

Lactation Curves of Valle del Belice Dairy Ewes for Yields of Milk, Fat, and Protein Estimated with Test Day Models

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ABSTRACT

Test day models were used to estimate the lactation curves for Valle del Belice ewes and to study the main environmental effects on milk yield and on percentage of fat and protein. Environmental effects were treated as fixed. A random effect was associated with each lactation to evaluate the mean correlation among all test day records of an individual ewe. Lactation curves were constructed by adding solutions for classes of either days in milk nested within parity or days in milk nested within season of lambing to appropriate general means. Parity primarily affected the lactation curve for milk yield, which was lower and flatter for first lambing ewes; effects on fat and protein were smaller. Season of lambing affected all traits. Seasonal productivity had the greatest effect on milk composition, resulting in an imbalance between fat and protein percentages. Flock and feed supplementation affected only the lactation curve for milk yield. The lactation curve of Valle del Belice ewes stood at a relatively high level. However, the presence of notable, perturbative effects (environmental and random variation) on milk yield and composition suggests that management is unable to meet the requirements of ewes consistently.

(**Key words:** sheep, lactation curve, environmental factors)

Abbreviation key: TD = test day.

INTRODUCTION

The Valle del Belice is a breed of dairy sheep that is a result of a cross of Pinzirita, Sarda, and Comisana breeds (6) and from subsequent selection by sheep producers. The breed consists of about 60,000 sheep that are raised in an area of southwestern Sicily. The husbandry is typically extensive:

sheep are fed natural pastures and fodder crops; supplementation, consisting of hay and sometimes concentrates, is occasional and not nutritionally balanced to stage of lactation. Despite this low level of feeding, the mean milk yield for a lactation length of 200 d is about 270 kg. Fat and protein percentages are 6 and 5.5%, respectively. These productivity levels and the remarkable ability of ewes to mobilize body reserves, resulting in weight losses up to 20% (8), seem to indicate the potential for high productivity. An evaluation of the real capacity for productivity of these animals could be useful because ewes that are capable of high milk yield in extensive farms can be of great economic importance for a rational exploitation of marginal areas; such a situation is very common in Mediterranean countries, where feed availability is seasonal and the level of management is often very poor. Knowledge of the shape of the lactation curve and estimates of the effects of the main environmental factors can be used to evaluate the biological efficiency of production (12) and to estimate the decreased losses from management improvements.

The classic method that has been used to determine the regular shape of the lactation curve is the fitting of experimental data to a time function that is continuous and able to be differentiated across the entire lactation. The most common equation is incomplete gamma function of Wood (24), which is defined by three parameters related to the shape of the lactation curve. However, many alternative, empirical mathematical models of the lactation curve have been suggested (17). Most of those models concerned dairy cattle, but the same equations have been used in studies on sheep and goats (2, 10, 11, 14). In theory, these methods also allow the evaluation of the main environmental effects on milk yield by ANOVA of the parameters that define the function actually used. In this way, Wood (25) partitioned the seasonal variation of cow yield into yield seasonality and calving seasonality.

For dairy ewes, the method of mathematical analysis of lactation curves was used to estimate the effect of type of lambing (16, 23) and of type of lambing and udder health state (16) on milk yield. However,

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when temporary environmental effects become predominant, the analytical description of lactation curves loses its discriminant power, and the continuous and regular pattern of milk yield variation is no longer separable from the environmental effects and from the residual random variation. In such situations, the regular shape of lactation curves can be better obtained by using a test day (TD) model. Actually, TD models usually treat the milk yield on each TD as a separate but correlated trait. However, TD yields can be also analyzed in order to obtain lactation curves by solving for least squares estimates of the fixed effects of different DIM on TD yield for which lactation is partitioned into numerous DIM classes (22). Compared with fit of the lactation curve, such a TD model has the following advantages: variable amounts of information from different lactations can be used, estimates of fixed effects can vary across stages of lactation, and estimates can be adjusted for sampling effects of data.

