily block spontaneous milk letdown, as reported in cows (Bruckmaier et al, 1997a; Wellnitz et al., 1999; Ayadi et al, 2003b), ewes (Rovai et al., 2000; McKusick et al., 2002) and goats (Knight et al., 1994; Salama et al., 2004).

Milk partitioning between the udder compartments (cisternal and alveolar) was determined in two different dairy sheep breeds, under the same production system, by Rovai et al. (2000) using an oxytocin receptors blocking agent as shown in Table 9.

Table 9. Milk partitioning in the udder of dairy ewes according to the breed and the use of Atosiban as an oxytocin blocking agent (Rovai et al., 2000).

Item	Manchega		Lacaune		SEM	Effect (*P* <)	
	Control	Atosiban[2]	Control	Atosiban		Breed	Atosiban
Milk yield[1], L/d	0.94	-	2.07	-	0.10	0.001	-
Milk composition[1]							
SCC, log_{10}/ml	5.07	-	5.22	-	0.31	0.632	-
Milk partitioning							
Cisternal, ml	122	118	299	239	79	0.001	0.001
Alveolar, ml	86	104	89	115	0.63	0.712	0.001
Total, ml	208	222	388	354	1.06	0.010	0.465
Cisternal: Alveolar (%)	59:41	53:47	77:23	68:32	-	0.001	0.001
Cisternal area, cm^2	12.4	13.1	24.0	23.2	0.90	0.001	0.961

[1] Average udder milk yield and composition during the experimental period (90 DIM).
[2] Oxytocin receptors blocking agent injected in jugular

As shown in Table 9, despite the differences in milk production (over 100%) at the same stage of lactation, alveolar milk was very similar in the two breeds, the difference being only 10% greater in Lacaune ewe. On the contrary, the difference in true cisternal milk was 102% greater according to the difference observed in yield. These differences suggest that the volume of cisternal milk is the only difference between Lacaune and Manchega breed and highlight the important role that cistern size plays in the milk yield of the dairy sheep.

Similarly, percentage milk fractions differed significantly according to breed, with superiority of cisternal fraction in Lacaune ewes, and consequently a greater percentage of alveolar milk in Manchega ewes. These results clearly support the interbreed changes due to selection programs schemes increasing the milk yield and consequently cisternal area of selected dairy sheep.

Carretero et al. (1999) studying the ultrastructure of the mammary gland in Manchega and Lacaune ewes reported the same mammary structures and pattern of development during lactation, describing an equally and extensive proliferation of the canicular system with a large number of alveolar sprouts between week 1 (suckling) and 5 (start of milking) in both breeds.

The use of an oxytocin receptors blocking agent is potentially a convenient method to determine with exactitude the amounts of cisternal and alveolar milk fractions, under normal conditions of milking (Knight et al., 1994). However, as observed in Table 9, the volume of milk fractions according to treatment tended to be different between breeds. The fractions were similar and accurate for Manchega ewes while the Lacaune presented a spontaneous milk ejection when entering to the milking parlor. These results suggest the necessity to use an oxytocin antagonist when we need to prevent the milk ejection and study the fractions of milk separately in well know adapted machine milking breed.

Machine milking ability

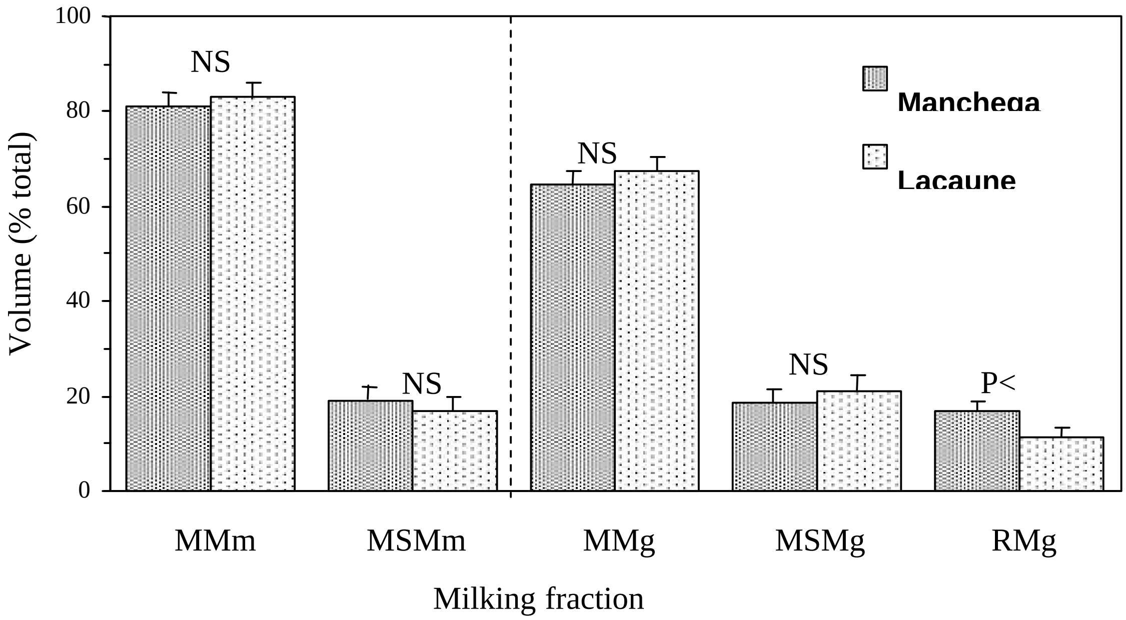
Machine milkability is normally estimated by fractional milking (i.e. machine milking, machine stripping, and extraction of residual milk after an oxytocin injection) or by analysis of milk emission curves obtained during machine milking without massage or extra stimulation of the mammary gland. The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

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

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

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

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



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

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

A good milk emission curve should mean a quick and complete milking, with a high milk flow rate and an effective ejection of alveolar milk under the action of the oxytocin. The milk emission pattern is related to the structure of the udder (cistern size), to the teat traits (size and position) and to the neuro-hormonal behavior of the ewe (Labussière et al., 1969; Bruckmaier et al., 1994, 1997; Marnet et al., 1998, 1999).

Globose and big cisterned udders with medium size, vertical and sensitive teats, that is able to open the sphincter rapidly and widely at low vacuums, is preferable.

An early typology of milk emission curves was proposed by Labussière and Martinet (1964), and widely adopted for the study of sheep dairy breeds (Labussière, 1983, 1988). The milk emission typology considers curves of different shape: '1 peak' (single), '2 peaks' (bimodal) and others, the last corresponding to animals with irregular or multiple milk emission curves (≥ 3 peaks). In some cases an ewe changes the milk emission typology on consecutive days, and more than two recordings are recommended in practice. The first peak occurs very early after cluster attachment and it is identified as cisternal milk, which is drained after the opening of the teat sphincter. The second peak corresponds to alveolar milk and occurs as a consequence of liberation of alveolar milk during the appearance of the milk ejection reflex by effect of released oxytocin (Labussière and Martinet, 1964; Labussière et al., 1969; Fernández et al., 1989b; Marnet et al., 1998). Milking-related release of oxytocin has been measured in dairy sheep by Mayer et al. (1989a) and Marnet et al. (1998). The machine milk fraction is normally greater and milk flow maintained high during a longer time in the bimodal ewes, which are considered favorable for machine milking in dairy ewes. Milking of ewes showing an 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 breed as indicated by Labussière (1988). Sheep breeds with a greater percentage of ewes showing 2 peaks being the most appropriate for machine milking. Nevertheless peak distribution in a flock changes according to the stage of lactation as observed by Rovai (2000) in a flock with breeds of different yield and milkability (Table 10). Number of ewes in the 1 peak typology increased at the end of lactation and on the contrary the ≥ 3 peaks decreased compensating the losses in the 2 peaks group.

Table 10. Distribution (%) of milk emission curves obtained in dairy ewes during machine milking according to breed and stage of lactation in (Rovai, 2000).

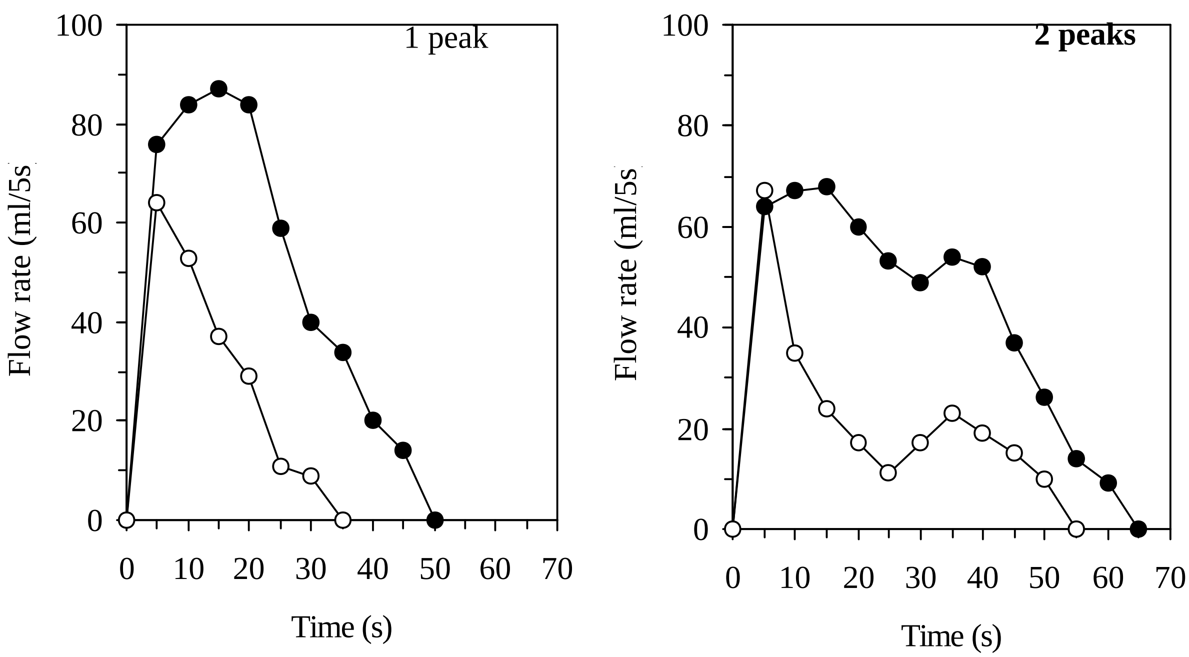
Stage of lactation (d)	Manchega			Lacaune		
	1 peak	2 peaks	≥ 3 peaks	1 peak	2 peaks	≥ 3 peaks
42[1]	28.6	56.7	14.7	8.0	57.2	34.8
	(62)[2]	(123)	(32)	(16)	(115)	(70)
70	29.6	64.2	6.19	9.8	49.4	40.8
	(67)	(145)	(14)	(25)	(126)	(104)
98	39.4	54.8	5.9	18.0	55.6	26.5
	(74)	(103)	(11)	(34)	(105)	(50)

[1]: First week after weaning at day 35.
[2]: Number of emission curves analyzed.

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

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

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



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

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

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

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

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

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

Rovai et al. (2003) studying the milking emission parameters recorded during machine milking in U.S. dairy-cross ewes (Table 10).

Table 10. Milking characteristics in U.S. dairy-cross ewes (Rovai et al., 2003).

Trait	Ewes crosses							
	EE (¾ EF)	*SEM*	**EF** (½ EF)	*SEM*	**LC** (½ LC)	*SEM*	**EF-LC** (¼EF-½LC)	*SEM*
n								
Milk yield, L	1.25 [a]	0.06	1.24 [a]	0.05	1.20 [a]	0.06	1.59 [b]	0.08
Lag time, s	2.16	0.19	2.24	0.15	2.12	0.20	2.25	0.24
Volume 1st minute, L	0.46	0.03	0.49	0.02	0.47	0.03	0.56	0.04
Volume without stripping, L	0.63 [a]	0.03	0.62 [a]	0.03	0.63 [a]	0.04	0.87 [b]	0.04
Total volume total, L	0.78 [a]	0.29	0.77 [a]	0.24	0.78 [a]	0.32	1.06 [b]	0.38
Time without stripping, s	1.26 [a]	0.09	1.21 [a]	0.07	1.31 [a]	0.09	1.61 [b]	0.11
Total time, s	1.63 [a]	0.12	1.61 [a]	0.09	1.75 [a]	0.13	2.13 [b]	0.15
Average flow rate, L	0.45	0.02	0.42	0.02	0.44	0.02	0.48	0.03

Milk yield volume was highest in East Friesian-Lacaune ewes according to their high milk production. Total milking time was also greatest in East Friesian-Lacaune ewes, increasing with parity, and decreasing during lactation. Volume at the first minute of milking was similar for U.S dairy-cross ewes regardless of different blood percentages. The volume of milk during the first minute of milking can assure the presence of alveolar milk ejection and milkability of these crossbred ewes. Bruckmaier et al. (1997) reported that milk flow curves with diffuse shape and peak flow rate below 0.4 kg/min represent extremely weak or totally absent oxytocin release.

Positive relations was observed between milking kinetics and udder traits (r = 0.15 to 0.38, and also between milk volume during the 1st minute and cisternal area (r = 0.34).

Summary and implications

Information collected during this paper show that to improve milkability, a well shaped and healthy udder of dairy sheep should have:

- Great volume and globosely shaped
- Teats of medium size (length and width), implanted near to vertical
- Soft and elastic tissues, with palpable gland cisterns inside
- Moderate height, no surpassing the hock
- Marked intermammary ligament

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

Breed differences are also detected despite the differences in milk yield, and values of milk partitioning are in accordance with the known milkability of each dairy sheep breed, the most productive ewes showing a larger machine milk fraction. The differences in cisternal fraction of milk reported on different dairy sheep breeds explain the different mammary gland anatomy and morphology among breeds and also selected ewes.

Mammary ultrasonography is an efficient method to evaluate the size and the productive capacity of the ovine udder (highly correlated with milk production). This method seems to indicate that cisternal size is a direct limiting factor for milk secretion in dairy sheep and its importance is greater than the amount of secretory tissue in the current situation.

Preliminar results on U.S. dairy-cross ewes shows a superior milk production of East Friesian-Lacaune ewes may be related to more cisternal milk storage area. The Lacaune breed resulted in poorer udder confirmation (larger teat angle, greater external cisterns).

LITERATURE CITED

Alvarez-Morujo A.J. and Alvarez-Morujo A. 1982. Variedades morfológicas del alveolo de la glándula mamaria. Zbl. Vet. Med. C. Anat. Histol. Embryol., 11: 65-75.

Arranz J., López de Munain, J.M., and Lara J. 1989. Evolución de las características morfológicas de la ubre de ovejas de raza Latxa a lo largo del periodo de ordeño. In: 4th International Symposium on Machine Milking of Small Ruminants. Kibbutz Shefayim, Tel-Aviv, Israel. pp. 80-93.

Barone R. 1978. Mamelles de la brebis et de la chèvre. In: Anatomie comparée des mammifères domestiques. Tome III. J. Tixier et Fils S.A., Lyon, France. pp. 491-495.

Bocquier F. and Guillouet Ph. 1990. Nutrition et alimentation de la brebis laitière. In: Seminario Avanzado sobre mejora de la calidad en la producción del ovino de leche. CIHEAM-IAMZ, Zaragoza. 38 pp.

Brooker B.E. 1984. An ultrastructural study of the sinus epithelium in the mammary gland of the lactating ewe. J. Anatomy, 138:287-296.

Bruckmaier R.M., Ritter C., Schams D., and Blum J.W. 1994. Machine milking of dairy goats during lactation: udder anatomy, milking characteristics, and blood concentrations of oxytocin and prolactin. J. Dairy Res., 61:457-466.

Bruckmaier R.M., Paul G., Mayer H., and Schams D. 1997. Machine milking of Ostfriesian and Lacaune dairy sheep: udder anatomy, milk ejection and milking characteristics. J. Dairy Res., 64:163-172.

Burri, P.H. and Tarek, M.R. 1990. A novel mechanism of capillary growth in the rat pulmonary microcirculation. Anat. Rec., 228: 35-45.

Caja G. and Such X. 1999. Curso de actualización sobre ordeño mecánico de ovino y caprino. SEOC-UAB, Bellaterra, Barcelona. CD Rom.

Caja G., Capote J., López L., Peris S., Such X.., and Argüello A. 1999a. Milk partitioning and milk flow rate of Canarian dairy goats under once daily twice daily milking frequencies. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 274-280.

Caja G., Such X., Ruberte J., Carretero A., and Navarro M. 1999b. The use of ultrasonography in the study of mammary gland cisterns during lactation in sheep. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 91-93.

Caruolo E.V., 1980. Scanning electron microscope visualization of the mammary gland secretory unit and myoephitelial cells. J. Dairy Sci., 63:1987-1998.

Carretero A., Ditrich H., Pérez-Aparicio F.J., Splechtna H., and Ruberte J. 1995. Development and degeneration of the arterial system in the mesonephros and metanephros of chicken embryos. Anat. Rec., 243:120-128.

Carretero A., Ruberte J., Caja G., Pérez-Aparicio F.J., Such X., Peris S., Manesse M., and Navarro M. 1999. Study on the structure and the development of the canalicular system of the mammary gland during lactation in Manchega and Lacaune dairy sheep. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 35-40.

Carta A., Sanna S.R., Ruda G., and Casu S. 1999. Genetic aspects of udder morphology in Sarda primiparous ewes. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 363-368.

Casu S., Carta R., and Ruda G.1983. Morphologie de la mamelle et aptitude à la traite mécanique de la brebis Sarde. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 592-603.

Casu S., Barillet F., Carta R., and Sanna S. 1989. Amélioration génétique de la forme de la mamelle de la brebis Sarde en vue de la traite mécanique: Résultats préliminaires. In: 4th International Symposium on Machine Milking of Small Ruminants. Kibbutz Shefayim, Tel- Aviv, Israel. pp. 104-133.

De la Fuente L.F., Fernández G., and San Primitivo F. 1996. A linear evaluation system for udder traits of dairy ewes. Livest. Prod. Sci., 45:171-178.

De la Fuente L.F., Pérez-Guzman D., Othmane M.H., and Arranz J. 1999. Amélioration génétique de la morphologie de la mamelle dans les races Churra, Latxa et Manchega. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 369-374.

Delouis C. and Richard Ph.. 1991. La Lactation. In: La reproduction chez les mammifères et l'homme. Ch. Thibault and M.C. Levasseur (Eds.). INRA. Paris. p. 487-514.

Ditrich, H. and Splechtna H. 1989. The opistonephric blood vascular system of the chicken embryo as studied by scanning electron microscopy of microcorrosion casts and critical point dried preparations. Scanning Microsc., 3: 559-561.

Fernández G., Alvarez P., San Primitivo F., and De la Fuente L.F. 1995. Factors affecting variation of udder traits of dairy ewes. J. Dairy Sci., 78:842-849.

Fernández G., Baro J.A., de la Fuente L.F., and San Primitivo F. 1997. Genetic parameters for linear udder traits in dairy ewes. J. Dairy Sci., 80:601-605.

Fernández G., Farias D., López M., and Silveira C. 1999b. Genetic improvement in milkability of the Corriedale breed: morphological study of the udder traits. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 434-437.

Fernández N., Arranz J., Caja G., Torres A., and Gallego L. 1983a. Aptitud al ordeño mecánico de ovejas de raza Manchega: I. Biometría corporal, características morfológicas de la ubre y cría de corderos. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 653-666.

Fernández N., Arranz J., Caja G., Torres A., and Gallego L. 1983b. Aptitud al ordeño mecánico de ovejas de raza Manchega: II. Producción de leche, reparto de fracciones y cinética de emisión de leche. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 667-686.

Fernández N., Caja G., Torres A., Molina M.P., and Gallego L. 1989a. Cinética de emisión de leche de ovejas de raza Manchega: II. Relación con otros criterios de aptitud al ordeño mecánico. Invest. Agr. Prod. Sanid. Anim., 4:23-33.

Fernández N., Caja G., Torres A., Molina M.P., and Peris C. 1989b. Cinética de emisión de leche de ovejas de raza Manchega: II. Parámetros de las curvas de emisión de leche durante el ordeño a máquina. Invest. Agr. Prod. Sanid. Anim., 4:9-21.

Fernández N., Díaz J.R., Peris C., Rodríguez M., Molina M.P., and Torres A.1999a. Machine milking parameters for the Manchega breed. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 65-68.

Franke, W.W. and Keenan T.W. 1979. Mitosis in milk secreting epithelial cells of mammary gland. An ultrastructural study. Differentiation, 13:81-88.

Gallego L., Caja G., and Torres A. 1983a. Estudio de la tipología y características morfológicas de las ubres de ovejas de raza Manchega desde el parto. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 100-116.

Gallego L., Torres A., Caja G., and Molina M.P. 1983b. Fracciones de leche en el ordeño de ovejas de raza Manchega: cuantificación y evolución durante la lactación. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 149-163.

Gallego L., Torres A., Caja G., Molina M.P., and Fernández N. 1985. Reparto de las fracciones de leche y su composición según el tipo de ubre. ITEA Prod. Anim., 58:21-28.

