Parameters of Test Day Milk Yield and Milk Components for Dairy Ewes

J. A. FUERTES, C. GONZALO,[1] J. A. CARRIEDO, and F. SAN PRIMITIVO
Departamento de Producción Animal,
Facultad de Veterinaria, Universidad de León,
24071-León, Spain

ABSTRACT

A total of 3119 test day records for milk yield, somatic cell count (SCC), and contents of fat, protein, casein, serum protein, lactose, and total solids were obtained weekly from 155 lactations of Churra ewes during both the suckling and milking periods. All of the variables were significantly affected by stage of lactation, number of live lambs weaned, age at parity, and parity number within age. The lactation curves for SCC and for percentages of protein, casein, fat, and total solids were related inversely to the lactation curves for milk yield and lactose percentage. The SCC curve reached its lowest point at wk 5, which coincided with the maximum milk yield. At wk 3, lactose content reached its peak, and contents of fat, protein, casein, and total solids reached their lowest points.

After weaning, monthly within-lactation correlations of the variables were simulated; values were 0.584 for yield, 0.468 for SCC, 0.371 for casein percentage, 0.360 for total solids percentage, 0.350 for protein percentage, 0.342 for fat percentage, 0.270 for lactose percentage, and 0.030 for serum protein percentage. Simplified procedures based on only one milking (a.m. or p.m.) could be effective in the testing programs for milk yield and SCC, thus, reducing the economic costs of milk recordings in mammary health and breeding programs.
(**Key words**: ewe, test day milk, somatic cell count, milk components)

Abbreviation key: **WLC** = within-lactation correlation.

INTRODUCTION

Ovine milk is very important in Mediterranean countries, some of which have well-established milk recording schemes. Normal husbandry in these countries traditionally includes a lamb suckling period of approximately 1 mo and a milking period that begins after lambs are weaned. The development of breeding programs that are primarily based on milk yield from ewes during the milking stage has led to a substantial increase in total milk yield, to an increase in milk yield during the suckling period, and, consequently, to an increase in the milking of ewes during such period (1).

Ewe milk is a product that is high in fat and protein and is mainly used in commercial or artisanal quality cheeses and yogurts. As a result, testing programs for breeding and mammary health should also consider milk composition and hygiene, as is done for dairy cows. Milk fat and total solids contents have traditionally been the most commonly considered composition variables of milk from dairy ewes. However, the factors of variation in the contents of milk protein and protein fractions, such as casein percentage or serum protein percentage are little known at present. The SCC of milk is a good indicator of the existence of subclinical mastitis (12), and SCC are beginning to be used in mastitis control programs for ewes. Nevertheless, little information is available about the effects of ewe environment on SCC or about the relationships between SCC and yield or composition of milk of dairy ewes (14). Lactose percentage is one variable that is directly associated with yield and is inversely related to SCC in cows (21, 33), but little is known about such variation in sheep (39).

Lactation curves for milk yield and milk components, and the effect of such factors as age, parity number, and number of lambs born or weaned are of interest for dairy ewe testing programs (14). Establishing lactation curves can be of interest to the study of the accuracy of the milk traits and lactational measures obtained from test day records.

The cost of monthly recordings of two daily milkings is too high for sheep compared with individual outputs (2); therefore, simplified procedures based on monthly recordings of only one daily milking (a.m. or p.m.) are of particular interest. Consequently, a more extensive knowledge of within-lactation correlations

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[1]Corresponding author.

(**WLC**) of yield, SCC, milk composition for a.m., p.m., and daily milkings is necessary.

The first objective of this paper was to study the lactation curves of the milk, SCC, fat percentage, protein percentage, casein percentage, serum protein percentage, lactose percentage, and total solids percentage of ovine milk during the suckling and milking periods. A second objective was to analyze the main variation factors (lactation week, age at parity, parity number within age, and number of live weaned lambs) of the previous variables. Finally, a third objective was to estimate the monthly WLC of test day milk yield and milk components for a.m., p.m., and daily milkings during the exclusive milking period with a view to their possible inclusion in the testing programs for ovine milk.

MATERIALS AND METHODS

From January 1995 to December 1996, a total of 3119 test day observations for milk yield, SCC, and contents of fat, protein, casein, serum protein, lactose, and total solids were obtained weekly from 155 lactations of 74 Churra ewes belonging to the flock of the University of León, Spain. The mean number of test days per lactation was 20.1, and each ewe averaged 2.1 lactations.