Two TD models were used in this study to estimate lactation curves of Valle del Belice ewes for milk yield, fat percentage, and protein percentage and to evaluate the effects of some environmental factors, such as parity, type of lambing, flock, feed supplementation, season of lambing, and calendar month of production.

MATERIALS AND METHODS

The original data consisted of 4187 TD records of 244 Valle del Belice ewes of three flocks; ewes lambed from August 1994 to April 1995. The data included daily milk yield, fat percentage, and protein percentage. Standard lactation length was set to 225 d and was partitioned into 15 DIM classes, each 15 d long.

Data were grouped according to the different levels of the main environmental variables that were thought to affect the lactation curves: three flocks; two levels of feeding (supplementation with 500 g/d of a commercial concentrate given during April and May or no supplementation), three parity groups (first, second, and third or greater), two types of lambing (one lamb or two lambs), three lambing seasons (named according to local custom: winter, from December to February; later, from March to April; or conventional, from August to November), and 12 calendar months of production (January to December).

Two forms of the TD model were used. The parity model was structured so that the effect of parity on lactation curves could be readily observed:

$$Y_{ijklmn} = (F \times S_i) + T_j + (DIM \times P_k) + (MO \times SEA_l) + L_m + e_{ijklmn} \quad [1]$$

where Y_{ijklmn} = TD record n (milk yield in kilograms, fat and protein percentage) of ewe m , belonging to the classes i , j , k , and l of the following factors: feed supplementation nested within flock ($F \times S_i$), type of lambing (T_j), DIM nested within parity ($DIM \times P_k$), and month of lactation nested within season of lambing ($MO \times SEA_l$). All of these factors were treated as fixed. Furthermore, a random effect L_m (244 individual lactations) was introduced to account for variation associated with each particular lactation.

The second model, the season model, was structured in such a way as to distinguish lactation curves of ewes with different season of lambing:

$$Y_{ijklmno} = (F \times S_i) + T_j + (DIM \times SEA_k) + MO_l + P_m + L_n + e_{ijklmno} \quad [2]$$

Symbols are the same as for Model [1], except that ($DIM \times SEA_k$) is DIM nested within season of lambing.

Effects of DIM were solved separately for each of the three parity classes in Model [1] and for each of the three classes for season of lambing in Model [2], resulting in a total of 45 classes for effects of both $DIM \times P_k$ and $DIM \times SEA_k$, respectively. Month of lactation explains variation linked to seasonal productivity and, in Model [1], was nested within season of lambing in order to determine whether the effect of seasonal productivity varied across different seasons of lambing. Conversely, effects of months of lactation were solved globally in Model [2] in which season of lambing was used to differentiate among the lactation curves of ewes that lambed during different seasons of the year.

The ratio of the variance component associated with the individual lactation factor and the total phenotypic variance (σ_L^2/σ_P^2) was regarded as a measure of the repeatability or the mean correlation among all TD records within each individual lactation.

Solutions for Models [1] and [2] and estimates of variance components linked to random factors were obtained using both the SAS Varcomp procedure combined with JAA20 (13) and the SAS mixed procedure (19). Lactation curves were constructed by plotting estimated daily milk yield and percentages of fat and protein over time. Estimates were obtained by adding DIM solutions to the appropriate general means.

RESULTS AND DISCUSSION

Parity Model

Lactation curves for milk yield, fat percentage, and protein percentage are shown in Figure 1. Lactation

curves for milk yield do not always show the typical pattern, which is characterized by an initial phase that increases to a maximum, followed by a decreasing phase. Actually, this difference has been already observed in studies of other breeds (4, 7, 18) for which, in 30 to 50% of cases, the increasing phase is reduced to a sudden pulse, and the continuous and regular part of the lactation curve consists only of the decreasing phase. In the present study, 41 of the 244 lactations considered showed this irregular pattern, and the mathematical representation of their lactation curves would require the use of a multiphasic logistic function (12). The lactation peak, when detectable (second lambing and some first lambing ewes), occurred between the 30 and the 60 DIM (Figure 1a). As expected, fat and protein percentages showed a pattern opposite that for milk yield; the lowest point of protein curve (Figure 1c), when detectable, occurred approximately at the same period of peak milk yield.