Gootwine E., Alef B., and Gadeesh S. 1980. Udder conformation and its heritability in the Assaf (Awassi x East Friesian) cross dairy sheep in Israel. Ann. Génét. Sél. Anim., 12:9-13.

Hatziminaoglou J., Zervas N., Sinapis E., and Hatziminaoglou P. 1983. Aptitude à la traite mécanique des brebis de race Karagouniko (Grèce). Données préliminaires concernantes la production et la composition du lait, la morphologie des mamelles et la cinétique d’émission du lait. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 607-624.

Hurley W.L. 1989. Mammary gland function during involution. J. Dairy Sci., 72:1637-1646.

Jatsh O. and Sagi R.1978. Effects of some anatomical and physiological traits on dairy yield and milk fractionation in dairy ewes. In: Proc. 2nd International Symposium on Machine Milking of Small Ruminants. INRA-ITOVIC, Alghero, Italy. pp. 60-79.

Johnsson I.D. and Hart I.C. 1985. Pre-puberal mammogenesis in the sheep. I. The effect of level of nutrition and growth and mammary development in female lambs. Anim. Prod., 41:323-332.

Knight C.H. and Wilde C.J. 1993. Mammary cell changes during pregnancy and lactation. Livest. Prod. Sci., 35:3-19.

Knight C.H., Stelwagen K., Farr V.C., and Davis, S.R. 1994. Use of an oxytocin analogue to determine cisternal and alveolar milk pool sizes in goat. J. Dairy Sci., 77 (Suppl. 1): 84 (Abstr.).

Kukovics S. and Nagy A. 1989. Relationships between sheep genotype and udder type as well as relative measurements of udder. In: 4th International Symposium on Machine Milking of Small Ruminants. Kibbutz Shefayim, Tel-Aviv, Israel. pp. 66-79.

Labussière J. 1983. Étude des aptitudes laitières et de la facilité de traite de quelques races de brebis du Bassin Méditerranéen. Projet M4 FAO. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 780-803.

Labussière J. 1988. Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. Livest. Prod. Sci., 18:253-273.

Labussière J. and Martinet J. 1964. Description de deux appareils permettant le contrôle automatique des débits de lait au cours de la traite à la machine. Premiers résultats obtenus chez la brebis. Ann. Zootech., 14 :63-126.

Labussière J., Bennemederbel B., Combaud J.F., and De la Chevalerie F. 1983. Description des pricipaux paramètres caractérisant la production laitière, la morphologie mammaire et la cinétique d'émission du lait de kla brebis Lacaune traite une ou deux fois par jour avec ou sans égouttage. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 656-652.

Labussière J., Dotchewski D., and Combaud J.F. 1981. Caractéristiques morphologiques de la mamelle des brebis Lacaune. Méthodologie pour l'obtention des données. Relation avec l'aptitude à la traite. Ann. Zootech., 30:115-136.

Labussière J., Martinet J., and Denamur R., 1969. The influence of the milk ejection reflex on the flow rate during the milking of ewes. J. Dairy Res., 36 :191-210.

Marie C., Jacquin M., Aurel M.R., Pailler F., Porte D., Autran P., and Barillet F. 1999. Déterminisme génétique de la cinétique d'émission du lait selon le potentiel laitier en race ovine de Lacaune et relations phénotypiques avec la morphologie de la mamelle. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 381-388.

Marnet P.G., Combaud J.F., and Dano Y. 1999. Relationships between characteristics of the teat and milkability in Lacaune ewes. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 41-44.

Marnet P.G., Negrao J.A., and Labussière J. 1998. Oxytocin release and milk ejection parameters during milking of dairy ewes in and out natural season of lactation. Small Ruminant Res., 28:183-191.

Martal J. and Chene N. 1993. Placenta and lactation. In: Biologie de la lactation. J. Martinet and L.M. Houdebine (Eds.). INRA Editions. Paris. pp 31-58.

Mayer H., Weber F., and Segessemann V. 1989a. Oxytocin release and milking characteristics of Ostfriesian and Lacaune dairy sheep. In: 4th International Symposium on Machine Milking of Small Ruminants. Kibbutz Shefayim, Tel-Aviv, Israel. pp. 548-563.

Mayer H., Weber F., and Segessemann V. 1989b. A method to record and define milk flow curves of sheep during routine machine milking. In: 4th International Symposium on Machine Milking of Small Ruminants. Kibbutz Shefayim, Tel-Aviv, Israel. pp. 564-575.

McCann M.A., Good L., Harvey R.W., Caruolo E.V., and Mann D.I. 1989. Effects of rapid weight gain to puberty on reproduction, mammary development and lactation in ewe lambs. Theriogenology, 32:55-68.

McKusick B.C., Berger Y., and Thomas D.L. 1999. Preliminary results: Effects of udder morphology on commercial milk production of East Friesian crossbreed ewes. Proc. 5th Great Lakes Dairy Sheep Symposium, Brattleboro, Vermont. pp. 81-90.

Molina M.P., Such X., Fernández N., Caja G., and Torres A. 1989. Supresión del repaso manual en el ordeño mecánico de ovejas de raza Manchega. 1. Efecto sobre la producción de leche y el fraccionamiento de la leche en el ordeño. In: 4th International Symposium on Machine Milking of Small Ruminants. Kibbutz Shefayim, Tel-Aviv, Israel. pp. 655-679.

Patan S., Alvarez M.J., Schittny J.C., and Burri P.H. 1992. Intussusceptive microvascular growth: A common alternative to capillary sprouting. Arch. Histol. Cytol., 55:65-75.

Pérez J., Gómez J.L., and García J. 1983. Contribución al estudio de la morfología de la ubre de la oveja Manchega.. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 583-591.

Peris S., Such X., and Caja G. 1996. Milkability of Murciano-Granadina dairy goats. Milk partitioning and flow rate during machine milking according to parity, prolificacy and mode of suckling. J. Dairy Res., 63:1-9.

Purroy A. and Martín J.L. 1983. Características de ordeño de la oveja Churra: Producción y composición de la leche, morfología de la ubre y cinética de emisión de leche. In: 3rd International Symposium on Machine Milking of Small Ruminants. Sever-Cuesta, Valladolid, Spain. pp. 568-581.

Purroy A., Martín J.L., and Jurado J.J., 1982. Aptitud al ordeño mecánico en ovejas de raza Churra. I. Características morfológicas de la ubre. An. INIA/Ser. Ganadera, 16:41-51.

Rovai M. 2000. Caracteres mamarios que afectan a la aptitud al ordeño mecánico de ovejas de raza Manchega y Lacaune. Ph.D. Thesis. Universitat Autònoma de Barcelona.

Rovai M., Such X., Piedrafita J., Caja G., and Pujol M.R. 1999. Evolution of mammary morphology traits during lactation and its relationship with milk yield of Manchega and Lacaune dairy sheep. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 107-109.

Rovai M., Such X., Caja G., and Knight, C.H. 2000. Interbreed differences in cisternal and alveolar milk partitioning in the udder according to yield in dairy sheep. J. Dairy Sci., 83 (Suppl. 1): 166 (Abstr.).

Ruberte J., Carretero A., Fernández M., Navarro M., Caja G., Kirchner F., and Such X. 1994a. Ultrasound mammography in the lactating ewe and its correspondence to anatomical section. Small Rumin. Res., 13:199-204.

Ruberte J., Carretero A., Fernández M., Pons M., Giné J.M., and Sautet J. 1994b. Anatomía de la ubre de la oveja. Ovis, 32:9-16.

Sagi R. and Morag M. 1974. Udder conformation, milk yield and milk fractionation in the dairy ewe. Ann. Zootech., 23:185-192.

Such X., Caja G., and Pérez L. 1999a. Comparison of milking ability between Manchega and Lacaune dairy ewes. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 45-50.

Such X., Caja G., Fernández N., Molina M.P., and Torres A. 1999b. The effects of type of pulsator on ther evolution of milk emission kinetics during machine milking in Manchega ewes. In: Milking and milk production of dairy sheep and goats. F. Barillet and N.P. Zervas (Eds.), EAAP Publication No. 95, Wageningen Pers., Wageningen. pp. 227-232.

Tenev S. and Rusev G. 1989. Micro y ultraestructura de la ubre de ovejas en razas de distinto rendimiento de leche. In: 4th International Symposium on Machine Milking of Small Ruminants. Kibbutz Shefayim, Tel-Aviv, Israel. pp. 47-65.

Turner C.W. 1952. The anatomy of the udder of sheep. In: The anatomy of the mammary gland. Lucas Brothers Publishers, Columbia, Missouri. pp. 315-331

Wilde C.J., Knight C.H., and Peaker M. 1996. Autocrine regulation of milk secretion. In: Progress in dairy science. C.J.C. Phillips (Ed.). CAB International, Wallingford, Oxon, United Kingdom. pp. 311-332.

Williams, J.M. and Daniel C.W. 1983. Mammary ductal elongation: Differentiation of myoepithelium and basal lamina during branching morphogenesis. Developm. Biology, 97: 274-290.

COMPARISON OF EAST FRIESIAN AND LACAUNE BREEDS FOR DAIRY SHEEP PRODUCTION IN NORTH AMERICA

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Summary

A study was initiated in the autumn of 1998 to compare the East Friesian (EF) and Lacaune (LA) breeds for performance in a dairy sheep production system typical of the upper Midwestern U.S. Matings were designed to produce breed groups of high percentage EF, high percentage LA, and various EF-LA crosses. This paper summarizes data collected through the summer of 2004. Based on these results, replacement of 50% EF breeding with 50% LA breeding will decrease lambs born per 100 ewes exposed by about 15, may result in a slight decrease in milk production (~7%), and will raise fat and protein content of milk by .3 to .6 percentage units. A two-breed rotational crossbreeding program with East Friesian and F1 East Friesian x Lacaune rams is proposed. This system will result in a flock in which about half of the ewes are 83%EF,17%LA and the other half are 67%EF,33%LA.

Background

The raising of sheep for milk is a new enterprise to North American agriculture (Thomas, 2004). Sheep in North America have been selected for meat and wool production. Therefore, one of the first major constraints to profitable sheep dairying was the low milk production of domestic breeds.

The East Friesian (EF) is a very high milk-producing breed with an origin in northern Germany (Alfa-Laval, 1984). The first importations of EF genetics into North America for the specific purpose of dairy sheep production were by Hani Gasser, British Columbia, Canada (semen in 1992) and Chris Buschbeck and Axel Meister, Ontario, Canada (embryos). The first crossbred EF rams were imported into the U.S. in 1993 from Hani Gasser by the University of Minnesota, the University of Wisconsin-Madison (UW-Madison), and Hal Koller, a dairy sheep producer in Wisconsin.

The EF cross ewes produced from these crossbred rams produced almost twice as much milk per lactation as domestic breed crosses (Dorset-crosses) under experimental conditions at the UW-Madison (Thomas et al., 1998, 1999, 2000). Continued experimentation with EF crosses at UW-Madison and their performance in commercial dairy flocks in the U.S. and Canada further showed their superiority for milk production, and most commercial operations moved quickly to crossbred, high percentage, or purebred EF ewes. The accelerated move to EF in North America was facilitated by further importations of semen, embryos, and live animals from Europe and New Zealand to both Canada and the U.S. after 1992.

A second dairy sheep breed, the Lacaune (LA) from France (Alfa-Laval, 1984), also is available in North America. Josef Regli imported Lacaune embryos to Canada from Switzerland in 1996 (Regli, 1999), and he remains the primary source of LA genetics in North America. The UW-Madison imported the first LA genetics into the U.S. in 1998; semen from three rams in the U.K. and two LA rams from Josef Regli. Subsequently, a few LA rams from the Regli flock were used by dairy sheep producers in Canada and the U.S., as well as some crossbred Lacaune rams from UW-Madison. Access of U.S. producers to LA genetics is now difficult due to the Canadian-U.S. border closure to movement of ruminants to the U.S. because of concerns about bovine spongiform encephalopathy (BSE), and the inability of either country to access additional LA genetics from Europe due to animal health import restrictions.

The LA is the most numerous sheep breed in France. It has been selected in France for increased milk production under a sophisticated selection program incorporating artificial insemination, milk recording, and progeny testing of sires for longer than any other dairy sheep breed in the world. Annual genetic improvement for milk yield in the French LA is estimated at 2.4% or 5.7 kg (Barillet, 1995).

British Milksheep also have been imported into North America, and they are a relatively popular breed in flocks in Ontario, Canada.

Materials and Methods

During the autumns of 1998 to 2003, Dorset-cross ewes at the Spooner Station and Polypay and Rambouillet ewes at the Arlington Station of UW-Madison were artificially inseminated or naturally mated to EF or LA rams. Lambs sired by 14 purebred EF rams and six purebred LA rams representing all (or at least the vast majority) of the lines of these two breeds in North America were produced. Lambs were fed high-concentrate rations in confinement. Male lambs and a few cull ewe lambs were marketed at approximately 125 pounds liveweight, and the vast majority of the ewe lambs were retained for breeding.

First-cross (F1) ewe lambs born and raised at both locations from 1999 through 2003 were mated at the Spooner Station in their first autumn at approximately 7 months of age, and they lambed for the first time at approximately one year of age the following spring. Generally, young F1 ewes and their descendants were mated to either EF or LA rams to producer higher percentage EF or LA offspring or various crosses of EF-LA breeding. Most older dairy-cross ewes were mated to Dorset, Hampshire, or Suffolk rams to produce terminal market lambs. Each year, all replacement ewe lambs were sired by EF or LA rams. Ewes were retained in the flock for at least two seasons unless culled for a debilitating condition. Lambs were raised on their dams or on milk replacer until 30 days of age. After weaning at 30 days of age, lambs were raised on high-concentrate diets in confinement.

This mating system ultimately will result in the production of ewes of a high percentage dairy breeding with some ewes containing only EF dairy breeding, some ewes only LA dairy breeding, and some ewes various combinations of both EF and LA breeding. Currently, large numbers of animals of 1/2 dairy breeding (1/2EF or 1/2LA) and 3/4 dairy breeding (3/4EF; 1/2EF,1/4LA; 1/2LA,1/4EF; or 3/4LA) have been evaluated. Smaller numbers of animals of 7/8 and higher dairy breeding have been evaluated, and they have been grouped into two groups depending upon if they contain more EF (7/8+(EF,LA)) or LA (7/8+(LA,EF)) breeding.

Dairy ewes were milked on one of three weaning/milking systems: DY30, DY1 or MIX. The DY30 system is as follows: ewes nurse their lambs for approximately 30 days, after which lambs are weaned onto dry diets, and ewes are milked twice per day until a test day on which their total daily milk yield is less than .25 kg. The DY1 system is as follows: lambs are weaned from ewes within 24 hours of birth and raised on milk replacer until weaned onto dry diets at approximately 30 days of age, and ewes are milked twice per day from 24 hours postpartum until a test day on which their total daily milk yield is less than .25 kg. The MIX system is as follows: for the first 30 days postpartum, lambs are separated from their dams overnight, ewes are milked once per day in the morning, and lambs are returned to their dams for the day; lambs are weaned onto dry diets at approximately 30 days of age, and after their lambs are weaned, ewes are milked twice per day until a test day on which their total daily milk yield is less than .25 kg. The DY30 system is used more often with ewe lambs in their first lactation than with older ewes. Among older ewes, the DY1 system is used more often than the MIX system.

The number of observations included in the analysis of each trait was as follows:

1. Birth weight – 1,794 lambs
2. 30-day weight – 1,469 lambs
3. 150-day weight (majority are male market lambs) – 651 lambs
4. Fertility – 942 exposures on 483 individual ewes
5. Number of lambs born/ewe lambing – 877 lambings
6. Lactation traits – 796 lactations on 402 individual ewes

Data were analyzed with the Mixed Procedure of the Statistical Analysis System (SAS). For lamb growth traits, models included the effects of dam breed group, sire breed, sex of lamb, birth type of lamb, dam age, and year of record as fixed effects and dam and sire as random effects. Models for reproductive traits included the effects of ewe breed group or sire breed of ewe, ewe age, and year of record as fixed effects and ewe and sire as random effects. Lactation models include the effects of ewe breed group or sire breed of ewe, weaning/milking system, ewe age, and year of record as fixed effects and ewe and sire as random effects.

Results and Discussion

Growth. Table 1 presents birth, 30-day, and 150-day weights for lambs born to ewes of different ages and dairy breed composition and sired by rams of different breeds. Lamb weights are given in English (pounds) units whereas the lactation traits presented later are given in metric (kilogram) units. While the U.S. is on the English system, some reliance on foreign information for dairy sheep has resulted in us thinking somewhat in the metric system when dealing with lactation production.

Table 1. Lamb growth traits (mean ± SE)

Item	Birth wt, lb.	30-day wt, lb.	150-day wt., lb.
Dam age, yr			
1	10.2±.3[c]	30.5±.6[b]	111.8±2.7[b]
2	11.3±.3[b]	31.4±.6[a]	118.4±2.8[a]
3+	12.2±.3[a]	32.2±.7[a]	113.0±3.3[ab]
Dam breed group			
Non-dairy	10.7±.4[a]	34.2±.9[a]	129.8±3.8[a]
1/2EF	11.1±.3[a]	31.7±.6[b]	120.1±2.9[b]
1/2LA	11.2±.3[a]	31.0±.6[bc]	113.0±3.0[c]
3/4EF	11.2±.4[a]	30.1±.8[c]	108.4±3.8[c]
1/2EF,1/4LA	11.7±.4[a]	31.1±.9[bc]	108.7±4.1[c]
1/2LA,1/4EF	11.3±.4[a]	32.1±.9[ab]	109.3±4.1[c]
3/4LA	11.1±.4[a]	30.9±.8[bc]	111.5±3.9[c]
7/8+(EF,LA)[e]	11.5±.4[a]	29.6±.9[c]	112.7±4.9[c]
7/8+(LA,EF)[f]	11.3±.5[a]	31.6±1.0[bc]	116.0±5.5[bc]
Sire breed of lamb			
EF	11.1±.2[a]	31.4±.5[abd]	106.4±2.5[c]
LA	10.2±.2[b]	29.2±.6[c]	107.6±2.6[bc]
Suffolk	11.7±.5[a]	33.7±1.2[a]	120.7±4.2[a]
Hampshire	11.6±.5[a]	30.9±1.3[abcd]	118.6±5.3[ab]
Dorset	11.5±.7[a]	31.6±1.5[abcd]	118.6±8.0[ab]

[a,b,c,d]Means within a column and within an underlined and bold item group with no superscripts in common are significantly different (*P* < .05).
[e]Dams are at least 7/8 dairy breeding with 3/4 or greater of EF breeding. A few ewes contain no LA breeding.
[f]Dams are at least 7/8 dairy breeding with 3/4 or greater of LA breeding. A few ewes contain no EF breeding.

First-lambing ewes produced lambs that were lighter (P < .05) at birth, 30 days, and 150 days than lambs produced by older ewes.

Dam breed group had no effect on birth weight. For both 30-day and 150-day weight, lambs born to non-dairy ewes had heavier (P < .05) weights than lambs born to dairy-cross ewes. The lambs born to non-dairy ewes were all raised on their dam and weaned at approximately 60 days of age, whereas the lambs born to the dairy-cross ewes were weaned onto dry diets at approximately 30 days of age, and many were raised artificially on milk replacer from shortly after birth. This difference in rearing systems may be the reason for these observed differences. Among lambs from dairy-cross ewes, there does not appear to be any consistent effect of the amount of dairy breeding in the dam or the EF or LA breeding composition of the dam.

Overall, Suffolk-, Hampshire-, and Dorset-sired lambs tended to have heavier weights than the EF- or LA-sired lambs. Between the dairy breeds, EF sires produced lambs with heavier ($P < .05$) birth and 30-day weights than did LA sires. Differences between the two dairy sire breeds for 150-day weight of their lambs were small and not statistically different.

These data suggest that the EF and LA breeds are slightly inferior to some common terminal sire breeds (Suffolk, Hampshire, Dorset) for growth rate. This is to be expected. A dairy sheep producer can take advantage of this fact by mating only the number of dairy ewes needed to produce replacement ewe lambs to dairy rams and mating the remainder of the ewes to terminal sires for market lamb production. The EF breed may be slightly superior to the LA breed for preweaning growth rate, and the LA breed may be slightly superior to the EF breed for post-weaning growth rate, but the differences are small. Growth rate is not an important consideration when dairy sheep producers decide between the EF and LA breeds.

Reproduction. Table 2 compares the reproductive performance of ewes of different ages, ewe breed groups, and sire breeds.

Percentage of ewes lambing of ewes exposed (fertility) was not significantly affected by any of the factors. Even though the differences are not significantly different, it is interesting to look at the fertility of the ewe breed groups within each percentage of dairy breeding subgroup. In each subgroup, the ewe breed group with the highest percentage of LA breeding had the lowest fertility (1/2 dairy breeding:1/2LA = 92.0%, 3/4 dairy breeding: 3/4LA = 91.2%, and 7/8 or greater dairy breeding: 7/8+(LA,EF) = 89.3%). Averaged over all ewe breed groups, ewes with a LA sire had a lower (not statistically significant) fertility (94.6%) than ewes with an EF sire (96.7%).