During the suckling period (34.2 ± 0.60 d postpartum), the lambs stayed continuously with the ewes except for the milk recording days. This recording was carried out beginning at the 2nd wk postpartum; prior to each milking, the lambs were separated from their mothers for 16 and 8 h before the corresponding a.m. (0900 h) and p.m. (1700 h) milkings, respectively, to provide the appropriate period for milk secretion. Milkings were recorded on consecutive days to avoid an excessive period of inanition for lambs, which could later affect mammary health. Before separation from the lambs, the ewes were milked to remove residual milk. This method was similar to that used after weaning and permitted the composition and yield of the milk in the suckling period to be known. After weaning, the ewes were milked twice a day at 0900 and 1700 h. Testing was carried out one day a week on both milkings. On test days, a 100-ml sample of milk was taken for the analysis of each milking, both in pre- and postweaning periods. Ewes were always machine-milked.

Contents of fat, protein, lactose, and total solids were determined by routine laboratory procedures using the automated infrared method (Milko-Scan 255; A/S N Foss Electric, Hillerød, Denmark). The SCC was determined with a Fossomatic 90 (Foss Electric) within 72 h of collection, using the previously described method (13). Serum protein content (noncasein nitrogen content × 6.38) was measured by a method of the International Dairy Federation (19), which was modified for use with ovine milk. This modification consisted of increasing the acetic acid concentration to 20% in order to reach the isoelectric point of the caseins in ovine milk. The percentage of protein in serum was determined by use of the Milko-Scan after the calibration of a specific channel for the usual concentration ranges of this protein fraction. The casein percentage was obtained by subtracting the serum protein from total protein content.

Ewes from the University of León flock were permanently housed with similar environmental, handling, and feeding conditions throughout the experiment; for this reason, neither birth month nor season factors were included in the statistical analysis.

The statistical study was carried out following two mathematical models, a mixed model and a fixed model. The mixed model was

$$Y_{ijklm} = \mu + L_i + W_j + A_k + P_{l(k)} + N_m + e_{ijklm} \qquad [1]$$

where Y_{ijklm} = test day measurement (milk, log SCC, fat percentage, protein percentage, casein percentage, serum protein percentage, lactose percentage, and total solids percentage) for a particular lactation L_i of a ewe of lambing age A_k at parity P_l within A_k, during postpartum week W_j, and with m number lambs weaned (N_m). Lactation was the only random effect, with 155 levels. The week, age, parity within age, and number of lambs weaned were fixed effects.

This mixed model was based on that applied by Stanton et al. (36) for estimating lactation curves of dairy cows for milk, fat, and protein. This model presents greater validity when used to study lactation curves with a high number of test day for lactation and could be considered a good approximation to more complex mathematical models. The lactation random effect explains more variation in test day yield than does any other factor.

The effect of test day week was divided into 21 postpartum intervals: 3 in the suckling period and 18 in the postweaning period.

The effect of age was represented by five annual classes: 1.5 (between 1 and 2 yr old), 2.5 (between 2 and 3 yr), 3.5 (between 3 and 4 yr), 4.5 (between 4 and 5 yr), and 5.5 (≥5 yr). The number of age classes was small so that the effect of the parity number within each age class could be studied (8). The parity subclasses were as follows: first and second parities within the age class 2.5 yr; first, second, and third parities within 3.5 yr; second, third, and fourth parities for 4.5 yr; and third, fourth, fifth, and sixth for 5.5 yr. The ewes in the 1.5-yr age class were all first parity.

The effect of number of live lambs weaned was divided into four levels according to whether 0, 1, 2, or 3 lambs were weaned.

This mixed model was used for the postpartum study of the lactation curves and the fixed environmental effects, based on data with 3119 test day records, 21 postpartum wk, and 155 lactations. The mixed model was also used for estimation of weekly WLC in the postweaning period because regulations for milk recording in dairy sheep are only concerned with such a period (18). This latter study was carried out using a data file of 2703 test day records, 18 postweaning wk, and 155 lactations.

The WLC was defined as the ratio of lactation variance to the sum of the residual and lactation variances (36). The WLC, as estimated by REML, as well as the corresponding standard errors, were obtained by the average information REML procedure using the programs of Gilmour et al. (10). The WLC of weekly test day was estimated in connection with the experimental design in which yields were collected weekly. However, because official milk testing programs for ewes are carried out monthly (18), approximate estimates of WLC were also made monthly, simulating four data files, each from 155 lactations, with monthly records based on total data. Approximate monthly WLC was obtained as the mean of the WLC of these four data files corresponding to a total of 2396 test day records. For each of these four data files, the first test day was simulated to have been carried out in the 1st, 2nd, 3rd, or 4th wk, respectively. Then, starting from each of these weeks, monthly records within one lactation of one ewe were taken.

For the study of the lactation curves and the fixed factors from the mixed model, the random effect of lactation was associated with a particular variance component (36) using the maximum likelihood option with the absorption of random effect as described in Harvey's LSML76 program (17). This procedure provides a good approximation of the convergence of the maximum likelihood iteration (32).