Repeatability coefficients were 0.45, 0.30, and 0.33 for milk yield, fat percentage, and protein percentage, respectively, which differed from the results obtained for dairy cattle by Stanton et al. (22) who found estimates of 0.53, 0.52, and 0.46 for the three traits considered. Our results are more similar to those found with Sarda sheep (3), but still different: 0.60, 0.39, and 0.47. These differences, which are particularly relevant for milk components, indicate some interesting aspects: a greater influence of temporary environmental factors on extensive sheep breeding than on intensive cattle breeding and better management of Sarda sheep than of Valle del Belice sheep, especially in controlling adverse environmental factors. Actually, variation in pasture quality and quantity and other temporary environmental factors affect milk composition more than does milk yield (3).

As expected, the lactation curve for milk yield of ewes at third or greater lambing was the highest (Figure 1a and Table 1). Figure 1a shows that the resistance to decline of milk yield was higher for ewes during first lactation than during later lactations. These results are in agreement with those for La-caune (1) and Sarda (3) breeds. Stanton et al. (22), who observed the same effect in dairy cows, suggested an explanation could be found in the maturation process, which is still in progress during the first lactation and counteracts the normal decline in milk yield. This effect is evident until 120 DIM; then the effect of maturation is gradually reduced and results in lactation curves similar to those of later lactations. However, compared with results for other breeds of dairy sheep, milk yield and persistency were high for all lactations (1, 3). Parity effect is less evident but is

still significant for protein percentage and fat percentage (Figure 1, b and c and Table 1). The lower protein percentage of milk for ewes during first and second lactation is probably related to the reduced rumen functionality, to the reduced synthesis efficiency of the mammary gland, and to the preferential utilization of the available amino acids in growing tissues. However, for practical purposes, this difference is so limited that milk composition can be considered the same for all lactations. The rate of increase