Litter size was different ($P < .05$) among ewes of the three age groups with older ewes giving birth to larger litters than younger ewes.

As with fertility, there are no significant differences among ewe breed groups within a percentage of dairy breeding subgroup for litter size. However, within each subgroup, an increase in LA breeding resulted in a decrease in litter size.

Averaged over all ewe breed groups, ewes sired by LA sires had smaller ($P < .05$) litter sizes than ewes sired by EF sires (1.69 vs. 1.85 lambs, respectively) (Table 2). When the number of lambs born per ewe exposed is calculated from the fertility and litter size values presented in Table 2, values for ewes sired by LA and EF sires are 1.60 and 1.79, respectively.

Differences between EF and LA breeds in reproduction should enter into a decision on which of these breeds to use. EF breeding can be expected to result in 10 to 20 more lambs born 100 ewes than LA breeding.

Table 2. Reproductive traits (mean ± SE)

Item	Fertility, %	Lambs born/ewe lambing, no.
<u>Ewe age, yr</u>		
1	94.3±1.5[a]	1.56±.04[c]
2	92.6±2.1[a]	1.65±.05[b]
3+	92.7±3.2[a]	1.89±.08[a]
<u>Ewe Breed group</u>		
1/2EF	95.4±2.6[a]	1.89±.06[a]
1/2LA	92.0±2.5[a]	1.79±.06[ab]
3/4EF	94.6±3.6[a]	1.82±.09[ab]
1/2EF,1/4LA	91.3±3.9[a]	1.67±.09[b]
1/2LA,1/4EF	96.0±4.0[a]	1.63±.09[b]
3/4LA	91.2±3.4[a]	1.50±.08[b]
7/8+(EF,LA)[e]	95.7±3.9[a]	1.66±.09[b]
7/8+(LA,EF)[f]	89.3±4.3[a]	1.64±.10[b]
<u>Sire breed of ewe</u>		
EF	96.7±1.4[a]	1.85±.06[a]
LA	94.6±1.4[a]	1.69±.07[b]

[a,b,c,d]Means within a column and within an underlined and bold item group with no superscripts in common are significantly different (*P* < .05).
[e]Ewes are at least 7/8 dairy breeding with 3/4 or greater of EF breeding. A few ewes contain no LA breeding.
[f]Ewes are at least 7/8 dairy breeding with 3/4 or greater of LA breeding. A few ewes contain no EF breeding.

Lactation. The effects of lactation number, weaning/milking system, ewe breed group, and sire of ewe are presented in Table 3. Only milk, fat, and protein obtained from ewes while they were machine-milked were used to determine performance for lactation traits. Milk produced during any nursing period was not estimated.

All measures of lactation performance increased (P < .05) as the ewes progressed from 1st through 3rd and greater lactations. The effects of weaning/milking system have been reported by our group previously (McKusick et al., 2001). The ranking of the systems from highest to lowest for lactation length and yield of milk, fat, and protein was: DY1, MIX, and DY30. The lowest percentage of milk fat was found in MIX milk. This is due to an especially low fat content of milk obtained during the once-a-day milking during the first 30 days of lactation when the ewes spend half of their day nursing their lambs. During this period, MIX ewes do not have complete milk ejection in the parlor, and milk fat is retained in the udder; supposedly to be released to their lambs later (McKusick et al., 2002).

There did not appear to be large breed effects on milk yield or lactation length. Within the dairy breeding percentage subgroups of 1/2 and 3/4 quarters dairy breeding, LA breeding tended to reduce milk yield, but in the 7/8+ dairy breeding group, the higher percentage LA ewes had somewhat greater yields. Averaged over all ewe breed groups, ewes with an EF sire produced 14.6 kg more milk over a 6.2 day longer lactation period than ewes sired by a LA sire, but these differences were not statistically significant.

Table 3. Lactation traits (mean ± SE)

Item	Milk, kg	Lactation length, d	Fat, kg	Fat, %	Protein, kg	Protein, %
<u>Lactation</u>						
1st	162.1±8.3[c]	137.8±3.6[c]	9.1±.5[c]	5.61±.08[c]	7.6±.4[c]	4.67±.05[b]
2[nd]	219.5±9.0[b]	160.3±3.9[b]	12.8±.6[b]	5.79±.09[b]	10.9±.4[b]	4.97±.05[a]
3rd+	254.4±11.9[a]	174.9±5.5[a]	15.6±.7[a]	5.95±.12[a]	13.0±.6[a]	5.00±.07[a]
<u>Weaning system</u>						
DY 1	234.1±8.9[a]	173.9±3.7[a]	13.9±.5[a]	5.80±.09[ab]	11.6±.4[a]	4.84±.05[b]
MIX	215.6±11.6[b]	164.2±5.7[a]	12.5±.7[b]	5.66±.11[b]	10.6±.6[b]	4.85±.07[ab]
DY30	186.4±9.7[c]	134.9±4.4[b]	11.1±.6[b]	5.90±.10[a]	9.4±.5[c]	4.94±.06[a]
<u>Ewe Breed group</u>						
1/2EF	208.5±11.1[bcd]	165.9±4.6[ab]	12.5±.7[b]	5.88±.12[b]	10.3±.5[b]	4.83±.07[bc]
1/2LA	190.2±12.0[d]	155.0±4.7[bcd]	12.6±.7[b]	6.55±.12[a]	10.1±.6[b]	5.28±.07[a]
3/4EF	199.0±13.5[bcd]	152.4±6.0[cd]	10.9±.8[b]	5.27±.14[d]	9.5±.7[b]	4.59±.09[d]
1/2EF,1/4LA	252.6±14.3[a]	170.6±6.4[a]	14.9±.9[a]	5.86±.15[bc]	12.5±.7[a]	4.90±.09[b]
1/2LA,1/4EF	217.2±15.3[abc]	160.2±6.5[abc]	12.4±.9[b]	5.59±.16[cd]	10.7±.8[b]	4.84±.10[bc]
3/4LA	197.3±14.1[cd]	146.8±5.9[d]	12.1±.9[b]	6.03±.15[b]	10.1±.7[b]	5.01±.08[b]
7/8+(EF,LA)[e]	205.8±14.3[bcd]	150.8±6.5[cd]	11.1±.9[b]	5.25±.15[d]	9.9±.7[b]	4.65±.09[cd]
7/8+(LA,EF)[f]	225.3±16.6[ab]	159.6±5.9[abcd]	13.2±1.0[ab]	5.84±.17[bc]	11.2±.8[ab]	4.91±.11[b]
<u>Sire breed of ewe</u>						
EF	209.4±9.8[a]	161.4±3.8[a]	12.3±.6[a]	5.75±.10[b]	10.3±.5[a]	4.81±.06[b]
LA	194.8±11.5[a]	155.2±4.0[a]	12.5±.7[a]	6.31±.11[a]	10.1±.6[a]	5.15±.06[a]

[a,b,c,d] Means within a column and within an underlined and bold item group with no superscripts in common are significantly different ($P < .05$).
[e]Ewes are at least 7/8 dairy breeding with 3/4 or greater of EF breeding. A few ewes contain no LA breeding.
[f]Ewes are at least 7/8 dairy breeding with 3/4 or greater of LA breeding. A few ewes contain no EF breeding.

Large and significant differences between the two breeds were observed for percentage fat and protein, with the LA superior to the EF. Within each of the percentage dairy breeding subgroups, the ewes with the highest percentage of LA breeding had the greatest percentage fat and protein. Averaged over all ewe breed groups, ewes sired by LA rams had greater ($P < .05$) percentage fat (6.31 vs. 5.75%, respectively) and percentage protein (5.15 vs. 4.81%, respectively). Even though the higher percentage LA ewes often had lower milk production than other breed groups, the higher fat and protein content of their milk resulted in the production of similar amounts of fat and protein.

The LA breed will increase the content of fat and protein in milk compared to the EF breed. Producers selling milk on a component basis or farmstead cheese makers may benefit from the use of LA genetics.

The single ewe breed group with the most outstanding lactation performance was the 1/2EF,1/4LA group. These ewes produced from 27.3 to 62.4 kg more milk than any other group. In addition, they had some of the highest fat and protein contents so their fat and protein yields were the highest among the breed groups.

Conclusions

Based on the results of this study, replacement of 50% EF breeding with 50% LA breeding will have a small effect on lamb growth, will decrease lambs born per 100 ewes exposed by about 15, may result in a slight decrease in milk production (~7%), and will raise fat and protein content of milk by .3 to .6 percentage units.

Since most sheep milk in North America is not sold on a component basis, the infusion of large amounts of LA breeding into EF flocks will likely result in a decrease in net income – primarily from fewer lambs produced. However, infusion of smaller amounts of LA breeding into an EF flock may result in increased lamb and ewe survival due to hybrid vigor while at the same time taking advantage of the positive effect of LA breeding on milk composition. A simple approach to accomplish this would be to use a rotational crossbreeding program with purebred EF and F1 EFxLA rams. Any ewe sired by an EF ram would be mated to an EFxLA ram, and any ewe sired by an EFxLA ram would be mated to an EF ram. A similar number of replacement ewe lambs would be selected from each sire breed. This system would result in a flock in which about half of the ewes would be 83%EF,17%LA and the other half would be 67%EF,33%LA.

References

Alfa-Laval. 1984. System Solutions for Dairy Sheep. Alfa-Laval International AB, S-14700. Tumba, Sweden.

Barillet, F. 1995. Genetic improvement of dairy sheep in Europe. Proc. 1st Great Lakes Dairy Sheep Symp. 1995, Madison, Wisconsin. pp. 25-43. Univ. of Wisconsin-Madison, Dept. of Anim. Sci.

McKusick, B.C., Thomas, D.L., and Berger, Y.M. 2001. Effects of weaning systems on commercial milk production and lamb growth of East Friesian dairy sheep. J. Dairy Sci. 84:1660-1668.

McKusick, B. C., Thomas, D. L., Romero, J. E., and Marnet, P. G. 2002. Effect of weaning system on milk composition and distribution of milk fat within the udder of East Friesian dairy ewes. J. Dairy Sci. 85:2521-2528.

Regli, J. G. 1999. Farm adapted breeds : A panel presentation of flock performance records – Lacaune dairy sheep. Proc. 5th Great Lakes Dairy Sheep Symp. 1999, Brattleboro, Vermont. pp. 51-54. Univ. of Wisconsin-Madison, Dept. of Anim. Sci.

Thomas, D. L. 2004. Overview of the dairy sheep sector in Canada and the United States. Proc. 10th Great Lakes Dairy Sheep Symp. 2004, Hudson, Wisconsin. Univ. of Wisconsin-Madison, Dept. of Anim. Sci. (In Press).

Thomas, D. L., Y. M. Berger, and B. C. McKusick. 1998. Milk and lamb production of East Friesian-cross ewes in northwestern Wisconsin. Proc. 4th Great Lakes Dairy Sheep Symp. 1998, Spooner, Wisconsin. pp. 11-17. Univ. of Wisconsin-Madison, Dept. of Anim. Sci.

Thomas, D. L., Y. M. Berger, and B. C. McKusick. 1999. Milk and lamb production of East Friesian-cross ewes in the north central United States. In: F. Barillet and N. P. Zervas (Ed.) Milking and Milk Production of Dairy Sheep and Goats - Proc. 6th Int. Symp. on the Milking of Small Ruminants, 1998, Athens, Greece. pp. 474-477. EAAP Pub. No. 95. Wageningen Pers, Wageningen, The Netherlands.

Thomas, D. L., Y. M. Berger, and B. C. McKusick. 2000. East Friesian germplasm: Effects on milk production, lamb growth, and lamb survival. Proc. Am. Soc. Anim. Sci., 1999. Online. Available : http://www.asas.org/jas/symposia/proceedings/0908.pdf.

THE EFFECT OF FEEDSTUFF ON MILK FLAVOR

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Abstract

Milk flavor is composed of a variety of chemical compounds, derived from numerous sources. Some compounds found in milk are directly linked to the diet of the animal producing the milk. In many cases, it is uncertain where the compounds originate. Two main hypotheses are that they originate in the plants eaten by the animal or they are products of digestion of precursors. Common animal feeds, such as TMR (Total Mixed Ration), pasture, corn, and hay, as well as a combination of them, can influence milk flavor and composition. Various feedstuffs also affect the performance of the producing animal. In general, TMR-fed cows have greater milk production, body weight, and body condition compared to pasture fed cows. Pasture-fed cows' milk contains more odor-active compounds that TMR-fed cows.

Introduction

Due to the small market for goat and sheep milk, a limited amount of information is available on the effect of feedstuff on sheep and goat milk composition and flavor. Given the complexities of flavor analysis, even cow milk research is very limited. However, most of the details presented in this paper relate to bovine milk. It should be noted that while sheep and goat milk have different composition and functional characteristics compared to cow milk, similarities in diet and milk production exist.

Feedstuff

A variety of feeding techniques exist for milk-producing animals. They include a strict pasture or grass-fed diet, a total-mixed-ration feed (TMR), or a combination of the two. Pasture fed animals generally have a varied diet from one region to the next due to different plant-life in different regions, as well as the influence of weather and other environmental factors. A TMR mix typically contains a variety of grains, seeds, and protein supplement. According to Bargo, "Energy is the primary limiting nutrient for high-producing dairy cows on pasture (Bargo 2002)". Grazing alone may not yield enough energy for high yielding animals, so it is common for farmers to supplement the animals' diet. Alternative supplementation to animal diet may include corn silage or hay silage. Advantages of corn supplementation and/or hay silage include cost efficiency as well as seasonal availability of pasture (Holden 1995).

Milk Flavor Composition

The flavor of milk is composed of a variety of compounds. Numerous studies (Carpino 2004, Bendall 2001, Mariaca 1997, Gordon 1979) have been conducted measuring different compounds associated with milk flavor. In particular, aromatic flavor compounds called alkylphenols greatly influence the “feed flavor” of milk. A few additional chemical c that contribute to the feed flavor in milk composition include methyl sulfide, acetone, butanone, isopropanol, ethanol, and propanol (Gordon 1979).

One study (Carpino 2004) used cheese to identify odor-active compounds in the milk of differently fed cows. Gas chromatography was used to analyze the amount present in the cheese. In particular, more aldehyde, ester, and terpenoid compounds are found in pasture fed cows than TMR fed cows (Carpino 2004). Terpenoids in plants are products of secondary metabolism and may be considered as biochemical indicators to characterize highland cheese (Mariaca 1997). There is a small debate as to whether it is specific compounds found in milk that give it its flavor, or whether it is a concentration of a certain set of chemicals that give it its flavor.

Origin of Aromatic Flavor Compounds

Milk flavor is directly influenced by the diet of the animal producing the milk. For example, in Switzerland it has been known that a “pasture rich in dicotyledons, mostly located in the highland, is said to give cheese a different flavor from that produced from pasture rich in gramineae, located in the lowland (et al Sehovic, 1988, 1991).” This study demonstrates that the flavor of milk is directly influenced by the diet of the animal due to the differences in plant life consumed by the animal.

Knowing that the diet of animals influences their milk flavor, questions arise as to where the flavor compounds in the milk originate. It is possible the flavors in milk are found originally in the plant matter eaten by the cows. One particular study (Carpino 2004) used cheese to analyze the flavor compounds found in milk and suggests that “most of the odor-active compounds ... from pasture-fed cows appeared to be compounds created by oxidation processes in the plants that may have occurred during foraging and ingestion by the cow (Carpino 2004).” In other words, they are present in the milk due to the degradation or alteration of compounds in the plants consumed by the cow. The results of this study demonstrate “clearly that some unique odor-active compounds found in pasture plants can be transferred to the cheese (Carpino 2004).”

However, a different study suggests “differences in milk flavor are primarily caused by concentration differences of a common set of flavor compounds rather than by the occurrence of compounds uniquely associated with a particular feed (Bendall 2001).” This suggests there are basic compounds found in all milk, and different feed types produce different ratios of such compounds, instead of different compounds associated with different feed existing in the milk.

An additional hypothesis is that “volatile plant odors that are inhaled by the cow during consumption of the plants pass quickly through the bloodstream to the milk (Dougherty et al., 1962).”

Effect of Feedstuff on Animal and Milk

Numerous studies (Carpino, 2004, Holden 1995, Polan 1985, Bargo 2002, Kolver 1998) have shown that cows fed with TMR have greater milk production, body weight, and body condition compared to pasture fed cows. In addition, TMR-fed cows' milk contains a higher milk fat content and protein content. Milk production and milk fat lowered only slightly when cows were fed a mixed diet (Kolver 1998, Holden 1995.). However, the same study showed there are up to twenty-seven odor-active compounds identified in milk from pasture-fed cows. In mixed-ration fed cows, only thirteen active compounds were detected. Pasture-fed cows contain a greater number of odor-active compounds than mixed-ration-fed cows did (Carpino 2004).

Corn silage is another feedstuff used for milk-producing animals. One corn silage study (Polan 1985) conducted over a period of three years concluded corn silage was not as effective in maintaining milk production but enhanced milkfat. The same study also concluded limited hay or hay available in paddocks did not increase milk production or milk fat concentration.

Research is still needed to further explore these areas such as originating flavor compounds. In addition, more research may be performed with a variety of animals such as goat, sheep, and cows in other regions. Overall advancement of this knowledge may help farmers produce an optimum product for consumers in the most economic manner worldwide.

Bibliography

Bargo, F., L.D. Muller, J.E. Delahoy, T.W. Cassidy. 2002. Performance of High Producing Dairy Cows with Three Different Feeding Systems Combining Pasture and Total Mixed Rations. J. Dairy Sci. 85: 2948-2963.

Bendall, J. 2001. Aroma Compounds of Fresh Milk from New Zealand Cows Fed Different Diets. J. Agric. Food Chem 49 4825-4832.

Carpino, S., S. Mallia, S. LaTerra, C. Melilli, G. Licitra, T.E. Acree, D.M. Barbano, and P.J. Van Soest. 2004. Composition and Aroma Compounds of Ragusano Cheese: Native Pasture and Total Mixed Rations. J. Dairy Sci 87:816-830.

Dougherty, R.W., W.F. Shipe, G.V. Gudnason, R.A. Ledford, R.D. Peterson, R. Scarpellino. 1962. Physiological mechanisms involved in transmitting flavors and odors to milk. I. Contribution of eructated gases to milk flavor. J. Dairy Sci. 45: 472-476.

Gordon, D.T., M.E. Morgan. 1979. Principal Volatile Compounds in Feed Flavored Milk. Journal of Dairy Science 55: 905-912.

Holden, L.A., L.D. Muller, T. Lykos, T.W. Cassidy. 1995. Effect of Corn Silage Supplementation on Intake and Milk Product in Cows Grazing Grass Pasture. Jour of Dairy Science 78: 154-160.

Kolver, E., L. Mueller. 1998. Performance and Nutrient Intake of High Producing Holstein Cows Consuming Pasture or a Total Mixed Ration. J. Dairy Sci. 81: 1403-1411.

Mariaca, R G., T. Berger, R. Gauch, M. Imhof, B. Jeangros, J. Bosset. 1997. Occurrence of Volatile Mono- and Sesquiterpenoids in Highland and Lowland Plant Species as Possible Precursors for Flavor Compounds in Milk and Dairy Products. Jour of Agricultural Chemistry. 45: 4423-4434.

Polan, C., R.E. Blaser, C.N. Miller, D.D. Wolf. 1985. Utilization of Pasture by Lactating Cows. J. Dairy Sci. 69:1604-1612

Sehovic, J. Secondary metabolites in some plants of grassland forages. Rech. Agron. Suisse 1988, 27, 153-165.

Sehovic J. Consideration on the chemical composition in the quality estimation of the natural grassland forages. Rev. Suisse Agric. 1991, 23, 305-310.

RESIDUES IN MILK AFTER THE USE OF HEALTH TREATMENTS

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Summary

Despite all of the efforts placed on disease prevention in milking flocks, some sheep will still get sick and require some sort of treatment. In many cases, this treatment involves using drugs which may create residues in the milk during and after administration. The regulations for drug residues and the use of drugs in food animals can be difficult to understand at times. However, dairy sheep producers need to adhere to drug residue guidelines and requirements just as dairy cattle or goat producers do. Avoiding residues is important for maintaining the quality and flavor of the resulting products as well as for preventing health problems in humans consuming these products.

Residues

Drug residues are residual drugs that are found in the milk or meat of an animal during and after treatment. The presence of residues in milk can be problematic for human health in multiple ways. Originally, the primary reason for eliminating drug residues from milk was to prevent severe reactions in humans that might be allergic to the drug. Beta lactams (Penicillin like drugs) were the drugs that were of primary concern. Although these reactions do not commonly occur, their severe consequences warrant significant attention.

Recently, more attention has been focused on antibiotic resistance in human pathogens caused by the use of drugs in food producing animals. Indirectly, residues in the milk or meat may select for resistant bacterial populations which may eventually transfer their resistance genes to human bacterial pathogens. While residues do not necessarily cause resistance, it is important to understand that they may be related in some situations. This issue has raised the public's awareness of treating food producing animals with antibiotics and many groups perceive this to be an unacceptable practice. By working to prevent drug residues, sheep producers can protect the natural and wholesome image of the products made from sheep's milk.