The second mathematical model used in the study was the model for fixed effects:

$$Y_{ijklm} = \mu + W_j + A_k + P_{l(k)} + N_m + e_{ijklm} \quad [2]$$

where the fixed effects were the same as in the previous model. However, in Model 2, only the data file that corresponded to the postweaning period (18 wk) was used because official recordings are carried out only during this period (18). Based on this second model, we estimated the residual correlation coefficients, adjusted for the fixed factors of the model, among the 8 variables that were considered in the study. Analyses were carried out using Harvey's LSML76 programs (17).

RESULTS AND DISCUSSION

The means for milk yield, fat percentage, protein percentage, casein percentage, serum protein percentage, lactose percentage, and total solids percentage (Table 1) are within the range of estimates that have been recorded for other dairy sheep breeds in Mediterranean countries (20). The arithmetic mean for SCC (229×10^3 cells/ml) was much lower than that recorded in other flocks of the same breed without a mastitis control program (14). Teat dip after milking, selective dry therapy, and culling of ewes with chronic mastitis were routinely applied in the flock used in our study, which would explain the low prevalence of infection of half-udders (below 10%), and, as a result, mean SCC values below the discrimination threshold for subclinical mastitis in dairy ewes (11, 12).

The lactation stage (postpartum week), parity age, number of live lambs weaned, and parity number within age contributed significantly to variation among variables.

The weekly means of the variables studied over a lactation are shown in Figures 1, 2, and 3. These lactation curves are similar to those for dairy cows (29, 34, 40) and those described for yield, fat percentage, and protein percentage for other breeds of sheep (4, 28). These results also reflect the effect ($P <$ 0.001) of the milking period on SCC of ovine milk (14, 25).

The lactation curves for SCC and percentages of protein, casein, fat, and total solids were related inversely to the lactation curves for milk yield and lactose content. The SCC curve reached its lowest

TABLE 1. Arithmetic means and standard errors of the test day variables of milk composition and yield for all of the lactation.

Variable	$\overline{X}$	SE
Milk yield, ml/d	1008	8.41
Log SCC	4.95	0.01
Fat, %	6.54	0.04
Protein, %	5.70	0.02
Casein, %	4.32	0.02
Serum protein, %	1.38	0.00
Lactose, %	5.35	0.01
Total solids, %	18.57	0.05

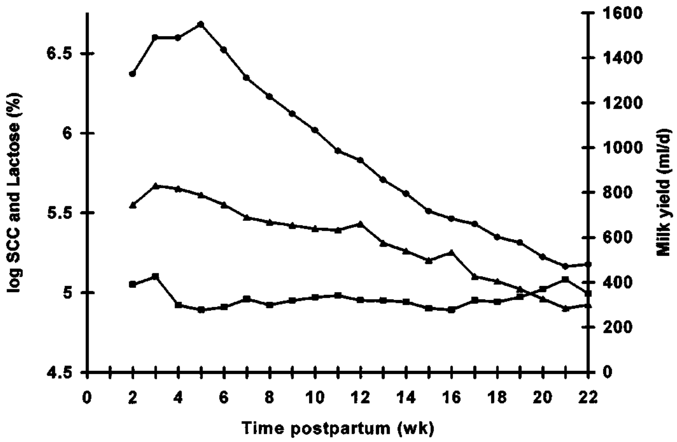

Figure 1. Weekly milk yield (SEM: 26.7; ●), SCC (SEM: 0.03; ■), and lactose (SEM: 0.03; ▲) contents throughout lactation.

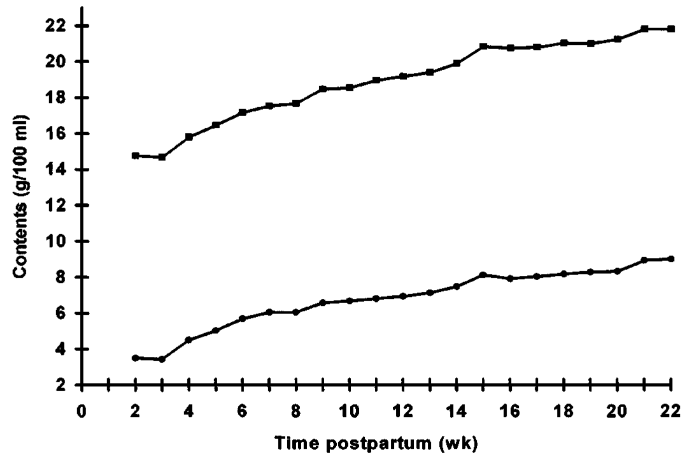

Figure 3. Weekly fat (SEM: 0.10; ●) and total solids (SEM: 0.13; ■) contents throughout lactation.

point at wk 5, which coincided with the maximum milk yield. Lactose percentage reached its peak at 3 wk, and fat, protein, casein, and total solids reached their lowest points at 3 wk. Other researchers (9, 26, 28) also recorded the minimum values for fat percentage, protein percentage, and total solids percentage and maximums for yield and lactose percentage between the 2nd and 5th wk postpartum in other dairy sheep breeds, in agreement with our results. Although the variation in SCC during lactation was highly significant ($P < 0.001$), the difference between the geometric means at the 5th wk and the end of lactation was 30×10^3 cells/ml. This difference between the extreme values of SCC was much less than that recorded for other flocks with high infection prevalences (12, 15) and thus could be attributed to a cellular concentration effect in decreasing milk quantities rather than an important worsening in the state of health of the udders throughout lactation.

