

ORIGINAL ARTICLE

Relationships between daily, morning, evening and peak yield and persistency in Turkish Saanen goats

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ABSTRACT

A matrix of persistency values is given instead of one value of persistency or persistency values based on succeeding test days. Overall, the persistency matrix of morning milk had higher values than the persistency matrix of evening milk. As the distance between the test days increased, the correlations dramatically decreased. The effects of morning milk yield $b = 0.23$ ($P < 0.01$) on standard deviation of morning and evening milk yield and on peak the milk yield was higher compared to the evening daily milk yield $b = 0.03$ ($P = 0.05$) and the total daily milk yield 0.10 ($P < 0.01$). Increased persistency means that the lactation curve may be flatter. Since the peak value of morning milk (1597 mL) was lower than evening milk (1799 mL), and morning milk was more persistent than evening milk, morning milk can be said to contribute more to the flatness of the lactation curve. Overall, the morning milk volume (938 mL) was larger than the evening milk volume (835 mL). A 3D plot of peak milk versus morning and evening milk yield indicated that increasing the evening milk yield increases the peak yield while the morning milk yield holds the peak value lower and the curve stable.

Key words: evening milk, morning milk, peak value, persistency, Turkish Saanen goats.

INTRODUCTION

Increased persistency of lactation may result in great benefits for the dairyman and flattening the declining portion of the lactation curve promotes more efficient lactation (Capuco *et al.* 2003). This may be achieved by a lactation curve with a lower peak value. Lactation curves with lower peaks may be more persistent and the overall milk yield may be larger in more persistent lactations. Research (Canadian Dairy Network 2004) has shown that higher persistency is mainly due to later and lower peak yields. However, Calus *et al.* (2005) reported a high correlation of 0.84 between persistency and peak milk yield.

Norman *et al.* (1999) noted that majority of the US cows on test are enrolled in an AM–PM plan in which the intervals between tests have increased. As persistency increases, the number of tests required decreases (Pala & Savaş 2005).

Accounting for covariances among test day milk yields in dairy cows, Ali and Schaeffer (1987) suggested a regression model to describe the curve of the

lactation and demonstrated the advantage of this over other models, including the model by Wood (1967). Based on this work, Ptak and Schaeffer (1993) used single test day records as repeated measurements and suggested factors to model the curve of the lactation.

The compound symmetry covariance structure, which has constant variance and constant covariance, results in a single estimate of persistency (Pala & Savaş 2005). More complicated covariance structures such as unstructured, autoregressive or ante-dependence covariance require more data to converge but they also require fewer assumptions and the results are more reliable.

Persistencies of morning, evening and total daily milk yields were calculated using a first order autoregressive moving-average covariance structure. The

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Received 11 November 2005; accepted for publication 28 February 2006.

effects of the morning, evening and daily total milk yield on standard deviation of the morning and evening milk and on peak milk yield were analyzed to investigate whether increasing the milk yields increased the variance of morning and evening milk and whether increasing them increased the peak milk yield. The effects of parity on the standard deviation and peak milk yield were also investigated.

MATERIALS AND METHODS

Data included 1602 records collected on 93 Turkish Saanen goats raised at the Uvecik Research Center, Canakkale, Turkey. The goats were kept on pasture during the day and were given 500–1000 g commercially available concentrate feed and 1.2 kg dried vetch every day. Concentrate feed was given two times a day before milking, which was done with a milking machine. The animals were milked in the morning at 07.00 hours and in the evening at 19.00 hours. The milk recordings were carried out at the Uvecik Research Center by the university personnel. The mean lactation length was 223 ± 39 days.

Repeated statement in Proc MIXED of SAS V8.2 (SAS 1999) was used to fit a lactation curve model as well as a variance–covariance model to account for correlations of all the observations arising from individual goats (Jennrich & Schluchter 1986; Everitt 1995). Various covariance structures (Jennrich & Schluchter 1986; Wolfinger 1996) were examined to fit the best model.

The model and analyses were similar to the second approach reported by Pala and Savaş (2005). Increased correlation means better persistency. Days in milk (DIM) was included to account for the total number of days the animal was in lactation. Because the shape of the lactation had to be accounted for, three transformations of the DIM as well as its original value were added (Swalve 1995).

The statistical model was

$$Y_{ijklmn} = \mu + A_i + B_j + \sum_{k=1}^4 b_{kl} x_k + D_m + E_n(B_j) + e_{ijklmn}$$

Where;

Y_{ijklmn} = test day record for morning, evening, or daily milk yield, standard deviation of morning and evening milk, or peak milk yield,

μ = overall mean

A_i = fixed effect due to test day (1, . . . , 30),

B_j = fixed effect due to parity (1, . . . , 5),

X_k = covariates:

$C_1 = \text{DIM}/c$ where c is constant, set to 300 days,

$C_2 = (\text{DIM}/c)^2$

$C_3 = \ln(c/\text{DIM})$

$C_4 = ((\ln(c/\text{DIM}))^2)$, the subscript l denotes that regression were nested within parity

D_m = total daily milk yield, or morning milk or evening milk yield (not included when the dependent variables were the milk yields)

E_n = effects of the subject within parity (all animals),

e_{ijklmn} = random error assumed to be normally distributed with mean of zero and variance σ^2_e .