Other factors make antibiotic residues undesirable in sheep's milk. Some residues can create an off-flavor in the milk or subsequent products. Residues may also interfere with the normal production process for some cheeses by inhibiting or killing bacteria necessary for the cheese production. Although these interruptions in production can be overcome, the presence of antibiotic residues in sheep's milk gives consumers the perception that products made from this milk are tainted and ultimately harmful.

The presence of drug residues is also highly scrutinized by regulatory authorities. All milk producers are required to adhere to the Pasteurized Milk Ordinance regardless of whether they produce cow's milk, goat milk or sheep milk. This is the regulation that describes antibiotic testing requirements designed to prevent antibiotic residues from entering the food chain. Each load of raw milk must be tested for the presence of antibiotic residues prior to its use in any product intended for human consumption. If a positive test occurs, that load of milk and any milk it has been mixed with must be discarded or diverted for use in an approved manner. Often, this results in disposing of the milk in a manure pit and a significant financial loss for the milk producer.

Although drug residues could be completely avoided by eliminating use of drugs during lactation, every sheep producer will find a need to use some drugs, whether they are antibiotics or other kinds of drugs, such as antiparasitics (treat internal and external parasites) at some point. Using these agents is acceptable provided the milk is withheld from sale for use in the human food chain for an adequate amount of time (milk withholding time). On the surface, this seems easy; however, very few drugs have an approved milk withholding time specified for sheep. Most milk withholding times are specified only for dairy cattle and cannot necessarily be translated into the same time for sheep. Nevertheless, dairy sheep producers have the same responsibility as other milk producers have to keep the milk they produce free from antibiotics.

One antibiotic is available and labeled to treat milking sheep. This drug has no meat or milk withdrawal time: Naxcel™. Provided this drug is used according to label instructions (1 to 2 mL/100 pounds once a day intramuscularly), no milk residues are created during or after its use. Naxcel™ is labeled to treat pneumonia in sheep. A prescription from a veterinarian is required to obtain this drug; however, dairy sheep producers can be confident they are producing milk free from residues when they choose this drug. In cattle, a residue has never been detected when this drug has been used according to label directions.

Antibiotics are usually the drugs most residue violations result from, however, as a sheep producer you must also be aware of residues created from other commonly used drugs, such as those used to treat parasites. In the U.S., there are no antiparasitic drugs that have an approved milk withdrawal for sheep. It is best to use caution and avoid treating sheep while they are in the milking string. Rather, utilize preventive treatments for internal and external parasites prior to lactation and after the ewe has been dried off.

Very little information is readily available regarding appropriate milk withdrawal times in sheep for other drugs. In fact, very few drugs are even approved for sheep in the U.S. which severely limits treatment choices for dairy sheep producers. While some drugs are labeled to treat sheep for specific conditions, these drugs do not have a milk withdrawal time specified for sheep. As a result, sheep producers must work closely with their veterinarians to establish safe milk and meat withdrawal times for drugs they choose to use.

Veterinarians are allowed to prescribe some drugs in an extralabel manner when other drugs are not labeled for use through AMDUCA (Animal Medicinal Drug Use Clarification Act). Extralabel use is any use of a drug that is different than what the drug is approved for. For example, changes from the label in dose, duration of treatment, route of administration, and species are extralabel uses of specific drugs and must be prescribed by a veterinarian. Veterinarians can obtain recommendations on the appropriate drug withdrawal time for some drugs from the Food Animal Residue Avoidance Databank (FARAD, www.farad.org).

Through this route, extralabel recommendations for sheep milk withdrawal times have been determined for a few drugs. For instance, the on-label milk withdrawal for cattle treated with oxytetracycline after IV administration is 96 hours. This has been determined to be adequate for sheep as well. For multiple doses or higher doses, 144 hours is recommended. This withdrawal time may not be accurate, however, if the drug was given in another manner, such as subcutaneously.

Even with this database of information, milk withdrawal times are not available for many drugs, especially those that are not antibiotics. Some information on drug withdrawal times is available from other countries that produce more milk from sheep than the U. S. This information can be helpful in estimating withdrawal times. However, beware of using information that cannot be scientifically substantiated. For instance, the British Sheep Dairying Association recommends allowing at least 2 extra days of withdrawal beyond the time recommended for cattle for intramammary antibiotic treatment and at least a 15 day withdrawal for injectable antibiotics (http://www.sheepdairying.com/MemSrv.htm). While these withdrawal periods may be correct for some antibiotics, each drug is metabolized differently, and the time frames needed for withdrawal may be different between drugs. Also, other countries have different drugs that may be labeled for use in sheep that are not approved or labeled for sheep in the U.S. Because of these inconsistencies, it is essential to work with a veterinarian that is familiar with the health and management of the flock and can make these drug treatment recommendations.

Certain drugs are prohibited from use in any food producing animal, including sheep. A few of these drugs may be approved for specific uses, however, uses not indicated on the label (extralabel use) are not allowed. These include some drugs you may have heard of including: chloramphenical, clenbuterol, furazolidone, nitrofurazone, and flouroquinolones like Baytril. In addition, using drugs in the feed in an extralabel manner is also prohibited. These drugs cannot be used in ways in which they were not approved, even with veterinary approval.

Unless you are treating with a drug for which a milk withdrawal time has been determined, utilize milk residue testing to confirm that milk from an individual animal contains a level of drug residue below the required limit. Most tests are not approved for use on individual animals so milk from an individual animal must be combined with milk from negative animals to perform the test correctly. For this reason, it is often more practical to have suspect samples tested at an outside laboratory rather than perform the testing on the farm. Outside laboratories are usually able to test for a wider range of drugs as well. Understand the costs involved in testing for some drug compounds. Inexpensive tests usually exist for many antibiotics, however, the tests for other compounds such as antiparasitics can be very expensive.

When a sick animal requires treatment, it is important to minimize the chance that any milk from that animal will reach the human food chain. Paying close attention to procedures you use to insure this does not happen can prevent you having to throw milk away due to contamination with a residue. Although residues in the cattle industry happen very infrequently, they often result from inattention to detail and accidentally milking a treated animal into the tank. To prevent this, be sure to visibly identify animals that are treated so anyone who may handle the animal understands that this animal's milk cannot be used.

While avoiding drug residues seems simple on the surface, many issues can make this task difficult when a sick animal requires treatment. As opposed to cattle, the drug arsenal for lactating sheep is limited because many drugs have had little research performed on them to verify proper milk withdrawal times. Despite this, every dairy sheep producer has a responsibility to prevent drug residues. Avoiding residues is of the utmost importance to maintain the image of sheep's milk as a wholesome and healthy product.

MILK COMPOSITION AND CHEESE YIELD FROM HARD AND SOFT CHEESE MANUFACTURED FROM SHEEP MILK

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Abstract

Hard and soft cheeses were produced from early, mid, and late season sheep milk. Fat recoveries in the cheeses were not affected by milking season while protein recoveries in cheeses from midseason were significantly higher than cheeses from early or late season milk. Cheese yields from early season milk was higher than mid or late season milk and was a result of higher solids in the milk. Recoveries of fat, protein, and solids from this study indicate that the Van-Slyke cheese yield formula can be used for calculating theoretical cheese yields from sheep milk.

Introduction

The U.S. dairy sheep industry is still in the early stages of development. Initial use of sheep milk for cheese manufacture was started in the mid 1980s. The first commercial dairy sheep flocks were established in Wisconsin starting about 15 years ago. In 1996, the University of Wisconsin-Madison accepted the mission of furthering research on dairy sheep production and management. Since then, Dr. David Thomas of the Animal Sciences Department and Yves Berger of the UW-Madison Agricultural Research Stations have been conducting extensive research on the genetics and management systems impacting sheep milk production (1, 2).

Since milk costs are high, it is necessary to review factors influencing milk composition and resulting cheese yield. Fat and casein are the two primary milk components that are recovered in the cheese making process and are directly related to cheese yield. The majority of ovine milk in the United States is produced on a seasonal basis, with lactation running from early spring until fall. Typically, with bovine milk both fat and protein tend to increase throughout the lactation that generally would result in higher cheese yield for late lactation milk (3, 4). In some previous studies on bovine milk (5, 6, 7) researchers have shown no significant increases and, in some cases, possible decreases in yield with late lactation milk. Changes in milk composition and increases in somatic cell counts (SCC) in late lactation milk have resulted in lower levels of casein and decreased cheese yield capacity (7, 8).

The composition of ovine milk during the milking season principally reflects the lactational and nutritional differences (9). In ovine milk, fat concentration increases at a disproportionate level to casein in late lactation so that the casein to fat ratio in the milk decreases throughout the lactation (10). Several reports of cheese yields for ovine milk have been published (11, 12, 13, 14); however, information on stage of lactation or season was not reported.

Currently, adequate information does not exist to predict cheese yield from ovine milk composition. The objectives of this study were to determine the influence of milking season on fat and nitrogen recoveries in hard and soft cheese, to determine actual and composition adjusted cheese yields from ovine milk, and to develop a predictive cheese yield equation using the Van Slyke model.

Discussion

Impact of Sheep Milk Composition on Cheese Yield

Since milk costs represent over 85% of the cost of producing cheese, it is critical to review factors influencing milk composition and resulting cheese yield. Fat and casein are the two primary milk components that are recovered in the cheese making process and are directly related to cheese yield. It then becomes critical for the manufacturers of sheep milk cheeses to be able to estimate cheese yields from milk of varying composition.

Currently, yield predictability relative to seasonal changes in sheep milk composition is missing. The objectives of this study were to determine the influence of milking season on fat and nitrogen recoveries in a hard pressed cheese and a soft sheep milk cheese and to determine actual and composition adjusted cheese yields from sheep milk. The hard-pressed cheese was similar to Manchego cheese produced from sheep milk in the La Mancha region in Spain. The soft cheese was similar to Camembert, which is a popular soft mold-ripened cheese.

Milk from East Friesian-crossbred, Lacaune-crossbred, and East Friesian-Lacaune-crossbred ewes was obtained at three different stages of the milking season (early, mid and late milking season) from the Agricultural Research Station of the University of Wisconsin-Madison located in Spooner, Wisconsin. Lambs were removed from the ewes 24-36 h post-partum and ewes were milked twice daily (15). Milk was collected from ewes starting at day 4 after lambing. Milk was collected daily from the flock until 909 Kg was obtained for each stage of lactation. Average composition of the pasteurized sheep milk for each portion of the 2002 milking season is shown in Table 1. Total solids, milk fat and total protein decreased as the season progressed. Casein concentration was similar in early and mid-season milk, but lower in late season milk. Early season milk contained a higher percentage of serum proteins as indicated by the lower casein to true protein ratio. The higher fat and protein in early lactation milk was also observed by McKusick et al. (15) when lambs were weaned at day 1 and ewes milked twice daily. The lower levels of fat and protein in early lactation milk reported by Pellegrini et al. (10) were from milk from ewes 48-55 days after lambing. The slightly lower fat and true protein in the August milk varied from the typical lactational trends of higher fat and protein in late lactation ovine milk reported by other workers (9, 10, 16). This most likely was due to the impact of hotter temperatures during the month of August or poorer pastures resulting in lower solids milk similar to that experienced in bovine milk (17, 18). SCC was not elevated in late lactation milk as previously reported by some researchers (19, 20). Average composition of the pasteurized sheep milk from the 2003 milking season used for the soft cheese production is shown in Table 2.

To accumulate sufficient milk for cheese making, the milk was frozen in covered and sealed polyethylene-lined 13-kg pails at –20°C and stored for less than 2 mo before it was used for cheese manufacturing. Five vats of cheese (136.2 kg of milk) were made from each stage of milking season. Milk was pasteurized at 72°C for 19 s. For the hard-pressed cheese, the milk was cooled down to the ripening temperature, 31°C and a mesophilic DVS culture (F–DVS 850, Chr. Hansen, Inc, Milwaukee, WI) was inoculated into the milk. Cheese was produced through the end of the whey drainage by the procedure as outlined in a previous study (12). For the soft cheese, the milk was cooled down to the ripening temperature, 32ºC and a mesophilic DVS culture (CH-N-19, Chr. Hansen, Inc, Milwaukee, WI) was inoculated into the milk. Cheese was produced by the American Style-Camembert procedure outlined by Kosikowski and Mistry (21).

Hard-pressed cheeses from February had higher fat and lower protein than cheeses from May or August milk as shown in Table 3. This was the result of having milk with a lower C/F ratio in the February milk. There was no significant impact of season on moisture of cheeses prior to brining. No significant differences were observed in coagulation rate or in time from set to hooping for the three sources of milk. Time from set to hooping ranged from 150 to 155 minutes. After 2 months of aging and drying, cheeses from February milk were also higher in fat and lower in protein than May and August milk. Soft cheeses from May milk had higher protein than cheeses from January or September milk but had equivalent fat and moisture contents as shown in Table 4.

Milking season had no significant effect on fat retention in either the hard pressed or the soft ripened cheeses produced from sheep milk (Table 5). The soft cheeses have slightly lower fat retention than the hard pressed cheeses. Fat retention in a hard-pressed sheep cheese is considerably lower than the 93% used for the theoretical cheese yield formula for Cheddar cheese (22). Lower fat retention with sheep milk may be due to the higher percentage of smaller fat globules in sheep milk (23) and the structure of the casein network of the curd at cutting. Higher casein milks may produce gels with larger pore size, leading to higher fat loss (24). There was no significant difference in recovery of N in the form of hard-pressed cheese during the milk season. Soft ripened cheese from May milk had a higher retention of N than either January or September milk. The soft cheeses also had a slightly lower N retention than the hard-pressed cheeses. Table 6 shows a comparison of the fat and protein recoveries from our current study with previously reported values for sheep milk cheeses. Pirisi et al. (25) reported fat retentions of 78.0 – 81.4% for an uncooked semi-hard cheese from sheep milk while Economides et al. (11) reported 86.9% fat retention in Halloumi cheese from sheep milk. Gonzalez et al. (26) reported 65% fat retention in La Serena cheese. Soft cheeses, e.g., Camembert and La Serena, showed a lower retention of protein than the lower moisture, firmer cheeses.

Predictive cheese yield formulae were also developed for each trial using the Van Slyke cheese yield equation as shown below:

$$\textit{Van Slyke Cheese Yield} = \frac{[\text{ (RFx\% Fat in Milk) + (RC x \% Casein in milk)] xRS}}{\text{(100-\% Moisture of Cheese)}}$$

$$RF = \frac{\text{(\% fat in cheese x cheese wt)}}{\text{(\% fat in milk x milk wt)}}$$

where *RF* is the fat recovered in cheese, *RC* is the casein recovered in cheese and *RS* represents the other milk solids and added salt recovered in cheese. *RF* values were determined experimentally for each cheese trial by dividing the amount of fat in milk by the amount of fat recovered in cheese (% fat in cheese x cheese weight / % fat in milk x weight of the milk). *RC* can be approximated from milk and cheese composition by dividing total cheese casein (paracasein) by total milk casein. We found that *RC* was 0.96 for early and mid-season milks and 0.94 for late-season milk. *RS* values for each cheese were calculated by substituting the *RF* and *RC* values into the following equation:

$$\text{RS} = \frac{\text{RF x \% Fat in Milk}}{\text{[(RFx \% Fat in milk) + (RC x \% Casein milk)\} x FDM}}$$

where fat in dry matter (**FDM**) was determined experimentally as follows:

$$\text{FDM} = \frac{\text{\% Fat in cheese}}{\text{100-\% moisture of cheese}} \text{ x100}$$

The fat, casein, and solids retention factors and cheese yields are shown in Tables 7 and 8. Composition adjusted cheese yields (CACY) were calculated at 39% moisture for hard-pressed cheese and 50% for the soft ripened cheese. Substantial differences in composition-adjusted % cheese yields, and small differences in % fat and % nitrogen recoveries between trials, indicate that differences in milk composition (casein and fat) was the major factor responsible for differences in cheese yield.

Table 9 lists the recommended retention factors to be used for estimation of cheese yields for hard and soft cheeses from sheep milk. Factors may have to be adjusted slightly for late lactation milk.

Conclusion

Results of this study showed that seasonal changes had a significant impact on milk composition, thereby affecting cheese yield. Cheese yields were directly related to the level of fat and casein in the initial milk. However, fat and protein recoveries in the cheese were not significantly different over the season. Results of the study showed that the Van Slyke-Price cheese yield formula could be effectively used to predict cheese yield for hard-pressed and soft cheeses made from ovine milk. The future potential for production of high quality specialty products from sheep milk is very promising. However, proper handling and storage of the milk through the manufacturing process is critical to the overall quality and yield of processed products.

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Table 1. Milk Composition - 2002.

	February milk	May milk	August milk
Total solids, %	19.28	18.81	17.29
Milk fat, %	7.58	6.74	6.59
True protein, %	5.33	5.27	5.09
Casein, %	4.34	4.33	4.25
Casein:fat ratio	.57	.65	.64
SCC/ml[1]	480,000	360,000	390,000

[1] SCC = Somatic cell count

Table 2. Milk Composition - 2003.

	January milk	May milk	September milk
Total solids, %	17.88	16.61	17.70
Milk fat, %	6.38	5.92	6.77
True protein, %	5.23	4.79	5.48
Casein, %	4.37	4.02	4.52
Casein:fat ratio	.68	.68	.67
SCC/ml[1]	310,000	400,000	470,000

[1] SCC = Somatic cell count

Table 3.

Composition of Hard Pressed Sheep Milk Cheese Before Brining and Ripening

Moisture, %	38.70	38.78	39.40
Fat, %[1]	34.46[a]	32.78[b]	32.53[b]
Protein, %[1,2]	22.63[b]	24.19[a]	23.59[a]
FDM, %[1,3]	56.22[a]	53.54[b]	53.68[b]

1 Means within the same row without a common superscript differ (*P* < 0.05).
2 Total % N X 6.31.
3 Fat in the dry matter.

Table 4. Composition of Soft Sheep Milk Cheese Before Brining and Ripening

	January milk	May milk	September milk
Moisture, %	54.72	49.95	50.82
Fat, %	24.93	27.42	26.85
Protein, %[1,2] 1	6.74[b]	20.78[a]	18.33[b]
FDM, %[3]	55.08	54.80	54.68

1 Means within the same row without a common superscript differ (*P* < 0.05).
2 Total % N X 6.31.
3 Fat in the dry matter.

Table 5
Impact of Milking Season on Fat and Nitrogen Recovery in Hard Pressed and Soft Ripened Cheese

	Early	Mid	Late
Fat recovery			
Hard Cheese	83.8	84.2	83.2
Soft Cheese	82.3	80.4	81.8
N recovery			
Hard Cheese	73.0	75.2	73.8
Soft Cheese	63.4 [b]	71.7 [a]	65.8 [b]

Table 6 Fat and Protein Recovery in Sheep Milk Cheeses

Reference	% Fat Recover	%Protein Recovery
Hard Cheese	83.2-84.2	73.0-75.3
Pirisi et al.	78.0-81.4	75.4-79.5
Soft Cheese	80.4-82.3	63.4-71.7
Gonzalez, et al..	65.0	65.0
Economides, et al.	86.9	78.6

Table 7. Cheese Yield and Retention Factors for Hard Pressed Cheeses

	Febuary Milk	May Milk	August Milk
RF Value	0.84	0.84	0.83
RS Value	1.07	1.08	1.08
RC Value	.96	.96	.96
Actual Yield %	18.45	17.29	16.78
CACY, %[1]	18.52	17.38	16.75
FDM, %	56.2	53.5	53.7

[1] CACY = Composition- adjusted cheese yield at 39% moisture

Table 8. Cheese Yield and Retention Factors for Soft Cheeses

	January Milk	May Milk	September Milk
RF Value	0.82	0.81	0.82
RS Value	1.01	1.01	1.03
RC Value	.96	.96	.94
Actual yield, %	21.08	17.35	17.35
CACY, %[1]	19.09	17.37	17.06
FDM, %	55.1	54.8	54.7

[1] CACY = Composition – adjusted cheese yield at 39% moisture.

Table 9. Recommended Retention Factors for Van Slyke Yield Formula

	Hard cheeses	Soft cheeses
RF value	0.84	0.82
RS value	1.08	1.01
RC value	.96	.96

References

Thomas, D.L., Berger, Y.M., & McKusick, B.C. Milk and lamb production of East Friesian-cross ewes in the north central United States. Pages 474-477 *in* Milking and Milk Production of Dairy Sheep and Goats – Proc. 6th Int. Symp. on the Milking of Small Ruminants, 1998, Athens, Greece. F. Barillet and N.P. Zervas, ed. EAAP Pub. No. 95. Wageningen Pers, Wageningen, the Netherlands (1999).

Thomas, D.L., Berger, Y.M., & McKusick, B.C. East Friesian germplasm: Effects on milk production, lamb growth, and lamb survival. Proc. American Soc. Anim. Sci., (1999). Available at: http://www.asas.org/jas/symposium/proceedings/0908.pdf.

Feagan, J.T. Factors affecting protein composition of milk and their significance to the dariry processing, Austr. J. Dairy Technol. 34:77-81.

Schultz, M. M., L. B. Hansen, G. R. Steuernagel, and A. L. Kuck. Variation of milk, fat, protein, and somatic cells for dairy cattle. J. Dairy Sci. 73:484-493 (1990).