The large volumes of milk obtained during the suckling period had very low contents of milk fat and protein. Conversely, milk yield was almost three times lower during the last lactation month, but milk fat and protein contents were 2.3 and 1.5 times higher, respectively, than those during the suckling period. Therefore, the decline in yield throughout lactation was more pronounced than the corresponding increases in fat and protein percentages. The ratio of casein content (×100) to total protein content attained its minimum value (72.1%) during the 5th wk postpartum, which coincided with the peak in milk yield. This ratio increased progressively throughout lactation until the maximum value (78.1%) was reached during the last week of lactation. As with

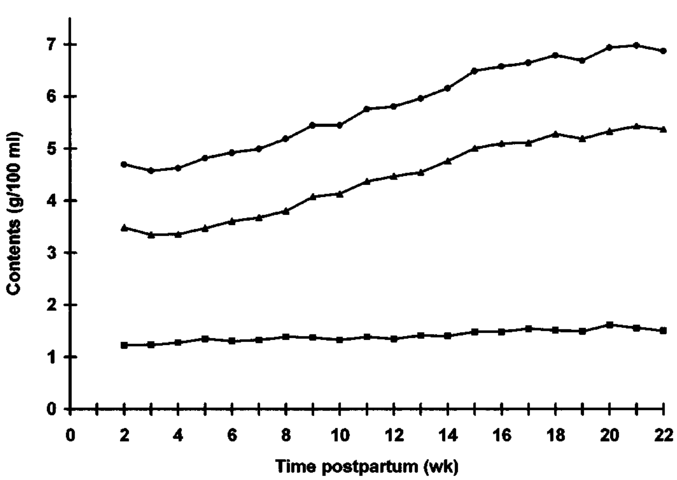

Figure 2. Weekly protein (SEM: 0.06; ●), casein (SEM: 0.05; ▲), and serum protein (SEM: 0.02; ■) contents during lactation.

TABLE 2. Least squares means of test day variables by the number of weaned lambs.

	Lambs weaned			
Variable	0	1	2	3
Milk yield, ml/d	754[d]	957[c]	1044[b]	1128[a]
Log SCC	5.09[a]	4.92[b]	4.94[b]	4.90[b]
Fat, %	7.20[a]	6.78[b]	6.59[c]	6.75[bc]
Protein, %	5.87[a]	5.73[b]	5.85[a]	5.83[a]
Casein, %	4.45[a]	4.34[b]	4.46[a]	4.42[a]
Serum protein, %	1.42	1.38	1.39	1.41
Lactose, %	5.38[a]	5.36[a]	5.28[b]	5.23[b]
Total solids, %	19.46[a]	18.86[b]	18.73[c]	18.81[c]
Test days, no.	136	1941	919	123

[a,b,c,d]Means in a row with no common superscript letters differ ($P < 0.05$).

TABLE 3. Least squares means of test day variables by parity age of ewes.

	Parity age				
Variable	1.5 yr	2.5 yr	3.5 yr	4.5 yr	>5 yr
Milk yield, ml/d	943[b]	1048[a]	1041[a]	944[b]	878[c]
Log SCC	5.02[a]	5.02[a]	4.97[ab]	4.86[c]	4.94[b]
Fat, %	6.15[d]	6.18[d]	6.67[c]	7.37[b]	7.78[a]
Protein, %	5.68[c]	5.65[c]	5.69[c]	5.95[b]	6.14[a]
Casein, %	4.30[c]	4.26[c]	4.31[c]	4.54[b]	4.69[a]
Serum protein, %	1.37[b]	1.39[b]	1.39[b]	1.41[b]	1.45[a]
Lactose, %	5.39[a]	5.40[a]	5.33[b]	5.22[c]	5.24[c]
Total solids, %	18.22[d]	18.23[d]	18.70[c]	19.53[b]	20.16[a]
Test days, no.	462	931	806	602	318

[a,b,c,d]Means in a row with no common superscript letters differ ($P < 0.05$).

other ruminant species (21, 31), the ratio of casein content to serum protein content was high; the minimum value of 2.6 occurred during the 5th wk, and the maximum value of 3.6 occurred in the 22nd wk postpartum. These progressive enrichments in caseins and fat in the milk throughout lactation are of great interest, given the existing relationship between the concentration of these components, the rennet clotting time, and the coagulum strength (30, 37).