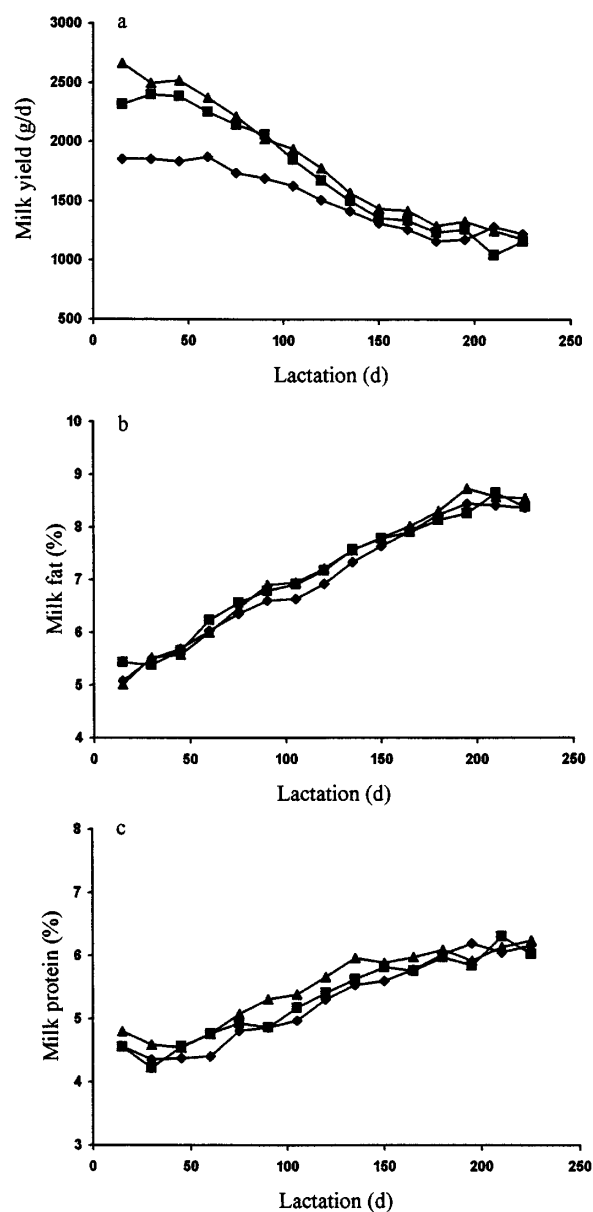


Figure 1. Estimates of the lactation curve for milk yield (a), fat percentage (b), and protein percentage (c) for Valle del Belice ewes in lactations 1 (♦), 2 (■), and ≥ 3 (▲).

TABLE 1. Least squares means of milk yield and percentages for the two models.

Model	Milk (kg)	Fat (%)	Protein (%)
Parity			
First	1681 ^C	6.84 ^b	5.07 ^B
Second	1938 ^B	6.90 ^{ab}	5.11 ^B
Third or greater	2015 ^A	6.97 ^a	5.35 ^A
Season			
Winter	1880 ^B	6.84 ^B	5.10 ^B
Later	1634 ^C	6.74 ^B	5.21 ^{AB}
Conventional	1936 ^A	6.99 ^A	5.27 ^A

^{a,b,c}Means within a column and model type with no common superscript differ ($P < 0.05$).

^{A,B,C}Means within a column and model type with no common superscript differ ($P < 0.01$).

of fat percentage that occurred through lactation does not seem to be affected by parity (Figure 1b). Protein percentage (Figure 1c) increased to a lesser extent; thus, the ratio between fat and protein percentage increased over time, as has been observed for other breeds (1, 3).

Effects of months of lactation within lambing season on milk yield, fat percentage, and protein percentage are reported in Figure 2. Figure 2a shows the positive effect on milk yield of spring months of lactation, when pasture availability is good, and the negative effect of summer months of lactation, when pastures are scarce and of poor quality and the temperature is high (20). The most interesting effects are observed on milk composition: regardless of lambing season, the effects of month of lactation on percentages of fat and protein (Figure 2, b and c) showed a pattern opposite to that for milk yield. When milk yield increased because of the effect of a favorable month, independent of stage of lactation, fat and protein percentages decreased, mainly because of a dilution effect. Moreover, disequilibrium situations, which were characterized by a drop in protein percentage relative to fat percentage, can be observed during summer and until November. This point disagrees with results obtained for Sarda ewes in which protein percentages tended to remain constant while fat varied in an irregular way (3). An explanation might be the greater potential of Valle del Belice sheep to counteract feed deficiency with a mobilization of body reserves because of the poor quality of its diet, which is low in energy and protein relative to nutritional requirements.

Season Model

Results of Model [2] are shown in Figures 3 and 4. Repeatability estimates were similar to those of the

parity model: 0.40 for milk yield, 0.30 for fat percentage, and 0.32 for protein percentage.

As previously mentioned, two types of seasonal effects on lactation curves must be considered. The first is the effect of the calendar month in which TD occurs; in Model [2], this effect was estimated as a mean effect of month of lactation, regardless of stage of lactation. The second is the effect of the season of lambing on the subsequent performance of a ewe;