Lelievre, J., O. J. Freese, and J. Gilles. Prediction of Cheddar cheese yield. N.Z. J. Dairy Sci. Technol. 18:169-172 (1983).

Ozimek, L., and J. Kennelly. The effect of seasonal and regional variation in milk composition on potential cheese yield. Pages 95-100 in Proc. of the IDF Seminar on Cheese Yield and Factors Affecting its Control, Cork, Ireland, April 1993, Int. Dairy Fed. Special Issue No. 9402, Int. Dairy Fed., Brussels, Belgium (1994).

Sapru, A., D. M. Barbano, J. J. Yun, L. R. Klei, P. A. Oltenacu, and D. K. Bandler. Cheddar cheese: influence of milking frequency and stage of lactation on composition and yield. J. Dairy Sci. 80:437-446 (1997).

Giles, J., and R.C. Lawrence. The yield of cheese. N.Z.J Dairy Sci. Technol, 20:205-214 (1985).

Barron, L.J.R., de Labastida, E.F., Perea, S., Chavarri, F., de Vega, C., Vicente, M.S., Torres, M.I., Najera, A.I., Virto, M., Santisteban, A., Perez-Elortaondo, F.J., Albisu, M., Salmeron, J., Mendia, C., Torre, P., Ibanez, F.C., & de Renobales, M. Seasonal changes in the composition of bulk raw ewe's milk used for Idiazabal cheese manufacture. Int. Dairy J. 11:771-778 (2001).

Pellegrini, O., Remeuf, F., Rivemalle, M.& Barillet, F., Renneting properties of milf from individual ewes: influence of genetic and non-genetic variables, and relationship with physcochemical characteristics. J.Dairy Res. 64:355-366 (1997).

Economides, S., Georghiades, E., & Mavrogenis, A.P. The effect of different milks on the yield and chemical composition of Halloumi cheese. Pages 2-7 in Tech. Bull., Agric. Res. Inst.-Cyprus, No. 90 (1987).

Jaeggi, J.J., Berger, Y.M., Johnson, M.E., Govindasamy-Lucey, R., McKusik, B.C., Thomas, D.L., & Wendorff, W.L. Hard ewe's milk cheese manufactured from milk of three different groups of somatic cell counts. J. Dairy Sci. 86:3082-3089 (2003).

Jordan, R. M., and W. J. Boylan. 1995. The potential for a dairy sheep industry in the Midwest. Pages 21-24 in Proc. of the 1st Great Lakes Dairy Sheep Symposium, Madison, WI, University of Wisconsin-Madison.

Wendorff, B. 2002. Milk composition and cheese yield. Pages 104-117 in Proc. of the 7th Great Lakes Dairy Sheep Symposium, Ithaca, NY.

McKusick, B.C., Berger, Y.M., & Thomas, D.L. 1999. Effects of three weaning and rearing systems on commercial milk production and lamb growth. Pages 16-31 in Proc. of the 5th Great Lakes Dairy Sheep Symp., Brattleboro, VT, Univ. of Wisconsin-Madison (1999).

Requena, R., Molina, P., Fernandez, N., Rodriguez, M., Peris, C., & Torres, A. Changes in milk and cheese composition throughout lactation in Manchego sheep. Pages 501-506 in Proc. of the 6th Inter. Symp. on the Milking of Small Ruminants, Athens, Greece. EAAP Publ. No. 95, Wageningen Pers, Wageningen, Netherlands (1999).

Barbano, D.M,, and Sherbon, J.W. Cheddar cheese yields in New York. J. Dairy Sci. 67:1873-1883 (1984).

Lawrence, R.C. Cheese yield potential of milk. Pages 109-120 in Monograph on Factors Affecting the Yield of Cheese, IDF Special Issue 9301., Int. Dairy Federation, Brussels, Belgium (1991).

Antunac, N., Mioc, B., Pavic, V., Lukac-Havranek, J., & Samazija, D. The effect of stage of lactation on milk quality and number of somatic cells in sheep milk. Milchwissenschaft 57:310-311 (2000).

Gonzalo, C. Microbiological and hygienic quality of ewe and goat milk: Somatic cells and pathogens. Pages 59-71 in Proc, of the IDF seminar on the production and utilization of ewe and goat milk, Crete (Greece). Internation Dairy Federation, Brussels, Belgium (1995).

Kosikowski, F.V., & Mistry, V.V. Chees and Fermented Milk Foods, Vol, II. Procedures and Analysis. F.V, Kosikowski, L.L.C., Westport, CT (1997).

Van Slyke, L.L., & Price, W.V. Cheese. Ridgeview Publ. Co., Atascadero, CA (1979).

Antifantakis, E.M. Coparision of the physico-chemical properties of ewe's and cow's milk. Pages 42-53 in Proc. Of the IDF seminar of the production and utilization of ewe and goat milk. IDF Bull. 202. International Dairy Federation, Brussels, Belgium (1986).

Johnson, M.E., Chen, C.M., &Jaeggi, J.J. Effect of rennet coagulation time on composition, yield and quality of reduced-fat cheddar cheese. J. Dairy Sci. 84:1027-1033 (2001).

Pirisi, A., Piredda, G., Corona, M., Pes, M., Pintus, S., & Ledda, A. Influence of somatic cell count on ewe's milk composition, cheese yield and cheese quality. Pages 47-59 in Proc. of the 6th Great Lakes Dairy Sheep Symp., Guelph, Ontario, Univ. of Wisconsin-Madison (2000).

Gonzalez, J., Mas, M., Lopes-Gallego, F., Mas-Mayoral, M., and Sonzalez-Crespo, J. Characteristics of Merino ewe milk and La Serena cheese produced on 3 typical farms. Investidacion-Agraria, -Produccion-y-Sanidad-Animales 6(2): 143-155 (1991).

SPECIALTY CHEESE CULTURE SELECTION

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Summary

Cheese culture selection is an important part of the cheese production process. Culture requirements vary depending on the type of cheese produced. Other factors that can affect this determination are the style of cheese, equipment used to process the cheese, and even packaging. While commercial culture varieties are comprised primarily of Lactococcuss and Streptococcus bacteria, other strains are also used. This discussion will involve culture selection, culture propagation, cultures and their effect on the cheese making process, as well as cultures and cheese ripening, and causes of slow starters.

In determining what type of culture should be used to produce a cheese, several factors should be considered. Among these would be temperature and tolerance: where the strains perform best, and what temperature is the maximum or minimum that they can withstand. If openings are required for gas production, for example, the necessary culture should be used. The culture must perform within the constraints of salt usage, and the effects of proteolysis and lypolysis considered.

Discussion

The primary function of a bacterial culture is to provide acid development through the fermentation process. This pathway is for lactose to be converted to glucose or galactose, and from these sugars then converted to the end product of lactic acid. In the discussion of culture selection, a grouping of cultures can be made by basic temperature requirements. These groups are called mesophilic or thermophilic with the temperature requirements for the thermophilic generally higher than mesophilic.

Each of these cultures run at different temperatures. In the case of L. acidophilus and L. bulgaricus, real growth doesn't begin until the temperature is above 95F. L. helveticus begins to show more growth at a lower temperature, while "O" type or mesophilic cultures have a flatter growth curve beginning around 77F. It is interesting to note that specific strains of culture can have slightly different growth curves. In the instance of S. thermophilus 1 vs. S. thermophilus 2, number one appears to do slightly better at a warmer temperature. Therefore, when selecting cultures for a specific type of cheese, factors such as equipment, packaging size and final product size; as well as temperature and growth curves of the specific strain of culture can also have an impact.

The taxonomy, or classification of cultures is determined by differentiation between various strains of bacteria based on several criteria. These differences help classify strains based on their specific characteristics and aid in the selection of cultures for specific cheese makes.

Graphic 1—Culture Selection-Temperature (see graph following article)

In looking at various types of cheese that can be produced, several cultures are primarily used. In the case of "dry salt" cheeses such as Cheddar, Colby, or Monterey Jack, "O" type cultures are utilized. These cultures are made up of combinations of Lactococcus lactis ssp.lactis and Lactococcus lactis ssp. cremoris. The primary end product of fermentation with these strains is lactic acid. In producing cheese varieties such as Blue, Cream or Baby Swiss, a different selection of cultures is required. These cultures are of the "D" classification. Lactococcus Lactis ssp. lactis biovar.diacetylactis is the organism used, and the end products of this fermentation are lactic acid, diacetyl, and carbon dioxide. The diacetyl flavor compound is what provides the "buttery" note associated with these cheeses, while carbon dioxide provides some of the openings. Another type of mesophilic culture is the "L" type, which is comprised of Leuconostoc mesenteroides ssp. cremoris. This culture is used in the production of cream cheese, as well as other continental cheeses, and its end products include diacetyl, ethanol, and carbon dioxide, though generally not as much CO_2 as is produced with Lactococcus lactis ssp. lactis biovar.diacetylactis.

Another difference is in what food sources the bacteria can utilize, such as lactose or citrate, as well as the previously mentioned temperature requirements.

Graphic 2-Mesophilic (see graph following article)

Graphic 3—Mesophilic Cultures (see graph following article)

In selecting cultures for mesophilic cheese type production, food sources as well as temperature are factors. While the previous graphic shows some growth at higher temperatures, the typical maximum temp for L. cremoris is 104 and L. lactis 113, with the general maximum temperature for L. diacetylactis and leuconostoc 113 and 88 respectively.

On the thermophilic side, the taxonomy also subdivides by the differentiation of bacteria shape, either coccus or rod. Streptococcus thermophilus is commonly referred to as "coccus", while Lactobacillus delbrueckii subspecies bulgaricus, and Lactobacillus helveticus are often called "rods". This is in reference to the circular shape of the thermophilus, as opposed to the elongated or rod shape of bulgaricus and helveticus. A characteristic of thermophilus is the rapid production of lactic acid, and it is used in cheese types such as mozzarella, grana varieties, and Swiss. Lactobacillus delbrueckii subspecies bulgaricus has lactic acid and acetaldehyde as its primary end products. It is similar to thermophilus type cultures in that it is also used in the production of the same types of cheeses. In fact, these can be used independently or in combination, again depending on the type and desired characteristics of the finished cheese.

Graphic 4 – Culture types: Thermophilic (see graph following article)

These cultures can also be defined by their fermentation food source, in this case lactose or galactose as well as temperature requirements. One differentiation is the ability of these cultures to ferment galactose, which can be a factor in producing cheese that is darker or "browner" than customer requirements dictate. Optimum growth ranges are similar but not identical.

As discussed earlier, various bacteria are classified into groups based on food source, temperature requirements, physical shape, and fermentation end products. Another criterion is salt, which performs many functions. Salt can slow the growth of bacteria, release water from the curd, condition the curd for pressing, enhance flavor, and discourage the growth of pathogenic and spoilage bacteria. However, identity standards and customer criteria will have an effect on the amount of salt used. In addition, the culture bacteria are affected at different rates by salt. For example, while Lactococcus can have its growth affected by 50% at salt levels of 5% (salt in moisture); salt levels of only .8 % similarly affect L. bulgaricus.

Graphic 5—Thermophilic cultures (see graph following article)

Graphic 6 – Salt Tolerance (see graph following article)

In addition to mesophilic and thermophilic cultures, other strains are used to provide cultures for specialty cheese types. For example, in the production of Swiss cheese, propionibacteria is used to produce the eyes and flavor associated with this cheese. Penicillium roqueforti is used to create cheeses such as Blue and Gorgonzola, while Brevibacteria is a culture used for the production of Limburger, Muenster, and Brick. Other cultures that can be used in the modification of flavor, or for use in other specific cheeses are Lactobacillus casei and other differentiated strains.

Graphic 7—Culture Types: Flavor and Ripening (see graph following article)

Some of these cultures can be used by themselves, but they are primarily used along with an acidifying culture to refine or develop a specific flavor. An economic consideration is the length of time required for storage of aged cheeses. The fact that specific cultures can accelerate flavor development can help reduce the time requirement of the aging process.

Cheese culture, or starter culture, has been developed and modified through the years. Originally, natural starter was used in the cheese production process. In order to obtain repeatability, when a good culture was obtained, steps were taken to insure that the starter was maintained. This could be done by adding back inoculated cheese milk or whey, or by maintaining a mother culture for repeated use. To standardize cheese production further, commercial cultures were developed either in the form of bulk starter culture or Direct Vat Culture.

The type of bacterial strains present can then refine these two styles of culture. In undefined, mixed multiple strains, there is a mix of known species, but unknown number of strains. In defined, mixed multiple strains, there is a mix of known species and strains. And in single strain cultures, there is a single strain of a known species. Commercial forms of culture can be frozen liquid (can), frozen pellets, or freeze-dried powder.

The growth of bacteria can be defined in four steps: the lag phase, log phase, stationary phase, and mortality phase.

Graphic 8—Growth Curve of Bacteria (see graph following article)

The type and environment of the starter culture will affect these phases. For example, a DVS culture will not initially acidify as quickly as bulk culture, and external ph control can assist the bacteria by keeping them in the stationary phase longer by maintaining a proper Ph. Ways to monitor the condition of a bulk culture include activity test, phage testing, and microscopic evaluation and by cell count.

Starter and the cheese process have a symbiotic relationship. Conditions in the vat affect the starter, and likewise the starter affects the finished cheese product. Amounts of starter vary by cheese variety, starter type, and the desired make time. Ripening times can vary from 30 to 75 minutes for Frozen Concentrated culture, to 10 to 30 minutes for ph controlled bulk starter. Ripening increases the level of desirable bacteria, starts acidification/lowers Ph, and controls the rate of acid production. The cooking step in cheesemaking stimulates thermophilic bacteria, and slows mesophilic growth and acidification. Washing the curd will also control acidification by affecting temperature and removing lactose. The salting step, among many functions, slows bacterial activity, though strain specific. (Graphic 6) The salted curd can then be placed in hoops, pressed/packaged while the bacteria continue to lyse and release peptidases into the cheese.

A number of cultures can be used for creating specific flavors in cheese. These cultures are often used with an acidifying culture.

Graphic 9—Cheese Ripening Cultures (see graph following article)

A ripening culture made up of lactococcus has various functions, including debittering, accelerating the ripening process, and enhancing flavor notes. The use of L. helveticus also contributes to debittering, enhancing cheese flavor, and contributing a sweet, nutty flavor. A combination of L. helveticus and L. acidophilus can be used to obtain the similar flavoring characteristics. In addition, other types of culture can be used to accelerate flavor production by enhancing cheese and farmhouse flavors.

When selecting the best culture for an application, situations can arise where the culture does not perform satisfactorily. For example, set temperature that is too high or low (outside of the cultures optimum range) will affect performance. The culture can also be affected by storage. If the culture is held outside its maximum storage time, or if the temperature of the freezer warms, cell damage can occur. Cultures for cheese production are primarily comprised of facultative anaerobes, and thus are influenced by excess agitation or air incorporation. Cultures can also be impacted by the presence of residual sanitizers, natural inhibitors, and antibiotics. Bacteriophage is also a major consideration in culture selection and performance.

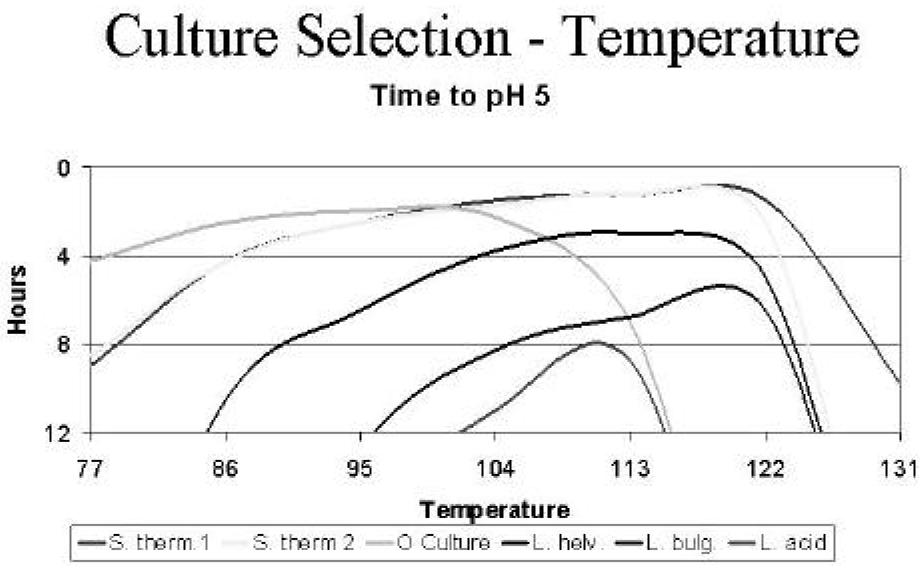
Graphic 10—Reasons for Slow Starter (see graph following paper)

One of the most common issues, especially in summer months, is the care and storage of the culture after shipment arrival. Frozen culture, that is warmed before being put away at a proper storage temperature, can sustain cell damage and affect acidification. If inhibitors have been ruled out as a source of slow growth, bacteriophage contamination may be the problem. Bacteriophage or phage means "eaters of bacteria", and are viruses that attack or lyse bacterial cells. They are the main cause of starter culture failure, and can only be controlled, as they cannot be eliminated from the environment. They can survive normal pasteurization, and have the ability to remain dormant but viable for years.

Phage can be tested or monitored through laboratory techniques that include an inhibition test or plating. Controlling phage can be accomplished by operational design, sanitation, and culture selection. Cheese vat rooms should be kept dry and maintain proper airflow. Whey/product on the floor should be minimized, and drains should be properly cleaned and sanitized. All product surfaces should also be properly cleaned and sanitized, using sanitizers such as chlorine that kill phage. Proper culture rotation assists in phage control, as well as direct inoculation methods which reduce in-plant contact time. A factor in any cheese culture selection is that some cultures are more phage resistant than others. In addition, strains can be categorized into groups that are attacked by specific phage

Conclusion

While cheese type is a primary consideration for culture selection, other factors can have an effect on what type of culture is used. Different types of cultures are available, as well as alternate styles of culture packages. Cultures are affected by conditions such as temperature or salt, and can be used to modify or accelerate flavor production. They must be given the proper food source and growth conditions to perform well in the vat and also be protected from bacteriophage. When these factors are considered, cultures can then be selected to help produce cheese of the desired quality and specification.