Lactation curves can be used to study the accuracy of estimation methods for lactation yield and composition. We have already carried out this application in a recent study on estimation errors in milk yield from different test day methods (7). Lactation curves can also be used to obtain lactational measures of milk composition adjusting test day for lactation stage. Such measures are the most frequently used for SCC in breeding programs (34, 38).

The effect of number of live lambs weaned was highly significant ($P < 0.001$) for milk yield, SCC, fat percentage, protein percentage, casein percentage, lactose percentage, and total solids percentage (Table 2). This effect was not significant ($P > 0.05$) for serum protein percentage. Milk yield increased 9.1 and 17.9% for the ewes that weaned 2 and 3 lambs, respectively, compared with those that weaned only 1. These results concurred with those obtained by other researchers (3, 8, 14); milk yield was higher after weaning for ewes that had twin lambs than for ewes that had given birth to singletons. However, the yield differences recorded by us were higher than those from other studies because we also included the suckling period in the study. The ewes that did not wean live lambs had the lowest milk yield and the highest values for SCC, fat percentage, protein percentage, lactose percentage, and total solids percentage in the milk, probably from a concentration effect. However, in flocks with poor hygiene conditions, some researchers (14, 16) have found that udder health deteriorated for ewes that suckled two lambs instead of one. This result seems to indicate that the effect of number of lambs weaned on milk SCC would be different according to the health condition of the flock. Thus, lambs would have a deleterious effect on the mammary health of infected ewes, and the effect of dilution derived from a higher yield would explain the decrease in SCC in healthy ewes giving birth to multiple lambs.

Parity age was highly significant ($P < 0.001$) for all variables (Table 3). The highest yields were for ewes aged 2.5 yr. The highest values for fat, protein, casein, serum protein, and total solids contents were obtained from the oldest ewes, coinciding with

TABLE 4. Phenotypic (above the diagonal) and residual (below the diagonal) correlations between test day variables.

	Milk yield	Log SCC	Fat	Protein	Casein	Serum protein	Lactose	Total solids
Milk yield		–0.10	–0.61	–0.65	–0.65	–0.38	0.48	–0.64
Log SCC	–0.10		0.01	0.09	0.05	0.21	–0.29	–0.01
Fat	–0.27	0.01		0.76	0.77	0.42	–0.52	0.96
Protein	–0.31	0.06	0.57		0.99	0.67	–0.61	0.88
Casein	–0.28	0.02	0.58	0.97		0.47	–0.58	0.89
Serum protein	–0.25	0.16	0.31	0.66	0.54		–0.49	0.51
Lactose	0.23	–0.29	–0.29	–0.37	–0.34	–0.33		–0.46
Total solids	–0.29	–0.03	0.93	0.79	0.79	0.45	–0.17	

TABLE 5. Least squares means (±SE) of test day variables studied after weaning by a.m., p.m., and daily milkings.

Variable	a.m.		p.m.		Daily	
	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE
Milk yield, ml/d	599	7.82	332	4.67	931	11.30
Log SCC	4.84	0.02	5.07	0.02	4.96	0.02
Fat, %	6.22	0.05	8.58	0.06	7.06	0.05
Protein, %	5.99	0.03	5.81	0.03	5.93	0.03
Casein, %	4.55	0.03	4.42	0.03	4.51	0.02
Serum protein, %	1.44	0.01	1.38	0.01	1.42	0.01
Lactose, %	5.31	0.02	5.22	0.02	5.28	0.01
Total solids, %	18.52	0.07	20.61	0.07	19.26	0.06

smaller yields and lower lactose concentrations (Table 3).

Parity number within each age also contributed significantly to the variation of most variables. Thus, within each age, as parity number increased, milk yield decreased ($P < 0.001$), but SCC and the composition variables increased ($P < 0.05$). The smaller variation corresponded to the serum protein percentage fraction for which no significant ($P > 0.05$) effect was found for ewes that were 2.5 or 4.5 yr old.

The residual correlations (Table 4) between yield and composition variables were negative and high (r = –0.25 to –0.31), except for lactose percentage, which had a positive correlation with yield (r = 0.23), as expected. The strong correlations between contents of protein and fat (r = 0.57) and casein and fat (r = 0.58) in ovine milk are also common in the milk of other ungulates (21). The correlations between lactose percentage and the three protein variables (r = –0.33 to –0.37) were negative and could be explained, as the synthesis of lactose in the Golgi vesicles is the primary regulator of the amount of water that dilutes the protein to its final concentration (21). A significant, negative correlation was found between SCC and milk yield (r = –0.10) and between SCC and lactose content (r = –0.29), thus pointing out that high SCC in milk, as a result of subclinical mastitis, is associated with low milk yield and low lactose content, as has been described for dairy cows (29, 33). The significant correlations between SCC and serum protein percentage (r = 0.16) and between SCC and total protein percentage (r = 0.06) were similar to those recorded by others for dairy ewes (30).