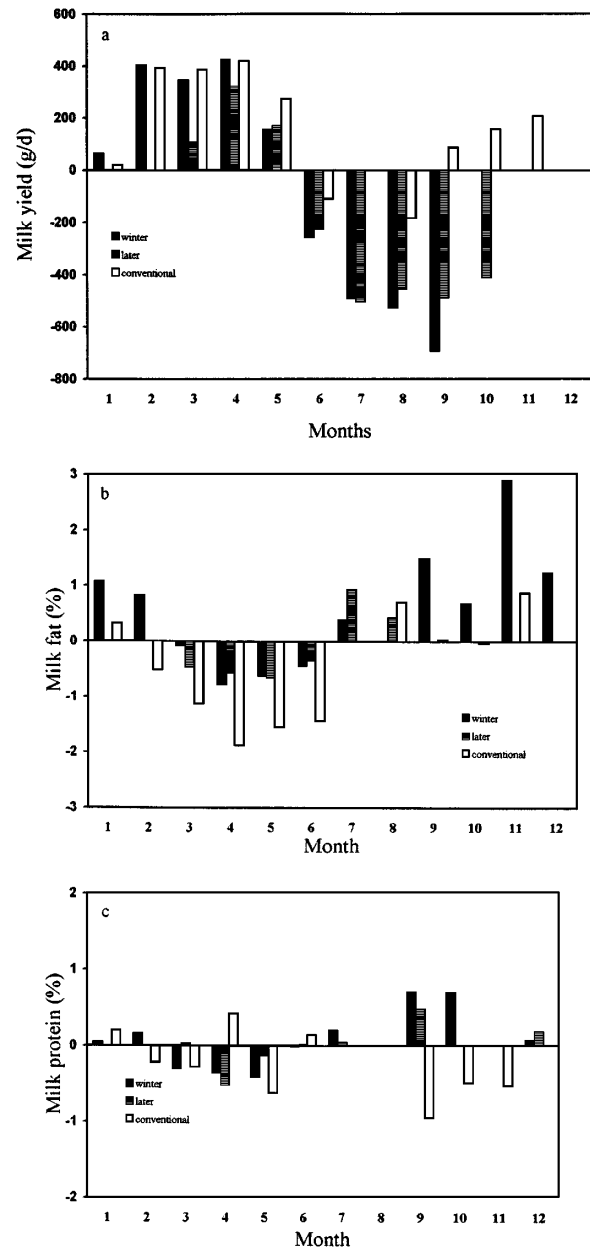


Figure 2. Effects for trend of month of lactation within lambing season for milk yield (a), fat percentage (b), and protein percentage (c).

Model [2] partitioned the season of lambing effect into three seasons in order to investigate its influence on the entire lactation curve. In fact, these two seasonal effects remained partially confounded because ewes that lamb during certain seasons produce in certain months. However, the curve for milk yield (Figure 3a and Table 1) of ewes that lambed during the conventional period was the highest, perhaps because ewes were pregnant during spring, when the forage availa-

bility of pastures reaches the maximum, which probably had a positive effect on the differentiation of udder secretory cells and on the accumulation of body reserves (5). Ewes that had lambed in the later season showed the lowest lactation curves, probably because of the slight accumulation of body reserves during pregnancy (winter) and the negative effects of month of lactation (early lactation during summer). Finally, ewes that had lambed during winter had an intermediate curve for milk yield, resulting from the compensation of two opposite seasonal effects: a negative influence of the lambing season (pregnancy in summer to autumn) and a positive effect of the month of lactation (most of lactation occurs in