Graphic 1- Culture Selection- Temperature

CULTURE TYPES: Mesophilic

Taxonomy:	Produces:	Used In:
• *Lactococcus lactis* ssp. *lactis* • *Lactococcus lactis* ssp. *cremoris* • " O Culture"	▪ **Lactic Acid**	❖ Cottage Cheese ❖ Cheddar, Colby Jack ❖ Others
• *Lactococcus lactis* ssp. *lactis* biovar. *diacetylactis* • " D Culture"	▪ **Lactic Acid** ▪ **Diacetyl** ▪ **Carbon Dioxide**	❖ Blue Cheese ❖ Cream Cheese ❖ Baby Swiss
• *Leuconostoc mesenteroides* ssp. *cremoris* • " L Culture"	▪ **Diacetyl** ▪ **Carbon Dioxide**	❖ Cream Cheese ❖ Continental Varieties

Graphic 2- Cuture Types: Mesophilic

Mesophilic Cultures

	Lactococcus lactis/cremoris	*Lactococcus diacetylactis*	*Leuconostoc*
Ferment Lactose	Acid	Acid	Acid & CO_2
Ferments Citrate	Acid	Acid, CO_2, Diacetyl	Acid, CO_2, Diacetyl, Ethanol
Optimum Growth Temp.	88 – 92° F	88 – 92° F	74° F
Maximum Growth Temp.	104° F – L crem. 113° F – L lactis	113° F	88° F

Graphic 3 – Mesophilic Cultures

CULTURE TYPES: Thermophilic

Taxonomy:	**Produces:**	Used In:
• *Streptococcus thermophilus* – "Coccus"	▪ **Lactic Acid Quickly**	❖ Mozzarella ❖ Grana Types ❖ Swiss
• *Lactobacillus delbrueckii subspecies bulgaricus* – " Rod" • *Lactobacillus helveticus*	▪ **Lactic Acid** ▪ **Acetaldehyde**	❖ Mozzarella ❖ Grana Types ❖ Swiss
– "Rod"	▪ **Lactic Acid Slowly**	❖ Mozzarella ❖ Grana Types ❖ Swiss ❖ Accelerated Cheddar

Graphic 4- Culture Types: Thermophilic

Thermophilic Cultures

	Streptococcus thermophilus	*Lactobacillus bulgaricus*	*Lactobacillus helveticus*
Ferment Lactose	Acid & Galactose	Acid & Galactose	Acid
Ferment Galactose	Mostly No	No	Yes
Optimum Growth Temp.	106 - 110° F	110 - 115° F	110 - 115° F
Maximum Growth Temp.	132° F	125° F	125° F

Graphic 5- Thermophilic Cultures

Salt Tolerance

Culture Type	50 % Inhibition	100 % Inhibition
Lactococcus	5.0 - 5.5 %	> 6.0 %
S. thermophilus	1.7 – 2.5 %	> 3.0 %
L. bulgaricus	0.8 – 2.1 %	2.0 – 3.0 %
L. helveticus	3.1 – 4.0 %	4.0 – 5.0 %

All % as Salt – In - Moisture

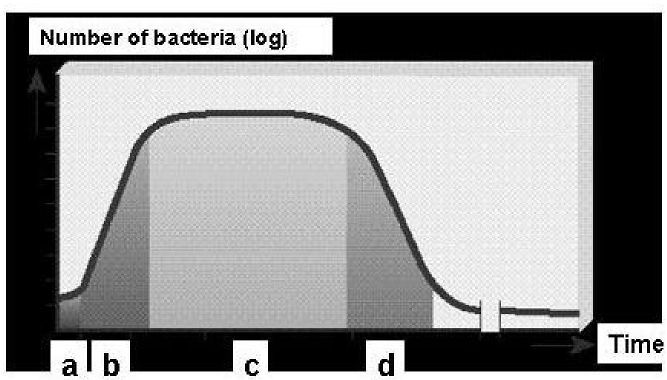
Graphic 6- Salt Tolerance

CULTURE TYPES: Flavor and Ripening

Culture	Cheese Type
Propionibacteria	Swiss
Penicillium roqueforti	Blue, Gorgonzola
Brevibacteria	Limburger, Brick, Muenster
Lactobacillus casei	Accelerated Ripening & / or Flavor Modification
Modified Strains	

Graphic 7- Culture Types: Flavor and Ripening

Growth Curve of Bacteria



- *a. Lag phase*
- *b. Log phase*
- *c. Stationary phase*
- *d. Mortality phase*

Graphic 8- Growth Cultures of Bacteria

Portfolio of Cheese Ripening Cultures

Segment	Ripening culture	Microorganisms in the culture	Cheese segments suited for the cultures	Main effect
Flavor Control™ Range	CR	*Lactococcus*	Continental Grana Emmenthal Cheddar	- Enhance flavor note - Debittering - Farmhouse flavor - Accelerated ripening
	LH	*L. helveticus*		- Enhance cheese flavor - Contribute sweet, nutty, meat like flavor - Debittering
	Emfour	*L. helveticus* + *L. acidophilus*		- Enhance cheese flavor - Contribute sweet, nutty-like flavor - Debittering
	PS	*Propionibacterium*		-Sweet, nutty flavor, CO_2 production
SWING™		Yeast PC, PR, Geo*) Brevibacterium Staphylococcus	Soft cheeses Continental cheeses	- Enhance cheese flavor in surface ripened cheese - Enhance farmhouse flavor in interior ripened cheese

Graphic 9- Portfolio of Cheese Ripening Cultures

Reasons for Slow Starters

- **Culture Abuse**
  - Set temperature (too high or too low)
  - Storage – time / temperature
  - Aeration – don't
  - Inoculation Level
  - Addition – was it added?
- **Inhibitors**
  - Antibiotics
  - Natural Inhibitors in Milk
  - Residual Sanitizers
    - Quaternary ammonia cpds. most inhibitory
- **Phage**

Graphic 10- Reasons for Slow Starters

PROCESSING OF FROZEN SHEEP MILK – CURRENT PROCEDURES AND DIFFICULTIES ENCOUNTERED

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Summary

The Old Chatham Sheepherding Company has been processing significant quantities of frozen sheep milk for eight years. Through extensive experimentation, the company has developed successful recipes, using a blend of frozen and sheep milk in both its yogurt and cheese product lines. The drawbacks of utilizing frozen milk include significant costs in freezing, storing, shipping and thawing prior to use. There are processing losses related to frozen milk, and the cause is sometimes difficult to determine. It is very important that additional research be conducted to identify quality control test methods that will show that milk has maintained a proper temperature during its life and at what age does the milk start to develop quality problems. Furthermore, better techniques need to be developed to handle the frozen milk during the thawing process. The market is developing for sheep milk cheeses and yogurts, and improving the reliability of using frozen sheep milk will enable producers at all levels to expand production and sales.

Introduction

The Old Chatham Sheepherding Company (OCSC) has been processing frozen sheep milk since 1997. Current consumption of frozen milk is approximately 250,000 lbs per year. Old Chatham Sheepherding Company also produces and processes approximately 270,000 lbs of fresh milk annually. Fresh milk production is relatively even throughout the year enabling OCSC to produce a steady supply of young sheep milk cheeses and yogurts for a national marketplace. In addition, OCSC purchases about 35,000 lbs of fresh sheep milk from a local New York state farmer during the April to August season. All frozen sheep milk purchased during the 2004 season came from members of the Wisconsin Sheep Dairy Cooperative.

Purchase Specifications

All frozen milk from Wisconsin must be produced to Wisconsin's requirements for Grade A sheep milk. OCSC is IMS (Interstate Milk Shippers) rated because of national distribution of yogurt products, resulting in the requirement for Grade A milk.

Freezing requirements – All milk will be chilled to 40 degrees F and held for a maximum of 4 days before shipment. Milk to be frozen will be placed in 5 gallon plastic dairy bags, labeled by date and producing farm. Initially, plastic pails were used, but the milk did not freeze as well and pails presented a disposal problem. Bags of milk will be frozen on open shelving in commercial style deep freezers and will be maintained at or below minus 10 degrees F until shipment.

Transportation

The frozen sheep milk is transported on shrink wrapped pallets weighing approximately 2000 lbs from individual farms to a freezer plant in Shakopee, Minn. OCSC uses this facility to store the bulk of its inventory throughout the year. OCSC attempts to maintain minimal inventory at its farm. Currently, 40 foot trailer loads of milk are transported to a freezer plant in Albany and on an as needed basis (5-6 pallets per week) are picked up and delivered to the farm by the OCSC' s refrigerated truck. Formerly, OCSC would receive the trailer load from Wisconsin directly and place the contents in a freezer unit designed to go on ships. Since this freezer has proven to be unreliable at times and milk has been lost, OCSC has added the above mentioned step. The transportation sequence adds considerable cost to the product.

Total Cost of Frozen Sheep Milk

Including all shipping and handling charges, the cost of the frozen milk in a ready to be used state (thawing included) at the creamery in Old Chatham is estimated to be $0.87 per pound. Freight, handling and storage costs, after leaving the farm, amount to approximately 26% of the total cost.

Processing

OCSC uses frozen sheep milk in producing camembert cheese, ricotta, yogurt and certain 100% sheep's milk cheeses. Through many years of experimentation, it has been determined that the maximum amount of frozen milk used in any given recipe is 65%. The balance must be fresh sheep's milk, and this is the reason that OCSC has spent considerable efforts to produce fresh milk in sizable quantities on a year round basis. If more than 65% of frozen milk is used, there may be texture problems in the yogurt, including graininess. Also, the product may have a less rich taste, it may be drier and the overall flavor may not be as developed as compared to cheese made with a combination 35% fresh and 65% frozen milk.

Prior to the thawing process it is necessary to weigh each bag of frozen sheep milk, because the weight of each bag varies significantly and to have accuracy in the sizing of a batch of milk, the volume in each bag must be known. In the future we are requesting that the bags be marked with their weight.

To melt the frozen sheep milk, OCSC uses the same vats that are used for pasteurization. The fresh milk is pumped into the vat and heated. Then the frozen milk is added slowly in chunk form. When the frozen milk is completely melted, the pasteurization process is continued to completion. Another reason to blend frozen with fresh is because using 100% frozen milk could result in the milk being burned on the sides, of the vat, as the vat heats up. It has been recommended that the melting temperature be increased to 140 degrees F, to prevent damage to the milk, and OCSC is currently running experiments to determine if there is a difference in quality.

Problems with Frozen Milk Processing

General comment – With the goal of making excellent and consistent quality sheep's milk cheese and yogurt, OCSC is placing renewed emphasis on the quality of the frozen milk. Occasionally, processing problems occur that are a mystery, and we believe that the characteristics of frozen milk handling and processing must be looked at more closely. We strongly believe that additional research on both the controls and the handling of frozen milk are necessary and examples are discussed below.

Handling and Transportation

Not only is it extremely important to freeze milk properly, but the milk must remain at minus 10 degrees F or colder until it is actually utilized. If the temperature of the milk increases to around 25 degrees F, separation will occur and the milk cannot be used for the most sensitive products such as camembert and yogurt. OCSC has some success in using milk that is showing signs of separation in ricotta processing. In the case of the OCSC, the milk is transported three times, and in each case, there is an opportunity for the milk to increase in temperature. When the milk is received, there is no way to know for certain if an unacceptable temperature variation has occurred. OCSC believes that a research project should be conducted to determine if a rise in temperature and subsequent re-freezing, at any time during the life of the milk, has a negative effect on the processability of the milk and what are the maximum allowable ranges to insure good quality milk. Possibly, the use of temperature recording chips can be a part of any experiment.

Due to the transportation distances and the number of times that a pallet of sheep milk is handled before it is utilized at OCSC, broken pallets and load shifting can occur, resulting in extra handling expense. OCSC plans to develop specifications for palletizing and shrink wrapping to minimize these handling problems.

Quality Control

To determine if separation has occurred during the life of the sheep milk, OCSC has developed a simple test where a core of milk is retrieved from a bag of milk. This sample is then placed in a small (two ounce) plastic cup and microwaved for 15 to 20 seconds. The cup is then swirled around and observed. If the milk has a tendency to separate, small chunks or sedimentation of milk will be observed on the walls of the cup. If no separation exists the walls will be smooth and only the milk residue is apparent. On occasion, this test does not give us perfect results, because the milk may be on the verge of separation failure but still pass the above test. This problem will show up as a thick residue on the bottom of the vat and soft curd, presumably from the separation of the protein and fat. If this occurs in a run of Camembert, the batch will be a total loss. In yogurt, we can usually salvage about 70% of the batch. If it occurs in a run of pure sheep’s milk, the batch can usually be saved but the yield will be lower. OCSC is currently conducting experiments to determine if PH measurement is a more accurate way to determine the quality of the frozen milk.

Age of milk

Even though more research is being conducted on the handling and processing of sheep milk, an unanswered question is how long the milk can be stored, under proper conditions, before quality degradation occurs. A concern exists at OCSC that milk stored for more than one year may result in processing difficulties. This occurs because every year the milk is produced and stored in the freezer plant between March and early September, but it may take more than one year for OCSC to utilize this milk. This fall, OCSC hopes to experiment with older milk and newer milk to determine if differences are apparent as a result of the experimentation. A positive outcome might be that a greater percentage of frozen milk could be used, in a given recipe, if the age of the milk was shorter.

Conclusion

The use of frozen sheep milk has been successful, in general, for the Old Chatham Sheepherding Company. However, greater quality control checks at every step are required so that better standards can be developed to reduce losses and improve product quality. Also, better handling and possibly new equipment needs to be developed to improve the thawing and handling procedures immediately prior to the actual use of sheep milk in production. Efforts in this area will hopefully lead to a reduction in processing costs.

MARKETING OF SHEEP MILK –
PROBLEMS FACED BY PROCESSORS

Sid Cook
Carr Valley Cheese Company, Inc.
La Valle, Wisconsin, USA

Summary

In the past five years of purchasing sheep milk there have been several issues and problems that we have faced:

1) The method of handling and transport
2) The milk volume
3) The vast variation of components seasonally and the impact on yield
4) The inventory and aging of sheep milk cheese
5) Concern of milk quality

Milk Delivery

The use of bags and pails was not effective for us. Large amounts of cream and milk stuck to the bags resulting in a 1% or less shrink. This method of transport adds both extra labor for both farm and plant as well as yield loss. For the past two seasons, we have received milk by bulk truck, and it is a vast improvement over years past, but more expensive for us.

Milk Volume

The volume per delivery, because of low per animal production with sheep, and the sizing of our vats resulted in less than batch amounts. In the first years, we would receive 1500 to 2000 pounds of milk per shipment by pails. This method was very inefficient as less than batch amounts cause moisture, texture and yield problems in the cheese as well as extra manufacturing costs.

At this time, we are receiving 8000 or more pounds per shipment by bulk truck, and this delivery system is working much better. Another related issue is seasonality of the milk; we can't purchase sheep milk year round at this time.

Cheese Yield

The yield varies greatly from spring to fall. When we start making cheese in the spring, our yield is 1.5 pounds of cheese per 10 pounds of milk, and we finish late summer and early fall with 1.6 pounds of cheese per 10 pounds of milk peaking at 1.8 pounds per 10 pounds of milk. It would be a great advantage to both producer and processor if a system was set up to pay more for high component milk. This would make both producer and processor more efficient.

Milk Quality; Aging and Inventory of Cheese

Because we make all hard and semi-hard cheese, it is necessary to age hard sheep milk cheese varieties at least six months so that sheep flavor notes are prominent. This makes it necessary to charge prices to cover the expense of the sheep milk, aging and inventory costs and money opportunity costs. We generally age our sheep milk cheeses one year and sell the cheese produced in one year in the following year. Storing the whole year of cheese until the next is expensive and capital consuming.

As a buyer of sheep milk in Wisconsin, we are required to commit and contract for sheep milk as much as three years in advance. It is difficult to forecast sales that far into the future. We are always concerned that we will have too little sheep milk, rather than too much. Our future sales depend on the quality of the milk first, then the quality of cheese-making. We have consistently won many awards with all of our cheeses including sheep and mixed milk varieties. It has not been an easy task to become a consistent sheep milk processor.

Conclusions

In conclusion, sheep milk processing has become a viable business for us over the past 5 years. We expect our demand to increase 20 to 40 percent over the next 5 years with some variation from year to year. We see a bright future with both processor and farmer working together to develop sheep milk dairying and products.

OUR FIRST BIG CHEESE SALE!!!!!

Mary Falk
Love Tree Farmstead Cheese
Grantsburg, Wisconsin, USA

Summary

I hope everyone will tolerate my little story of OUR BIG CHEESE SALE!!!! seeing as I digressed just a tad from the typical standard paper on marketing. I decided to share this story, an embarrassingly true account, feeling that the main points of marketing may just become a bit more memorable if recounted in real life format versus academia style banter. I highlighted the main points of marketing for a small farmstead cheese maker in bold type so that anyone could scan through the paper and pick out the parts that might interest him/her best. This paper by no means includes all the secrets of the trade, because there aren't any.

Being successful at marketing farmstead cheese is painfully simple: use the best ingredients, and give the best of yourself, and the cheese will basically sell itself. But it can't drive a car, so you do need to be mobile.

Our Start

The year I received my Wisconsin Cheese Makers's license, 1996, we made plans on experimenting with sheep cheese over the next couple of years while also selling sheep milk through the Wisconsin Sheep Dairy Cooperative. On a spring day in 1997, Dave came home from a Co-op board meeting, upset with the direction that the Co-op was heading in. Dave felt that we should be heading in a much different direction. He resigned that afternoon from the Board of Directors and told me that he would have our cheese room and aging cave ready in two months, and he said, "I hope that you will have cheese ready to go by then." So much for having the luxury of time for experimentation!

In June of 1997 we made our first licensed batch of cheese that we aged in our first fresh air aging cave. The cheese was made from pristine, sweet, and raw sheep milk so even though we had certified lab bacterial counts showing that our milk surpassed even the pasteurized milk standards on every batch of sheep milk in our cheese vat, the law dictated that it still had to cure in the cave for 60 days minimum. As part of my year long apprenticeship requirement for my Wisconsin Cheese Maker's license, I had attended a university short course in Madison called, "Cheesemakers' Shortcourse". Although the course didn't really teach us anything about how to actually make cheese, it was indeed thorough and detailed food science. It didn't really teach us much about the art of cheese production, but appeared to be more focused on teaching us the skill of how NOT to kill somebody. During this course of five days, we had it drilled into our heads about the potential evils that raw milk can carry with it if not properly handled or pasteurized. The Wisconsin Center for Dairy Research professors can all now peacefully retire knowing that their warnings about possible contaminations of E. coli 0157, lysteria, tuberculosis, brucellosis, staph, and many, many other potential pathogens, are all now firmly entrenched deep in the heart of my very soul.

We only made 40 wheels that first short “cheese season”, since we had agreed to **keep** our **mistakes as small and as affordable as possible**. By August, I was selling some young soft pasteurized cheese called fromage blanc. Many people are really shocked when I tell them that the Aveda Corporation was one of my very first sales, and they seem to wonder how I developed the nerve and confidence to approach Aveda in the first place. Actually, I didn’t have time to develop any confidence or guts, we were just really broke, and we needed to generate some cash. I guess that there is a lot of truth to the old adage, “Fear is a Great Motivator!“

Dave was still working part time off of the farm although the responsibilities of the cheese plant and the milking flock were making it harder and harder for him to be able to leave the farm for any length of time.

Our farm is in a relatively remote location, approx. 70 miles north and west of St Paul, MN, 85 miles south of Superior, WI and about 60 miles north of Hudson, WI. The nearest town is 8 miles to the east. If you ever thought that selling lamb in the north woods of Wisconsin was difficult, just try selling sheep cheese!

We had one local restaurant that was interested in our cheese - an exclusive lodge retreat located 14 miles northeast of us, and they were our **very first** customers. Since they were even more remote than us, they only served dinner a few days a week, so they weren’t buying more than five pounds of cheese at a time, but hey, it was a start! Plus chef “Terry” wasn’t the typical run of the mill broaster house fry cook which is what you would typically expect to find in our area. Instead, he was an import, from New Orleans, and very skilled in his art. When I delivered cheese to the Lodge, I **always allowed for lots of extra time to spend with him so I could glean every little bit of culinary gems that I could squeeze out of him.** That is also why **I never delivered the cheese when it was his busy prep time. I always asked when was a good time to stop by when he would have plenty of time to taste my new experiments**. He was honored that I respected his opinion, and I was thrilled to have access to some very, very valuable culinary advice. **Networking with the chefs** proved to be one of the **best marketing moves** that I ever made. He was a **font of information for possible pairing ideas for beverages and foods that truly set the cheese in it’s best light**. He also gave me tips on how to present the cheese on sales calls. He even gave me some of his **favorite quick appetizer recipes that I still give out to my customers when I sell my cheese today.**

After practicing my sales calls on Terry for a couple of weeks, I knew that I had to get the bustle in gear and really start to move some inventory. I reviewed the local yellow pages for possible restaurants that were located within a 50-mile radius. That’s when I noticed that Aveda Corporation had a small but exclusive restaurant located in their day spa, just 30 miles south of us. I gave them a call and set up a time when I could visit with the head chef. I carefully packed a rather charming wicker basket with loads of samples, and we sat together and tasted and sampled the cheeses for about 15 minutes. Then the chef asked if I would mind taking the time to sample some wine in order to help pick the appropriate pairing for the cheese. An hour later, I strolled out of the restaurant, trying hard to remember if I had just made a sale or not. **Thankfully I wrote down some notes during our meeting.** Evidently, after having one, or two, glasses of wine, the chef recommended that I also contact their corporate headquarters since they had a rather large restaurant on site for employees and visitors at their factory. **By taking the time to demonstrate the multiple culinary uses for our cheese and allowing time for everyone to become a little relaxed and more social, I was rewarded with the name of the head chef at the corporate headquarters and her extension number. This is the beauty of networking**! **I learned early on that if you approached a sales call with the same demeanor as the Welcome Wagon Lady, many doors just seem to fly open!**

Having a brave moment in time, I telephoned the head chef and gave her my referral from the chef at the other Aveda restaurant. I was in! She wanted to meet with me the next day! The corporate office was 60 miles south of our farm, so it was a bit of a hike, but I was on fire now!!! The meeting went well, and she began to order our cheese.

The account was small to begin with since we only had a few soft cheeses to choose from. Then the chef heard that I had made some raw milk cheese which was aging in our cave. She immediately placed an order for 100 pounds of cheese for a wedding that would take place around the same time that the first cheeses would become "legal." I thought that she was off her rocker, but I played as though it was no big deal, never telling her that I didn't have a clue as to what the cheese was going to taste like since we had never made it before! I had made a similar cheese earlier in the year from milk from our herd of goats, and it was good, but the sheep milk was a whole new ballgame!

All I knew was that I put premium, pristine clean milk into those batches of raw milk cheese, and I crossed my fingers that nature and science would take care of the rest.

The night before the wedding, I delivered the cheese to Aveda's kitchen. Since the restaurant kitchen was in a flurry, I tried my best to stay out of the way as the delivery men were running in and out, food all over the place and chefs and their assistants furiously hacking away at vegetables, fruits, and all sorts of delicious looking pastries and appetizers. Instead of feeling excited about making my first monumental BIG CHEESE SALE, I was instead feeling guilty and a bit depressed. I confessed to the chef that was managing the kitchen that night that I didn't feel right about delivering 100 lbs of cheese. I felt that the "wedding chef" had way, WAY, over estimated how much cheese she was going to need for the appetizer. We really needed the money, but **I didn't want to ruin a possible future business account by taking advantage of the chef either.**

The chef on duty just smiled and said, “Oh, 100 pounds is just the perfect number for 500 people. After all, this is a vegetarian wedding and the cave aged cheese is going to be the main course.

“Vegetarian?” I asked.

“Of course!” said the chef, “Everyone knows that Horst (the owner of Aveda) is vegetarian. He wouldn’t have anything less for his daughter on her wedding day!”