Table 5 shows the mean values for a.m., p.m., and daily milkings for the variables studied after weaning. Differences can be explained by the unequal interval between milkings: 8 h between the a.m. and p.m. milkings and 16 h between p.m. and a.m. milkings. Milk yield was 64.3 and 35.7% of total daily yield for a.m. and p.m. milkings, respectively, for these intervals, which meant greater SCC, fat, and total solids contents in the p.m. milking. The protein variables varied less between milkings; these variations were always below 2 g/L. These results are consistent with the ratios of a.m. to p.m. milkings recorded for dairy ewes by others (1, 6) for milk yield, fat percentage, protein percentage, and total solids percentage using different intervals between milkings. The arithmetic means of SCC for the day and for the a.m. and p.m. milkings were 247, 223, and 300×10^3 cells/ml, respectively; similar variations between milkings have been recorded for SCC of Lacaune ewes (25).

TABLE 6. Postweaning weekly within-lactation correlations (±SE) of the yield, SCC, and milk composition variables for a.m., p.m., and daily milkings.

Variable	a.m.		p.m.		Daily	
	r	SE	r	SE	r	SE
Milk yield, ml/d	0.597	0.021	0.487	0.023	0.644	0.020
Log SCC	0.427	0.023	0.498	0.023	0.507	0.023
Fat, %	0.375	0.020	0.383	0.020	0.450	0.023
Protein, %	0.404	0.021	0.345	0.022	0.419	0.021
Casein, %	0.439	0.023	0.354	0.022	0.460	0.023
Serum protein, %	0.083	0.011	0.119	0.014	0.118	0.014
Lactose, %	0.293	0.020	0.128	0.014	0.322	0.021
Total solids, %	0.389	0.022	0.380	0.022	0.450	0.023

TABLE 7. Postweaning monthly within-lactation correlations (±SE) of yield, SCC, and milk composition for a.m., p.m., and daily milkings.

Variable	a.m.		p.m.		Daily	
	r	SE	r	SE	r	SE
Milk yield, ml/d	0.537	0.021	0.430	0.020	0.584	0.020
Log SCC	0.383	0.023	0.471	0.023	0.468	0.022
Fat, %	0.250	0.023	0.286	0.023	0.342	0.022
Protein, %	0.295	0.023	0.234	0.023	0.350	0.023
Casein, %	0.350	0.023	0.270	0.023	0.371	0.023
Serum protein, %	0.028	0.019	0.042	0.019	0.030	0.019
Lactose, %	0.280	0.023	0.064	0.039	0.270	0.023
Total solids, %	0.300	0.023	0.280	0.023	0.360	0.023

The strong variations between milkings in milk yield, SCC, and contents of fat and total solids require daily adjustments of these variables to estimate lactation yields in DHIA records systems when they are measured for one monthly milking. For dairy cows, the correction factors are known for estimation of daily milk yield or daily fat percentage, based on a.m. or p.m. milkings for different intervals between milkings (5, 27, 35), but little information exists for dairy ewes (7).

Table 6 shows weekly WLC of random effects corresponding to weekly test day values for milk yield and components for a.m., p.m., and daily milkings. These weekly WLC were in accordance with monthly WLC (Table 7), although slightly higher, as expected.

As Table 7 shows, monthly WLC of milk yield and SCC were similar to those for dairy cows, but the values for fat and protein contents were lower than those for cows (22, 23, 27). An important variation in the test day record for fat content of the milk can be a result of characteristics that are specific to milk ejection in ewes under conditions of machine milking (24). Monthly WLC of the daily test records were always similar to or greater than WLC when only one milking, a.m. or p.m., was sampled. This result is consistent with those obtained in other studies (5, 27, 35). Monthly WLC for milk yield for a.m. milkings were slightly higher than those for the p.m. milkings. Nevertheless, those variables that are most influenced by a concentration effect, such as fat percentage and SCC, had somewhat higher WLC for the p.m. milkings than for the a.m. milkings (Table 7). Very low WLC of lactose percentage for p.m. milkings are difficult to explain and will require further study because this trait has not been well studied in dairy ewes. Monthly WLC of casein percentage for a.m. and p.m. milkings were slightly higher than those of total protein percentage, but WLC for serum protein percentage were very low, probably because this later variable shows important random variations throughout lactation. The heterogeneity of this fraction, which includes a high number of proteins with different biological significance, as well as a small amount of NPN (21, 30), could explain this very low WLC.

Concentrations of fat, protein, casein, serum protein, and total solids showed relatively low monthly WLC for daily milk and even lower WLC for simplified procedures based on only one milking (a.m. or p.m.). In this respect, simplified test day procedures could lessen the accuracy of testing programs for milk composition. However, milk yield and SCC showed, in all cases, appreciably higher monthly WLC.