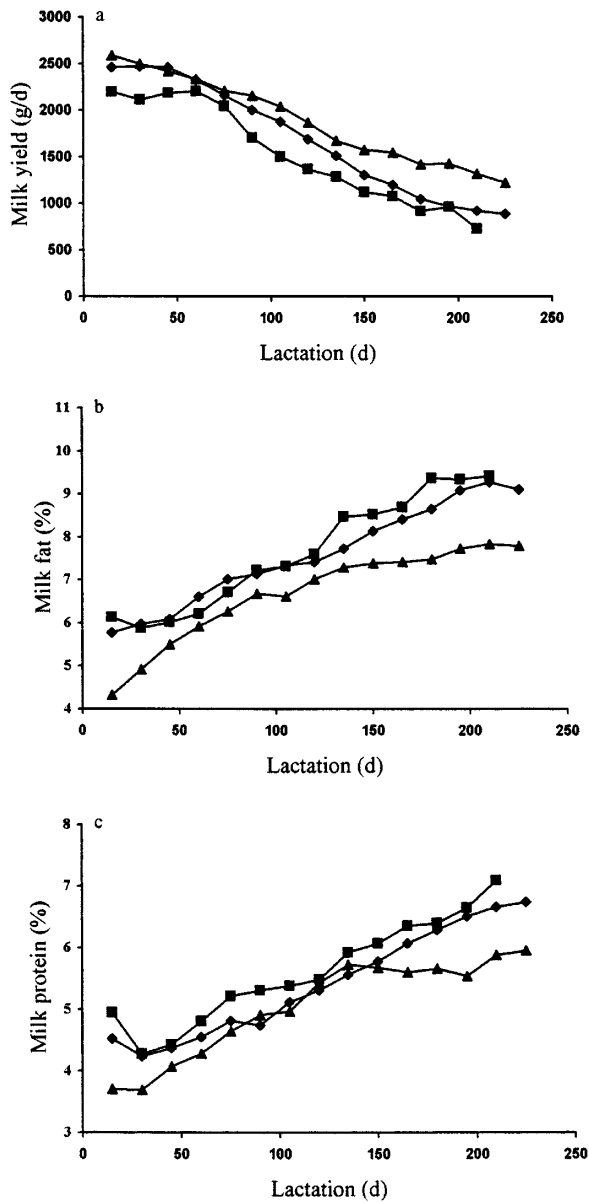


Figure 3. Estimates of the lactation curves for milk yield (a), fat percentage (b), and protein percentage (c) for Valle del Belice ewes lambing during winter (♦), later (■), and conventional (▲) lambing season.

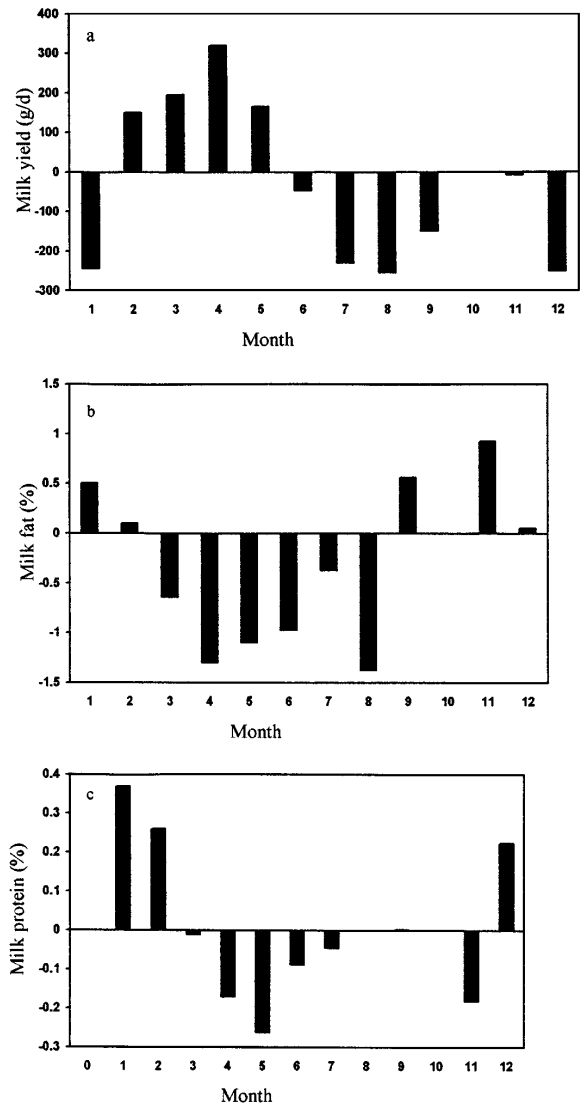


Figure 4. Effects for trend of month of lactation effects for milk yield (a), fat percentage (b), and protein percentage (c).