I gulped. Dave and I had tasted the cheese, and we thought that the cheese was good, but what did we know. It was the first raw milk sheep cheese that I had ever made, and for Horsts’s daughter’s wedding to boot? Good grief!!!

Two months earlier when the Aveda “wedding chef” had asked me if I could possibly provide a stellar cheese for a wedding that was in August, I had said “Sure, it will be the best!” As if I had been making cave aged cheese my whole life. What was I thinking? I had assumed that the cheese was going to be used as tasty little morsels in the appetizers. **Perhaps somewhere in my sub conscious mind I knew that if I didn’t just jump right in and get my feet wet, I never would get wet enough to learn how to swim**. Besides, I was a bona fide, card carrying licensed Wisconsin cheese maker. I knew all about pathogens and raw milk. ALL about them!! Why shouldn’t I be confident? After all I had slaved in a cheese factory for a solid year, and I now had my very own little cheese room. Life was grand! The fact that I had successfully completed a year’s apprenticeship program had helped to give me just enough courage to walk into the Aveda Corporation’s headquarters and introduce myself as a “licensed Wisconsin sheep cheese maker”. I thank the good Lord that the first batches of soft pasteurized cheese were grand too! They were an easy sell, and I was feeling very blessed for a beginning cheese maker. Ahh, but now I had risked everything by daring to feel confident, and I was sure of myself and actually expecting that my first cave aged raw milk cheeses were going to be good to the taste and healthy too.

My Catholic heritage suddenly caught up with me in one giant turn of my stomach. Time for “True Confessions“: Wisconsin law states that raw milk cheese must be aged no less than 60 days before being sold to the public. The cheese was actually aged only 58 days. When the chef told me the wedding date I did not say, “Sorry, but I cannot make this sale of cheese to you because it will be two days too young!” Instead I had dared to believe that my cheese was good enough to be released from the cave two days early. Now God was indeed going to “get” me after all!

The seminars on pathogens came flooding back and washed over me like curdled milk. When I thought the cheese was just going to sit under a slice of olive or be hidden with some pesto or disguised in a pizza tid bit, everything was O.K. But now; now the cheese was the guest of honor at the wedding dinner table, and everyone will be staring at it, and poking at it, and slicing it, and God forbid, really tasting it! I was feeling too sick and weak to grab the cheese from the chef and make a run for it. Instead I just smiled weakly as I said, “Please give my blessings to the bride and Horst”.

I quietly said a round of Hail Marys under my breath as I slowly walked out of the bustling kitchen.

The drive home from Aveda was the longest hour of my life. How was I going to explain to my loving husband that I had just set the stage to not just make a customer dissatisfied, but possibly, just possibly I was going to kill her to? And not just one person would die. Quite possibly 500 people would die; after all, the cheese was only 58 days old!!!!!

It was different when I thought that the cheese was just going to be a little dab on a cracker hidden under olives and salsa and cucumber pate. But to know that everyone was going to fill themselves up on the cheese; well that just greatly increased the overall food poisoning odds, and the scales of probability would weigh in on my judgement the next afternoon. I was more than likely going to hell.

I felt sick.

I slowly explained to Dave what happened. I described in detail the crisp vegetables and the abundance of fresh fruit, that there was no other source of protein to be seen for miles, and that it was the daughter of Aveda's owner that was getting married, not just any local schmuck. Quietly I asked him, "What was I thinking?" He just smiled and said, "The cheese will be lovely, everything will be fine." How dare he feel smug! Didn't he know that I had just quite possibly set in motion the demise of 500 people?

I hardly slept at all that night. When I did manage to fall into a light slumber, it was interrupted by nightmares of ambulance sirens screaming as they careened through town , one after another, after another, after another. Helicopters flying overhead, airlifting critically sick patients to the metro emergency food poisoning units. A wedding had become twisted into a funeral, all because of me and my 58 day old cheese.

The next day I had a difficult time focusing on any task at hand. Dave looked at me with sympathy and said,"It's all going to be just fine." I told him again about my fears and, again, he reassured me that the cheese was going to be great, and that everything was going to be fine. I felt sick again. I looked at the clock. The wedding reception was being held at 3:00 pm. It was only 12:00 pm. We still had time to **make a run for the Canadian border!**

I managed to keep myself busy for the next few hours. The hands of the clock dragged on. It was 3:30 pm. The phone rang. My stomach flopped. Dave answered it, never saying a word as he handed me the phone. I heard the voice on the other end of the line say, "Hi! Is Mary available for the phone. This is the chef from Aveda calling!" It was too late to run. They found me.

Resigned to my fate, I tried to sound polite, my voice croaking out a very small, "hello".

The chef chattered on and on about how everyone had eaten the cheese and that the kitchen had ordered just the perfect amount for the wedding. They were so very happy with all the cheese that I brought them, and they were so thrilled with my concern for their happiness; not wanting them to be overwhelmed with too much cheese…how funny, it was all gone! All eaten up!

Oh, and by the way, the crowd at the reception was wondering if the cheese maker could possibly make an appearance and take a bow, they absolutely loved the cheese! I was stunned. I tried not to sound too surprised as I thanked them for their kudos, I politely declined making an appearance.

Finally a decent movie came on the T.V., and Dave and I snuggled up on the couch, more than ready to get engrossed in the Saturday afternoon flick, only to find my mind wandering off, as I listened for the wail of ambulances in the far off distance.

We have just now completed our 8th season of making cheese here on the farm, and we still haven't made anyone sick, or killed anyone. We now direct market our cheese at the St Paul, MN Farmers market on Saturday mornings where **we visit with all of our customers, exchange recipe ideas, and sell cheese.** We sell the bulk of the cheese at the market for retail price, **limiting our wholesale accounts to just a few select restaurants and stores in Minnesota and Wisconsin.** We have found over the past 8 cheese seasons that we would rather sell direct and get more money for our cheese and have a much smaller and more manageable flock. Instead of managing over 300 ewes (not counting lambs) and selling wholesale into New York, Washington D.C., and San Francisco, **we chose to quit subsidizing the lifestyle of the wholesalers and market our cheese direct instead.** Our flock is currently at around 200 ewes, with a new goal to whittle the flock down to around 165 sheep (including ewe lambs).

Life is much more pleasant now, and Dave hasn't had to work off of the farm since 1998. Our typical cheese is aged for approximately three to four months, and our younger cheeses are still very good.

Since that tense first season of selling cheese, I have had a bit more time to study about raw milk and it's challenges; so here's a quick word about raw milk: pasteurized milk has to meet a standard that says that it shall contain no more than 20,000 bacteria count AFTER pasteurization. The typical **cow** dairy has a routine bacteria count in their bulk milk of under 10,000. Our sheep milk routinely tests at the certified lab at under 5,000.

I am sincerely hoping that over the next few years our great dairy state of Wisconsin will eventually move to science based regulations and allow us to sell young raw milk cheese if the cheese milk meets pasteurized milk standards. There is a very brisk demand for young raw milk cheeses. They not only allow for a much faster cash flow than sitting on a stockpile of cheese, but enlisting new science based standards would make the possibility of starting a farmstead

cheese operation much more attractive to a small farmer, especially one who is on a shoe string budget. Something as sensible as science based regulations could be just the solution for helping to preserve the viability of the small family farm.

OVERVIEW OF THE DAIRY SHEEP SECTOR IN CANADA AND THE UNITED STATES

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Summary

Dairy sheep production in Canada and the U.S. started about 25 years ago. The East Friesian and Lacaune are the major dairy breeds, with fewer numbers of British Milksheep. It is estimated that 1.2 to 1.8 million kg of sheep milk were produced in 2003 from approximately 10,000 to 11,000 ewes on 65 to 75 farms. Approximately 50% of dairy sheep producers process milk on their farms; primarily into specialty cheeses. A majority of the sheep milk for commercial processors is frozen on the farm and shipped frozen to the processing plant. The Dairy Sheep Association of North America was established in 2002 to foster the industry.

Introduction

Dairy sheep production is a new agricultural venture with the first flocks established in the mid-1980's, and it is in the very early stages of becoming an economically important agricultural industry. No official records are kept at the provincial/state or national level on the population of dairy sheep or their production. However, it is a fact that milk production from dairy sheep is very small relative to milk production from both dairy cows and dairy goats. The objectives of this paper are: 1) to present estimates of dairy sheep numbers and production in Canada and the U.S., and 2) to present an overview of the industry.

Breeds

The first commercial dairy sheep farms were established with non-dairy breeds of sheep because true dairy sheep were not present in North America (NA) until the early 1990's. East Friesian (EF) and Lacaune (LA) genetics for dairy production were first imported into NA by Canada in 1992 and 1996, respectively (Thomas et al., 2001). Initial research in the U.S. showed that EF-crossbred ewes produced almost twice as much milk as domestic non-dairy ewes (Thomas et al., 1999; 2000). The majority of dairy sheep farms in NA now milk crossbred ewes containing 50% or greater EF and/or LA breeding, and the proportion of dairy sheep genetics in flocks is increasing. The British Milksheep also is found on some farms, especially in Canada. There are additional dairy breeds in Europe and the Mideast that could contribute positively to the NA dairy sheep industry. However, very strict animal health regulations in both Canada and the U.S. have not allowed importation of animals, semen, or embryos of breeds other than the EF, LA and British Milksheep. Even the sample of these three breeds in NA is much smaller than desired, especially for the LA, but additional bloodlines in locations from which imports can be obtained have not been identified.

Population and Milk Production

This paper presents the results from the first effort to gather quantitative data on the dairy sheep industry in NA. A survey was developed by Alastair Mackenzie, vice-president of the Dairy Sheep Association of North America (DSANA) and a dairy sheep producer from Quebec, Canada, and administered to participants at the 9th Great Lakes Dairy Sheep Symposium in Quebec City in November 2003. The survey instrument can be found at the end of this paper. Twenty-three surveys were returned at the symposium. The University of Wisconsin-Madison sent the survey in the summer of 2004 to an additional 61 entities known or thought to be milking sheep in NA. Twenty-two additional surveys were completed and returned from this mailing (36% return rate), resulting in a total of 45 completed surveys. Eight of the returned surveys were from producers who had not milked sheep in 2002 or 2003; and two producers had milked ewes in 2002, not milked in 2003, but intended to milk again in 2004. Therefore, 35 surveys were returned from producers who had milked ewes in 2003.

In addition to the 35 farms that were confirmed to have milked ewes in 2003, an additional 37 farms were identified by members of DSANA or other survey respondents as dairy sheep producers. It was assumed that these 37 farms milked sheep in 2003. To the extent that this assumption is correct, it was estimated that 72 farms milked ewes in Canada and the U.S. in 2003. The greatest concentrations of producers are in eastern Canada (provinces of Ontario and Quebec), northeastern U.S. (states of Vermont and New York), and the Midwestern U.S. (states of Wisconsin and Minnesota). Table 1 presents the estimated number of dairy sheep producers in Canada, the eastern U.S. (U.S.-East), and the western U.S. (U.S.-West).

Average flock size in Canada and the U.S. was 146 milking ewes with little difference between the three regions (Table 1). However, there were large differences between regions in the variation in flock size. Flocks in Canada and the U.S.-East were much more variable in size than flocks in the U.S.-West as indicated by both the range and standard deviation of flock size. The median values presented in Table 1 are the flock sizes at which 1/2 of the flocks are smaller in number and 1/2 of the flocks are larger in number – it is the flock size that is in the middle of the range. In the U.S.-East, 1/2 of the flocks are smaller than 54 ewes; in Canada, 1/2 of the flocks are smaller than 100 ewes; and in the U.S.-West, 1/2 of the flocks are smaller than 145 ewes. Overall, 1/2 of the flocks in Canada and the U.S. milked less than 100 ewes in 2003.

Flock sizes are increasing in NA. Average number of ewes in flocks in NA in the year that survey respondents started, or expected to start, to milk (average start year is1999, range from 1991 to 2004) was 77 milking ewes. This increased to 140 ewes in 2002, 146 ewes in 2003, and was expected to increase to 177 ewes in 2004.

Milk production per ewe in flocks of the survey respondents in the three regions is presented in Table 2. Large differences were reported among regions: 212 kg/ewe in the U.S.-East, 168 kg/ewe in Canada, and 140 kg/ewe in the U.S.-West. Production per ewe was much more variable among flocks in the U.S.-East and Canada than among flocks in the U.S.-West. The median milk production among all flocks was 146 kg milk/ewe, and the average production was 174 kg/ewe.

Table 3 presents an estimate of the total number of ewes milked and the total amount of sheep milk produced in Canada and the U.S. in 2003. Each of the 40 flocks that did not respond to the survey were estimated to have the same average number of ewes (146.3) and average milk production per ewe (173.5 kg) as the respondent flocks for a total estimated milk production of each non-respondent flock of 25,383 kg. With this assumption, it was estimated that 10,648 ewes in Canada and the U.S. produced 1,847,228 kg of milk in 2003.

There is no way to assess the accuracy of these estimates, but I think they may be somewhat of an overestimate of production. For example, 57% of the 23 producers in the U.S.-West are members of the Wisconsin Sheep Dairy Cooperative (WSDC), and this cooperative marketed about 204,000 kg of milk in 2003, which is only 37% of the total estimated milk production of the region. If the remaining 43% of the producers produced the same amount of milk per flock as the members of the WSDC, they would have produced approximately 154,000 kg of milk for an estimated total of 358,000 kg for the US-West region compared to the estimate of 548,048 kg presented in Table 3 - 190,000 kg less than estimated in Table 3.

The number of producers in Ontario in 2003 may be a significant overestimate. Larry Kupecz (2004), President of the Ontario Dairy Sheep Association, in an address given on March 5, 2004, said that there were an estimated 40 dairy sheep farmers in Ontario, but only 5 to 6 were currently milking due to marketing difficulties with the milk. He indicated that approximately 250,000 liters (kg) of sheep milk was produced annually. Interestingly, six Ontario producers responded to our survey and estimated that they produced a total of 245,000 kg of milk – almost exactly the estimate given by Larry Kupecz. From the list of producers I was provided, the estimated number of producers in Ontario was 17 (Table 1). If the 11 additional producers were not milking, this would decrease the estimated milk production for Ontario (and Canada) by approximately 280,000 kg.

Just rectifying the apparent WSDC and Ontario discrepancies in milk production indicated in the above paragraphs with the estimates in Table 3 would decrease total milk production from 1,847,228 kg to 1,377,228 kg. Of course there also may be some additional farms milking sheep that have not been indicated to us, or the non-respondent farms on our list may have production greater than average production of the respondents, which would result in the values in Table 3 being an underestimate of milk production. It may be safe to estimate milk production in 2003 somewhere between 1.2 and 1.8 million kg; the midpoint of this range being 1.5 million kg.

Management Systems

Types of sheep management and milking systems are quite variable between flocks. Some flocks receive only pasture during the grazing season, others are grazed on pasture but supplemented with concentrates, and still others are fed harvested roughage and concentrates in confinement. It was very common to start milking ewes after weaning the lambs at 30 to 60 days postpartum (DY30 system) in the early 1990's. Some flocks still delay milking until after the weaning of lambs, but there are an increasing number of producers who milk the ewes from shortly after parturition. Ewes may be milked only once per day during very early lactation while the lambs are nursing and then switched to twice-per-day milking after the lambs are weaned at 30 days of age (MIX system), or ewes may be milked twice-per-day from shortly after parturition with the lambs reared on milk replacer (DY1 system). Research in the U.S. has shown that the MIX system has the greatest net returns (McKusick et al., 2001), if milk is sold on weight or volume. However, milk from MIX ewes during the 30 days when they are nursing their lambs has a significantly lower fat percentage than milk from DY1 or DY30 ewes, and would receive a penalty in price if the milk is sold on the basis of fat content.

Almost all farms utilize machine milking. Milking systems vary from elevated platforms with cascading yoke stanchions and milking into buckets to double-24 milking parlors with a pit for the milkers and several milking units attached to a pipeline to a carousel milking system.

Milk Quality

Minimum standards for milk hygiene are enforced by provincial/state and national governments and generally follow the guidelines established for cow milk. The Grade "A" Pasteurized Milk Ordinance (PMO) in the U.S. requires milk at the farm to have a bacterial count of not more than 100,000/ml of milk and a somatic cell count of not more than 750,000/ml of milk (USDHHS, 2002). Unlike goat milk that has a naturally high somatic cell count, sheep milk produced under sanitary conditions should not have difficulty in meeting these minimum standards. Measures of milk composition and quality from 355,000 liters of sheep milk marketed cooperatively in the U.S. in 2002 and 2003 were 453,000 somatic cells/ml, 41,000 bacteria/ml, 6.2% fat, 4.9% protein, and 17.1% total solids.

Milk Marketing and Transportation

Marketing of milk is the biggest concern for a person considering entry into dairy sheep production. The problem generally is not a lack of demand for sheep milk in NA, but instead the production of small amounts of sheep milk on individual farms that are great distances from a milk processor willing to process sheep milk. One solution to this problem is for dairy sheep producers to pool their milk and ship larger quantities of milk periodically to processors. Two sheep milk marketing cooperatives (Ewenity Dairy Cooperative in Ontario, Canada - http://www.sheepmilk.com/odsa and The Wisconsin Sheep Dairy Cooperative (WSDC) in Wisconsin, USA - http://www.sheepmilk.biz/)

collect milk from their members and market it to processors. Both cooperatives also have increasing amounts of their milk custom-made into cheese and market the cheese. This adds value to the producers' milk and results in greater net returns.

Cooperatives require a tremendous commitment of volunteer time on the part of members, especially in the initial years of the organization. Large amounts of time devoted to the formation and development of these new sheep milk cooperatives occurred at the same time that producers were establishing their own dairy sheep farms. Producers generally were short of both time and money. However, time and effort spent in the development of these cooperatives is paying dividends. For example, the WSDC has seen almost a 10-fold increase in the amount of milk sold in 2003 compared to 1996 when the cooperative was established (Figure 1), and there is a continued good demand for their milk. Without the WSDC, the dairy sheep industry in the upper Midwest of the U.S. would not be as viable as it is today.

Most milk sold from farms is first frozen in plastic bags in large commercial freezers on the farm. Bags of frozen milk are accumulated on the farm and shipped in large quantities in refrigerated trucks to processors. Research has shown that this milk can be frozen at -27ºC for at least 12 months with no detrimental effects on processing characteristics (Wendorff, 2001). The ability to freeze milk and make a quality product from the thawed milk has allowed small producers who are great distances from processors to enter the industry. A small producer can accumulate the milk produced from his flock in his freezer during the milking season and send his milk individually or along with that of other producers to a processor in a large shipment once or a few times per year. Since sheep are seasonal breeders and most sheep milk is produced seasonally during the spring and summer, a frozen stockpile of milk allows processors access to milk year round.

Frozen milk, however, is not without its problems. The costs of installation and maintenance of a large commercial freezer and of freezer bags are large expenses for dairy sheep producers. Processors experience increased costs in storage of frozen milk and in the amount of time required to thaw milk prior to processing compared to fluid milk (Clark, 2004; Cook, 2004). Some frozen-thawed milk separates and has a large amount of sediment that doesn't allow its use in all sheep milk products. Failure to keep the milk cold enough while frozen on the farm or partial thawing during transportation to the processor may be the cause (Clark, 2004). In areas where there is a large concentration of dairy sheep farms in close proximity to a major processor, it is now possible to accumulate large quantities of fresh milk during peak lactation periods to send directly to processors in bulk tank trucks without freezing. This is greatly preferred by processors (Cook, 2004). As the industry grows and more milk is available, fluid shipments of milk will increase. However, there will still be a need for some frozen milk to sustain processors during times of the year when sheep milk is not produced.

The few sheep milk processors in NA appear to be pleased to have sheep milk available, and most have increased the amount of sheep milk they process each year as the supply slowly increases. The largest commercial sheep milk processor in NA produces 115,000 kg of cheese and 4500 kg of yoghurt per year. The champion specialty cheese over 725 cow, goat, and sheep milk cheeses entered in a 2004 annual competition organized by the American Cheese Society was a sheep milk cheese. The maker of this champion cheese runs a commercial processing plant and purchases sheep milk from a cooperative of producers. Several other NA sheep milk cheeses have received major honors at national and international cheese competitions in the last few years.

Farmer's that sell milk to processors generally receive within the range of $1.30 to $1.65 per kg. The vast majority of the milk is sold by weight with no premiums or discounts for milk composition or quality. It is envisioned that value-based pricing of sheep milk will become a reality in the future as the supply of milk increases. Of course, milk cannot be sold if it does not meet the minimum quality standards for bacterial and somatic cell counts established by the government.

Farms that are not a member of a marketing cooperative sell their milk direct to a commercial processor, process their milk into cheese or other products on their farm, have their milk custom processed into cheese by a commercial processor, or sell their milk to another dairy sheep producer who processes their own milk plus purchased milk.