CONCLUSIONS

Lactation stage had a highly significant effect on variation in milk yield and milk composition. Lactation curves can be used to obtain lactational measures of yield and composition from monthly test day adjusted for stage of lactation. Milk yield and SCC had moderately high monthly WLC for all daily, a.m., and p.m. milkings after weaning. As a result, the use of simplified procedures based on the monthly sampling of only one milking for both variables could be employed in order to decrease the high economic cost of the testing programs for mammary health and breeding in dairy ewes.

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REFERENCES

1 Barillet, F. 1989. Expression de la production laitière à la traite des brebis Lacaune en système allaitement × traite mécanique. Proc. 4th Int. Symp. Machine Milking Small Ruminants. Int. Committee, Tel-Aviv, Israel:463–495.

2 Barillet, F., N. Boichard, D. Bouloc, D. Gabiña, A. Piacere, M. Roussely, and J. P. Sigwald. 1987. Accuracy and development of simplified sampling procedures with regard to the aim of milk recording in dairy sheep and goats. Page 1014 *in* Proc. 38th Annu. Mtg. Eur. Assoc. Anim. Prod., Sheep and Goat Commission, Lisbon, Portugal.

3 Carriedo, J. A., R. Diez, and F. S. Primitivo. 1982. Genetic study of some factors influencing the milk production of dairy ewes. II: Environmental factors. Proc. 2nd World Congr. Genet. Appl. Livest. Prod., Madrid, Spain VIII:753–757.

4 Carriedo, J. A., and F. S. Primitivo. 1979. Curvas de lactación en rebaños de ovejas Churras. An. Fac. Vet. León 25:99–106.

5 DeLorenzo, M. A., and G. R. Wiggans. 1986. Factors for estimating daily yields of milk, fat, and protein from a single milking for herds milked twice a day. J. Dairy Sci. 69:2386–2394.

6 Fadel, I., J. B. Owen, R. Kassen, and H. Juha. 1989. A note on the milk composition of Awassi ewes. Anim. Prod. 48:606–610.

7 Fuertes, J. A., C. Gonzalo, L. F. de la Fuente, and F. S. Primitivo. 1997. Errores de estimación de la producción láctea a partir de diferentes métodos de control lechero en el ganado ovino. Inf. Tec. Econ. Agrar. 18:242–244.

8 Gabiña, D., F. Arrese, J. Arranz, and I. Beltrán. 1993. Average milk yields and environmental on Latxa sheep. J. Dairy Sci. 76: 1191–1198.

9 Gallego, L., P. Molina, A. Torres, and G. Caja. 1983. Evolución de la cantidad y composición de la leche de ovejas de raza Manchega desde el parto. Pages 285–297 *in* Proc. 3rd Symp. Int. Ordeño Mecánico Pequeños Rumiantes. Com. Español, Valladolid, Spain.

10 Gilmour, A. R., R. Thompson, and B. R. Cullis. 1995. Average information REML: an efficient algorithm for variance parameter estimation in linear mixed models. Biometrics 51: 1440–1450.

11 González-Rodriguez, M. C., C. Gonzalo, F. S. Primitivo, and P. Cármenes. 1995. Relationship between somatic cell count and intramammary infection of the half udder in dairy ewes. J. Dairy Sci. 78:2753–2759.

12 Gonzalo, C. 1996. Microbiological and hygienic quality of ewe and goat milk: somatic cells and pathogens. Pages 59–71 *in* Production and Utilization of Ewe and Goat Milk. IDF Special Issue No. 9603. Int. Dairy Fed., Brussels, Belgium.

13 Gonzalo, C., J. A. Baro, J. A. Carriedo, and F. S. Primitivo. 1993. Use of the Fossomatic method to determine somatic cell counts in sheep milk. J. Dairy Sci. 76:115–119.

14 Gonzalo, C., J. A. Carriedo, J. A. Baro, and F. S. Primitivo. 1994. Factors influencing variation of test day milk yield, somatic cell count, fat, and protein in dairy sheep. J. Dairy Sci. 77:1537–1542.

15 Gonzalo, C., J. C. Marco, M. de la Cruz, M. C. González, F. García, and A. M. Rota. 1996. Present-day situation of somatic cell count in milk of small ruminants: case of Spain. Pages 335–341 *in* Somatic Cells and Milk of Small Ruminants, Wageningen Pers Publ., Wageningen, The Netherlands.

16 Gross, S. J., E. J. Pollak, J. G. Anderson, and D. T. Torell. 1978. Incidence and importance of subclinical mastitis in sheep. J. Anim. Sci. 46:1–8.

17 Harvey, W. R. 1977. User's guide for LSML76. Mixed model least squares and maximum likelihood computer program. Mimeo, Ohio State Univ., Columbus.

18 International Committee for Animal Recording. 1992. Regulations for milk recording in dairy sheep. Group of Experts for Milk Recording in Dairy Sheep. Eur. Assoc. Anim. Prod., Rome, Italy.