TABLE 2. Least squares means of milk yield and percentages for various fixed effects.

Factors	Model 1			Model 2		
	Milk	Fat	Protein	Milk	Fat	Protein
	(kg)	(%)	(%)	(kg)	(%)	(%)
Flock						
1	1802 ^A	7.28 ^a	5.42 ^a	1789 ^B	7.47 ^a	5.43 ^b
2	1455 ^B	7.07 ^{ab}	5.21 ^b	1471 ^A	7.28 ^{ab}	5.19 ^a
3	1720 ^A	6.99 ^b	5.46 ^a	1740 ^B	7.19 ^b	5.45 ^b
4 ¹	1802 ^A	7.21 ^a	5.39	1803 ^B	7.40 ^a	5.38
5 ¹	1590 ^B	7.17 ^a	5.24	1610 ^A	7.37 ^a	5.23
6 ¹	1813 ^A	6.87 ^b	5.46	1822 ^B	7.07 ^b	5.44
Lambing						
Single	1660	7.15	5.33	1670	7.35	5.32
Twins	1734	7.04	5.40	1741	7.25	5.38
Parity						
1				1514 ^B	7.22	5.23 ^{B,b}
2				1750 ^A	7.34	5.33 ^{AB,b}
3				1853 ^A	7.34	5.49 ^{A,a}

^{a,b,c}Means within column with no common superscript differ ($P < 0.05$).

^{A,B,C}Means within a column with no common superscript differ ($P < 0.01$).

¹Feed supplementation.

spring). Effects of the lambing season are also evident in curves for fat and protein percentages (Figure 3, b and c); the pattern is opposite that of milk yield.

The effects of month of lactation on the single TD record are shown in Figure 4 for the three traits considered. Those data confirm the effects suggested by Model [1]: an increase of milk yield (Figure 4a) during the months characterized by higher quantitative and qualitative availability of forage and a marked depression during summer, a trend that is opposite that for fat and protein percentages (Figure 4, b and c); with occurrence of disequilibrium, situations in which fat percentage remains normal but protein percentage decreases.

Table 2 presents the least squares means for the different levels of flock \times feed supplementation, type of lambing, and parity. Flock and parity had a significant influence on milk yield. The effect of type of lambing seems to be unimportant, in contrast with that observed in other studies (2, 9, 21). These results might be due to the insufficient energy supply in the early stages of lactation; the higher milk yield of ewes with twins than of ewes with a single lamb can be expressed only under good feeding conditions (15). As far as milk composition is concerned, the effects of the different variables were relatively small, except for the effects of parity on protein percentage.

CONCLUSIONS

The TD models are more effective than the other methods currently in use for generating estimates for

the lactation curve of milk yield, fat percentage, and protein percentage because TD models can better account for environmental effects. These effects, which can be substantial for species raised in extensive conditions, are particularly important for the understanding of the productive capacity of the Valle del Belice ewes. The analysis with the two TD models showed the relatively high level of the continuous and regular part of milk yield and of fat and protein percentages. These positive aspects seem to indicate that these ewes have a great potential for high milk yield, but their milk yield is depressed by adverse environmental effects, mainly related to the seasonality of both lambing and lactation. In this study, the effects of these two seasonal factors were of the same magnitude. However, the effects of seasonal productivity seem to have a greater role in altering milk composition, resulting in an inversion of the known correlation between fat and protein percentages and in a marked decrease in milk protein content. This alteration is indicative of poor management, especially feeding. Particularly during summer, feeding does not meet the nutritional requirements of the lactating ewes.

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