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

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Abstract

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

Introduction

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

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

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

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

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

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

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

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

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

Materials and Methods

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

1. *Udder circumference (ucirc):* a scrotal circumference tape was placed around the widest portion of the udder.
2. *Udder width (uwid):* a large caliper was used to measure the distance between the widest lateral points of the udder.
3. *Udder length (uleng):* a large caliper was used to measure the distance between the most cranial and caudal points of udder attachment at the intramammary groove.

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

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

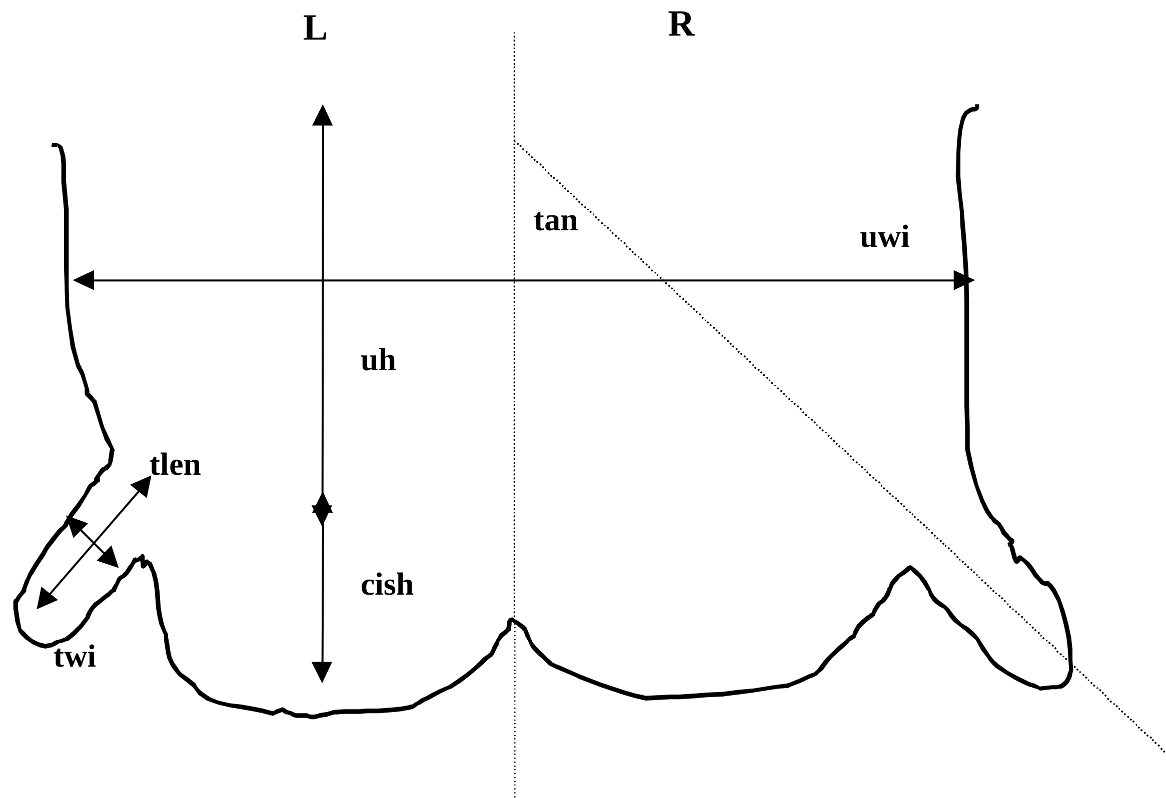

Figure 1. Caudal schematic view of a ewe udder demonstrating anatomical and morphologic measurements taken. Udder height (uht), udder width (uwid), cistern height (cisht), teat angle (tang), teat length (tleng), and teat width (twid).

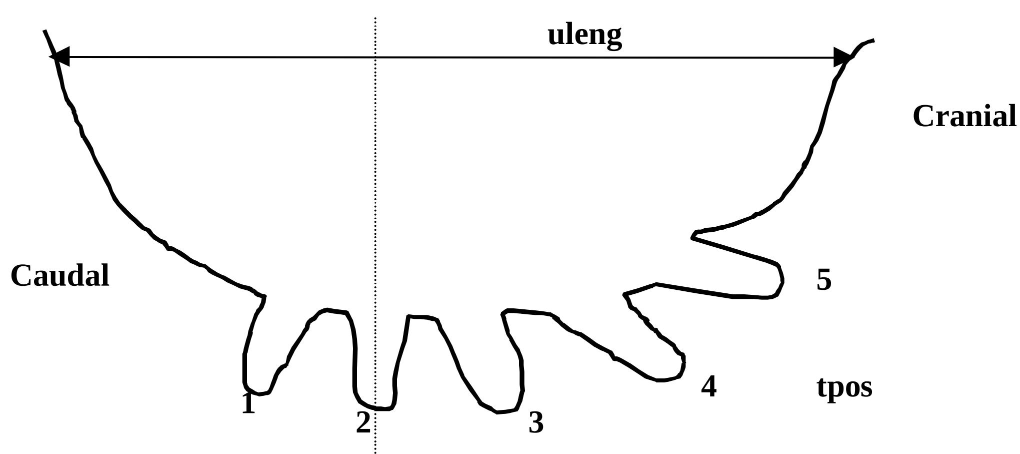

Figure 2. Lateral schematic view of a ewe udder demonstrating anatomical and morphologic measurements taken. Udder length (uleng) and teat position score (tpos).

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

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

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

The dependent variables, Y, in the models were:

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

Main effects accounted for in the models included:

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

Regressors (covariates) in the models were:

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

Results and Discussion

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

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

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

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

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

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

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

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

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

*** $P < .01$, ** $P < .05$, * $P < .10$

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