19 International Dairy Federation. 1964. Determination of the casein content of milk. IDF Doc. No. 29. Int. Dairy Fed., Brussels, Belgium.

20 International Dairy Federation. 1981. The composition of ewe's and goat's milk. IDF Doc. No. 140. Int. Dairy Fed., Brussels, Belgium.

21 Jenness, R. L. 1985. Biochemical and nutritional aspects of milk and colostrum. Pages 164–197 *in* Lactation: A Comprehensive Treatise. B. L. Larson, ed. The Iowa State Univ. Press, Ames.

22 Kennedy, B. W., M. S. Sethar, J. E. Moxley, and B. R. Downey. 1982. Heritability of somatic cell counts and its relationship with milk yield and composition in Holsteins. J. Dairy Sci. 65: 843–847.

23 Kennedy, B. W., M. S. Sethar, A. W. Tong, J. E. Moxley, and B. R. Downey. 1982. Environmental factors influencing test-day somatic cell counts and relationship with milk yield and composition in Holsteins. J. Dairy Sci. 65:275–280.

24 Labussière, J. 1988. Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. Livest. Prod. Sci. 18:253–274.

25 Lagriffoul, G., M. R. Aurel, F. Barillet, D. Bergonier, J. Bernard, and X. Berthelot. 1993. Evolution of somatic cell count for Lacaune dairy ewes: preliminary results. Pages 110–119 *in* Proc. 5th Int. Symp. Machine Milking Small Ruminants. Int. Committee, Budapest, Hungary.

26 Latif, M. G., M. M. Abdel-Salam, and A. Haider. 1989. Factors affecting the milk yield and composition of Rahmany and Barki sheep and their crosses. Page 459 *in* Proc. 3rd Egyptian Br. Conf. Anim., Fish Poult. Prod., Alexandria Univ., Alexandria, Egypt.

27 Lee, A. J., and J. Wardrop. 1984. Predicting daily milk yield, fat percent, and protein percent from morning or afternoon tests. J. Dairy Sci. 67:351–360.

28 Molina, P. 1987. Composición y Factores de Variación de la Leche de Ovejas de Raza Manchega. Ph.D. Diss., Univ. Politécnica, Valencia, Spain.

29 Ng-Kwai-Hang, K. F., J. F. Hayes, J. E. Moxley, and H. G. Monardes. 1984. Variability of test-day milk production and composition and relation of somatic cell counts with yield and compositional changes of bovine milk. J. Dairy Sci. 67:361–366.

30 Pellegrini, O., M. R. Aurel, G. Lagriffoul, C. Marie, F. Remeuf, M. Rivemale, and F. Barillet. 1996. Relations entre les comptages de cellules somatiques, les caracteristiques physicochimiques et l'aptitude à la coagulation par la présure de laits individuels de brebis de race Lacaune. Pages 253–258 *in* Somatic Cells and Milk of Small Ruminants. Wageningen Pers Publ., Wageningen, The Netherlands.

31 Quiles, A., C. Gonzalo, F. Fuentes, M. Hevia, and J. M. Sânchez. 1991. Protein composition and variation of caprine colostrum (Murciano-Granadina breed) by means of polyacrylamide-SDS gel electrophoresis. Anim. Prod. 52:311–316.

32 Schaeffer, L. R. 1976. Maximum likelihood estimation of variance components in dairy cattle breeding research. J. Dairy Sci. 59:2146–2151.

33 Schultz, L. H. 1977. Somatic cells in milk—physiological aspects and relationship to amount and composition of milk. J. Food Prot. 40:125–131.

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

35 Smith, J. W., and R. E. Pearson. 1981. Development and evaluation of alternate testing procedures for official records. J. Dairy Sci. 64:466–474.

36 Stanton, T. L., L. R. Jones, R. W. Everett, and S. D. Kachman. 1992. Estimating milk, fat, and protein lactation curves with a test day model. J. Dairy Sci. 75:1691–1700.

37 Storry, J. E., A. S. Grandison, D. Millard, A. J. Owen, and G. D. Ford. 1983. Chemical composition and coagulating properties of renneted milks form different breeds and species of ruminant. J. Dairy Res. 50:215–229.

38 Wiggans, G. R., and G. E. Shook. 1987. A lactation measure of somatic cell count. J. Dairy Sci. 70:2666–2672.

39 Wohlt, J. E., D. H. Kleyn, G. W. Vandernoot, D. J. Selfridge, and C. A. Novotney. 1981. Effect of stage of lactation, age of ewe, sibling status, and sex of lamb on gross and minor constituents of Dorset ewe milk. J. Dairy Sci. 64:2175–2184.

40 Wood, P.D.P., and J. M. Booth. 1983. Variation in milk cell counts during lactation of British Friesian cattle. Anim. Prod. 36:335–339.