Farmstead Cheese Production

Due to a lack of local commercial processing factories for sheep milk in most areas of NA, many sheep producers make cheese on their farm in small batches and market it directly to individuals, food stores, and restaurants. Of the 42 respondents to the survey who had milked sheep between 2000 and 2003, 21 (50%) processed milk on their farm (Table 4) into value-added products. The percentage of producers in the U.S.-East and Canada that processed milk on their farm (71 and 56%, respectively) was much higher than the percentage that processed milk on their farm in the U.S.-West (10%). This may be due to the fact that the WSDC was formed in 1995, so producers in this region have had a marketing outlet for fluid milk for over 8 years. In other regions of NA, there were no other options except to process the milk they produced. Also, eastern Canada and the northeast U.S. may have had more of a tradition of producing farmstead cheeses than the U.S.-West region. Wisconsin requires all cheese makers to be licensed, and passing an examination and a one-year apprenticeship are required to obtain a license. These requirements do not encourage producers to become farmstead cheese makers.

Of the 21 farms processing milk, 14 (67%) of them were purchasing additional milk from other producers and creating a market for milk in their area (Table 4). Of the 21 producers not processing milk on their farm, a majority (57%) wished to process milk in the future. However, there were large differences among regions in the desire to enter into processing of milk. Seventy-five % of the non-processing farms in Canada and the U.S.-East wished to process in the future, whereas only 33% of the non-processing farms in the U.S.-West wished to process in the future (Table 4). This again seems to indicate the satisfaction U.S.-West producers have with their milk marketing alternatives, and, perhaps, the lack of good outlets for sheep milk in Canada and the U.S.-East at the present time. However, farmstead processing of milk is an important characteristic of the NA sheep dairy industry because 33 of 42 survey respondents (79%) either are processing milk now or wish to process milk in the future. And we must always remember that it is the growing demand by NA consumers for specialty, artisan, or farmstead cheeses that is responsible for the existence and future growth of the dairy sheep industry in NA.

Eleven of the 21 farmstead processors responded with estimates of their annual production (Table 5). Ten farms produced 136,347 kg of cheese, 5 farms produced 18,737 kg of yoghurt, 1 farm produced 3,500 kg of ice cream, and 3 farms produced 6,637 soaps and lotions. Variability of production among farms was large.

Genetic Improvement Programs

There are no regional, national, or international genetic improvement programs for dairy sheep traits in NA. Annual increases over time in production that have been noted in most flocks have been a result of improved management and the increase in the percentage of dairy breeding in the ewe flock. However, as the industry matures, there will be a desperate need for proven sires with high estimates of genetic value for economically important traits. Implementation of a national or NA genetic improvement program is a challenge for the industry.

Support Organizations

The only dairy sheep research flock in NA was established in 1995 at the University of Wisconsin-Madison, Spooner Agricultural Research Station. This flock is composed of approximately 350 milking ewes of various percentages and combinations of EF and LA breeding. The University of Vermont has an Extension Small Ruminant Dairy Specialist to work with producers of dairy goats and sheep in Vermont. In addition, the University of Guelph, Ontario; Cornell University, New York; University of Vermont, and the University of Wisconsin-Madison have research and/or extension programs in sheep milk processing and/or dairy sheep production.

Regional or national organizations include:

1. Ewenity Dairy Cooperative, Ontario (http://www.sheepmilk.com/odsa) – a milk marketing cooperative for producers in southern Ontario
2. The Ontario Dairy Sheep Association, Ontario (http://www.sheepmilk.com/odsa) – an organization of producers and processors to foster the industry in Ontario
3. Wisconsin Sheep Dairy Cooperative, Wisconsin (http://www.sheepmilk.biz/) – a milk marketing cooperative for producers in the upper Midwest U.S.
4. Several state, provincial, and national specialty cheese organizations (Examples: Vermont Cheese Council - http://www.vtcheese.com, American Cheese Society – http://www.cheesesociety.org/, La Société des Fromages

du Québec, Québec) - embrace and encourage specialty cheese production from sheep milk

The Dairy Sheep Association of North America (DSANA) was established in 2002 to foster the industry in all of NA (http://www.dsana.org/index.php). A quarterly newsletter is published by DSANA, and the association has taken over the organization of the annual Great Lakes Dairy Sheep Symposium. The University of Wisconsin-Madison and the Wisconsin Sheep Breeders Cooperative started this symposium in 1995. The symposium now rotates each year among sites in Wisconsin, northeastern U.S., and eastern Canada. Symposium sites in 2002, 2003, and 2004 have been in Ithaca, New York; Quebec City, Quebec; and Hudson, Wisconsin, respectively. Speakers consist of NA scientists, producers, and processors as well as international experts. The proceedings produced from these symposia contain the most up-to-date information available to the NA dairy sheep industry. Past proceedings can be viewed at: http://www.uwex.edu/ces/animalscience/sheep/.

Table 1. Estimated number of dairy sheep producers in Canada and the U.S. and milking ewes per flock in 2003.

Region	State / Prov.	Estimated no. producers	Survey Respondents No.	%	Total Milking Ewes	Milking ewes per flock no. Ave.	Median	Range	S.D.[1]
Canda	AB	1	0	0					
	BC	2	2	100					
	ON	17	6	35					
	QC	8	7	88					
	All	**28**	**15**	**54**	**2268**	**151.2**	**100**	**10-800**	**187**
US-East	ME	2	2	100					
	NJ	1	1	100					
	NY	5	3	60					
	PA	1	0	0					
	SC	1	1	100					
	VA	1	1	100					
	VT	10	4	40					
	All	**21**	**12**	**47**	**1657**	**138.1**	**54**	**5-850**	**236**
US-West	CA	1	0	0					
	CO	1	0	0					
	IA	1	0	0					
	MN	3	1	33					
	MO	2	0	0					
	NE	1	1	100					
	WI	14	6	43					
	All	**23**	**8**	**35**	**1195**	**149.4**	**145**	**80-305**	**74**
Canada + US		**72**	**35**	**49**	**5120**	**146.3**	**100**	**5-850**	**183**

[1] S.D. = standard Deviation, a measure of variability in flock size.

Table 2. Milk production per ewe in 2003 in flocks of survey respondents

Region	Flocks, no.	Total. Milk, kg	Total ewes, no.	Milk per ewe, kg. Average	Median	Range	S.D.[1]
Canda	15	381,843	2268	168.4	150	12-472	105
US-East	9	282,674	1332	212.2	142	5-600	178
US-West	8	167,216	1195	139.9	94	54-222	70
All	32	834,388	4795	173.5	146	5-600	121

[1] S.D. = standard deviation, a measure of variability in flock milk production per ewe

Table 3. Estimated number of ewes milked and milk production in Canada and the U.S. in 2003

Region	Survey respondent	Flocks, No.	Total Milking ewes, no.	Total Milk
Canda	Yes	15	2268	381,843
	No[1]	13	1902	329,997
	All	**28**	**4170**	**711,840**
US-East	Yes	9	1332	282,674
	No[1]	12	1756	304,666
	All	**21**	**3088**	**587,340**
US-West	Yes	8	1198	167,216
	No[1]	15	2195	380,832
	All	**23**	**3390**	**548,048**
Canada + US	**All**	**72**	**10,648**	**1,847,228**

[1] Flocks in all regions that did not respond to the survey were assumed to have the same average number of milking ewes per flock (146.3) and milk production pre ewe (173.5 kg) as the average of all flocks responding to the survey.

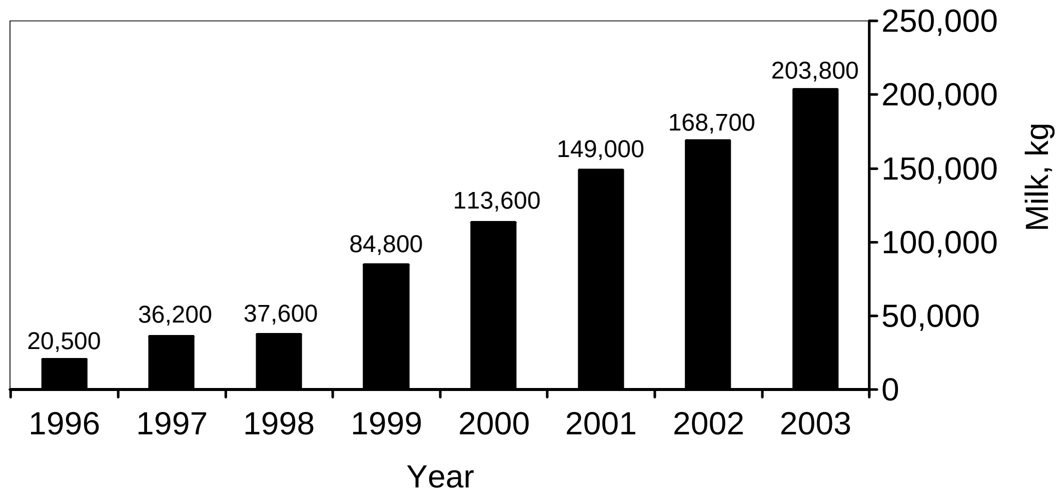
Table 4. Proportion of dairy sheep producers responding to the 2003-04 survey that process milk on their farm, purchase milk from other producers for processing, or wish to start processing milk

Region	Process milk on the farm, no. (%)		Process milk on the farm and purchase milk from others, no. (%)		Do not now process milk on the farm, but wish to in the future, no. (%)	
	Yes	No	Yes	No	Yes	No
Canada	10 (56%)	8 (44%)	5 (50%)	5 (50%)	6 (75%)	2 (25%)
US-East	10 (71%)	4 (29%)	2 (20%)	8 (80%)	3 (75%)	1 (25%)
US- West	1 (10%)	9 (90%)	0 (0%)	1(100 %)	3 (33%)	6 (67%)
All	21 (50 %)	21 (50%)	7 (33%)	14 (67%)	12 (57%)	9 (43%)

Table 5. Farmstead production of value-added sheep milk products from respondents to the 2003-04 survey

Product	No. of Farms	Annual production/ farm, kg			
		Total	Average	Median	Range
Cheese	10	136,347	13,635	2,500	100-133,636
Yogurt	5	18,737	3,747	4,545	68-7,500
Ice Cream	1	3,500	-	-	-
Soap/ Lotions	3	6,637	2,212	26	14-6,597

Figure 1. Milk Sales by the Wisconsin Sheep Dairy Cooperative



References

Clark, J.T. 2004. Processing of frozen milk – Current procedures and difficulties encountered. In: Proceedings of the 10th Great Lakes Dairy Sheep Symposium. University of Wisconsin-Madison, Dept. of Anim. Sci. (In Press). Available: http://www.uwex.edu/ces/animalscience/sheep/.

Cook, S. 2004. Marketing of sheep milk – Problems faced by processors. In: Proceedings of the 10th Great Lakes Dairy Sheep Symposium. University of Wisconsin-Madison, Dept. of Anim. Sci. (In Press). Available: http://www.uwex.edu/ces/animalscience/sheep/.

FAO. 2004. Agricultural Data. FAOSTAT. Agricultural Production. Available: http://apps.fao.org/faostat/collections?version=ext&hasbulk=0&subset=agriculture. Accessed September 30, 2004.

Kupecz, L. 2004. State of the industry. Available: http://www.sheepmilk.com/odsa/industry_state.html. Accessed March 17, 2004.

McKusick, B.C., Thomas, D.L., and Berger, Y.M. 2001. Effects of weaning systems on commercial milk production and lamb growth of East Friesian dairy sheep. J. Dairy Sci. 84:1660-1668.

Thomas, D.L., Berger, Y.M., and McKusick, B.C. 1999. Milk and lamb production of East Friesian-cross ewes in the north central United States. In: F. Barillet and N. P. Zervas (Ed.) Milking and Milk Production of Dairy Sheep and Goats - Proc. 6th Int. Symp. on the Milking of Small Ruminants. EAAP Pub. No. 95. Wageningen Pers, Wageningen, the Netherlands. 474-477.

Thomas, D.L., Berger, Y.M., and McKusick, B.C. 2000. East Friesian germplasm: Effects on milk production, lamb growth, and lamb survival. Proc. American Soc. Anim. Sci., 1999. Available: http://www.asas.org/jas/symposium/proceedings/0908.pdf.

Thomas, D.L., Berger, Y.M., McKusick, B.C., Gottfredson, R.G. and Zelinsky, R. 2001. Comparison of East Friesian and Lacaune breeding for dairy sheep production systems. In: Proceedings of the 7th Great Lakes Dairy Sheep Symposium. University of Wisconsin-Madison, Dept. of Anim. Sci. 44-51. Available: http://www.uwex.edu/ces/animalscience/sheep/.

USDHHS, U.S. Dept. of Health and Human Services. 2002. Grade “A” Pasteurized Milk Ordinance, 2001 Revision. Available: http://www.cfsan.fda.gov/~ear/pmo01toc.html.

Wendorff, W.L. 2001. Freezing qualities of raw ovine milk for further processing. J. Dairy Sci. (E. Suppl.):E74-E78.

North American Dairy Sheep Industry Survey
Dairy Sheep Association of North America and
Department of Animal Sciences, Cooperative Extension
University of Wisconsin-Madison

1) Name / Nom: ____________________________________

2) State/Province État/Province? ___________________

3) How many animals did you milk, and approximately what was your total milk production in either **pounds** ☐ **or litres** ☐ (please tick appropriate box) in the following years.

Combien de brebis avez-vous trait, et approximativement quelle était votre production totale annuelle en **livres** • **ou litres** • (s.v.p. cocher la bonne case)

2002 (milking animals / brebis traites)_______________.Production ______________?

2003 (milking animals / brebis traites)_______________.Production ______________?

Projection for / pour:

2004 (milking animals / brebis traites)_______________.Production ______________?

4) What breeds of sheep or percentages of breeds is your flock made up of?

De quelle race ou pourcentage de race se compose votre troupeau?

____

5) What year did you start milking sheep, and how many animals were milked in that year?

En quelle année avez-vous commencé à traire des brebis et combien de brebis avez-vous trait cette année-là?

____

6) Do you add value to your own milk / transformez-vous votre lait?

☐Yes / oui ☐No / non

7) If you answered No to Question 6, would you like to add value to your milk? Si vous avez répondu NON à la question No.6, aimeriez-vous transformer vore lait?☐Yes/oui ☐No/Non

8) If you answered Yes to Question 6, do you also buy milk from other producers/co-ops? Si vous avez répondu OUI à la question No.6, est-ce que vous achetez du lait d'une coopérative ou d'autres producteurs

☐Yes / oui ☐No / Non

Sample

9) What type of products do you sell, and in what approximate quantities ?
Quels types de produits vendez-vous, et en quelle quantité approximative?

☐Milk / lait ______________Litres/lbs/livres   ☐Cheese / fromage ______Kg/lbs/livres

☐Yogurt _____________kg/lbs/livres   ☐Soap / savons _________kg /lbs/livres

10) Do you direct market your products yourself or use a cooperative, or other?
Est-ce que vous faite la mise en marché de votre lait vous-même, par une coopérative, ou autre?

☐Yourself / vous-même   ☐Other / autre   ☐Cooperative / coopérative

11) If you sell milk, approx. how much as a percentage was frozen in 2003?
____________%

Si vous vendez votre lait, quelle quantité , en pourcentage, l'a été sous forme congelée
________%

12) Do you know of any other dairy sheep farmers that are not known in the industry in your area?
Connaissez-vous d'autres producteurs de lait de brebis qui ne sont pas répertoriés dans votre région?

If Yes, please give their name and address, if known (or at least the town, state/province). Si OUI, s.v.p donnez leur nom et adresse, si connue (ou au moins le village, état/province, pays).

13) Do you have any other comments?Avez-vous d'autres commentaires?

PLEASE MAIL OR FAX THIS FORM TO DAVE THOMAS AT:

Dave Thomas
University of Wisconsin-Madison
1675 Observatory Dr.
Madison, WI 53706
USA

FAX : 1-608-262-5157
Email: dlthomas@wisc.edu

Thank you for your contribution. This will help the progress in our industry. Merci pour votre collaboration, ce sondage servira à faire avancer le développement de notre industrie.

HASKINS FARM TOUR

Paul and Sally Haskins
Swedish Mission Farm
River Falls, Wisconsin, USA

Swedish Mission Farm is located just west of River Falls, Wisconsin and is approximately one-half mile from the University of Wisconsin-River Falls, Mann Valley Farm. Our farm has been in the Haskins family since 1961 and is named after the Swedish Mission that existed near the site in the early 1800's. The farm comprises two adjacent farms and is a partnership between Paul & Sally Haskins and Paul's sister, Gina Haskins. We are currently farming about 100 owned and rented acres. All family members are employed off the farm although Paul does not work summers as a teacher.

Our facilities include a 45' by 60' dairy barn that houses the parlor and milk room, a 30' by 120' open-sided barn for sheep housing and a 50' by 70' barn for horses, rams and lambs. The parlor is a double 12 high-line with a pit and six DeLaval milking units and cascading yoke headgates. Milk is stored in a 300 gallon bulk tank and a 9' by 16' walk-in freezer. Parlor throughput averages about 80-90 ewes per hour in the early season, going all the way up to 120 ewes per hour later in the summer.

We will milk about 170 ewes in 2005 including East Friesian, Suffolk, Icelandic, Laucaune and crosses of the four breeds. The breeding program is designed to produce a hybrid ewe that milks well and produces high quality market lambs when bred to a terminal sire. With 2005 being only our third season of milking, we have not yet completed the transition to milking all dairy ewes. Our milking season will run from early April until September. This insures that most milk is from ewes grazing rotationally on one of our multiple pastures. The pastures range from cool season grass pasture to stands of pure alfalfa and Kura clover. The goal of our pasture system is to make the ewes nutrition relatively stable from early spring all the way through September, thus increasing milk yield over a grass pasture system alone.

Our management practices and philosophy are best described as relatively high input. Our goal is to provide an environment where the ewes are fed well and are comfortable year around, with absolute minimal stress. The ewes are fed alfalfa haylage and barley over the winter. We try to grow all our own feed to reduce costs. The ewes are then transitioned to pasture and fed an energy supplement while milking. Although we are not organic, our ewes and lambs are never fed hormones or antibiotics of any kind. Lambs are weaned 24-48 hours after birth and fed milk replacer or left with the ewe for 30 days depending on the age and breed of the ewe.

Additional farm operations include raising pasture poultry, a small number of beef steers and pigs, and horses for pleasure riding. Additional farm income is derived through custom baling work and hay/straw sales. Swedish Mission Farm runs smoothly year around due to our highly skilled and enthusiastic labor force consisting of our three boys: Paul-age 10, Max-age 7, and Jackson-age 4, and our Border Collie, Rex. We are planning to employ labor in the spring to take care of lambs and assist with milking.

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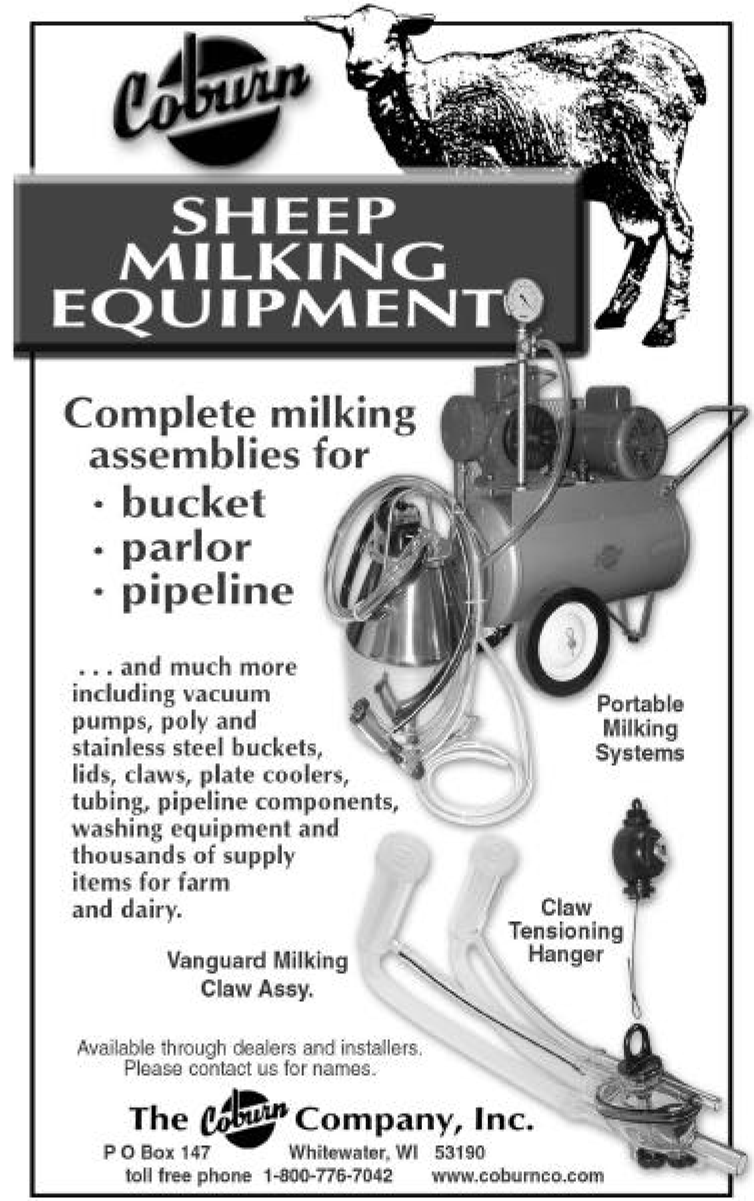
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