The standard deviation of morning and evening milk was calculated from each animal's morning and evening milk yields in each test day. Each animal had one standard deviation per test day per lactation and this was used as one of the dependent variables.

The error term was not assumed to be independently distributed because the data were repeated in time and thus, the covariance matrix was modeled to account for the dependencies in errors.

The highest milk yield for a goat within parity was used as the peak milk yield. In the analysis of peak yield, the test day was not included because each animal had one peak yield per lactation and the repeated effect of the subject was included only directly and not within parity. The mean milk yields were used for the peak analyses.

An additional model for the peak milk yield used the total, morning and evening test day milk yields as the regression explanatory variables (test day 1 milk yield, . . . test day 9 milk yield) to investigate which of the test days had significant effects on the peak milk yield. Similarly, Lin and Togashi (2005) treated each daily estimated breeding value of the lactation as a separate trait to modify the lactation curve on a daily basis.

Akaike's information criteria (Akaike 1974) and Schwarz's Bayesian criteria (Schwarz 1978) associated with the models were computed to find the fittest covariance structure of the repeated model. The first order autoregressive moving-average model was used as the covariance structure. The model has three covariance parameters and the $(i,j)^{\text{th}}$ element is

$$\sigma^2(\gamma p^{|i-j|-1} 1(i \neq j) + 1(i = j)) \quad (1)$$

where p is the autoregressive parameter, γ models a moving-average component, and σ^2 is the residual variance. In the right side of the equation, $1(i = j)$ is 1 when $i = j$ and 0 otherwise, and $1(i \neq j)$ is 1 when $i \neq j$ and 0 otherwise (SAS 1999).

Peak milk yield, morning milk and evening milk yields were processed using PROC G3GRID to create a data set that the G3D procedure can use to produce a three-dimensional surface plot. Then proc G3D was used to create the plot. The plot showed the changes in peak milk yield with morning and evening milk yields. In the figure, the X axis is the morning, the Z axis is the evening and the Y axis is the peak milk yield.

RESULTS

Akaike's information criteria (Akaike 1974) and Schwarz's Bayesian criteria (Schwarz 1978) associated with the models are given in Table 1. In the table, the smaller numbers indicate a better fit (SAS 1999). Among the models, the factor analytic model had the lowest Akaike's information criteria for morning milk while the first order autoregressive moving-average model had the lowest Schwarz's Bayesian criteria. When both criteria were considered, the first order autoregressive moving-average model had the highest fit for morning milk, evening milk and total daily milk. The advantage of the model was more obvious for evening milk and total daily milk.

The correlations were larger in tests closer together while they diminished as the test days separated further apart. This is to be expected since test days closer to each other will have more similar conditions than those further apart. The milk yield may not change from test 1 to test 2, while the difference may be greater between test day 1 and test day 7. In Table 2, for example, the correlation between morning milk of test day 3 and 4 was 0.75, while the correlation between test day 1 and test day 2 was also 0.75. This was because the method assumes equal correlations between test days that have equal distances. Below is

an example of the first order autoregressive moving-average model:

$$\sigma^2 \begin{pmatrix} 1 & \gamma & \gamma p & \gamma p^2 & \gamma p^3 \\ \gamma & 1 & \gamma & \gamma p & \gamma p^2 \\ \gamma p & \gamma & 1 & \gamma & \gamma p \\ \gamma p^2 & \gamma p & \gamma & 1 & \gamma \\ \gamma p^3 & \gamma p^2 & \gamma p & \gamma & 1 \end{pmatrix}$$

As seen in this matrix, the covariance parameter is the same for equal distances.

Though more than one persistency value was given in Table 2, it is clear overall that evening milk had a lower persistency than morning milk. The persistency of the total daily milk yield was closer to the morning persistency values, compared with the evening persistency values.

The effect of the total daily milk yield on the standard deviation of the morning and evening milk yield was $b = 0.10 \pm 0.006$ ($P < 0.01$). The positive estimate indicated that the difference between the morning milk yield and the evening milk yield increased as the total milk yield increased. The effects of parity on

Table 2 Estimated correlations between test days for morning, evening and total daily milk yield

Distance between test days	Morning	Evening	Total
1	0.7537	0.6729	0.7788
2	0.6620	0.5713	0.6704
3	0.5815	0.4851	0.5771
4	0.5107	0.4119	0.4967
5	0.4486	0.3497	0.4276
6	0.3940	0.2969	0.3681
7	0.3461	0.2521	0.3168
8	0.3040	0.2140	0.2727

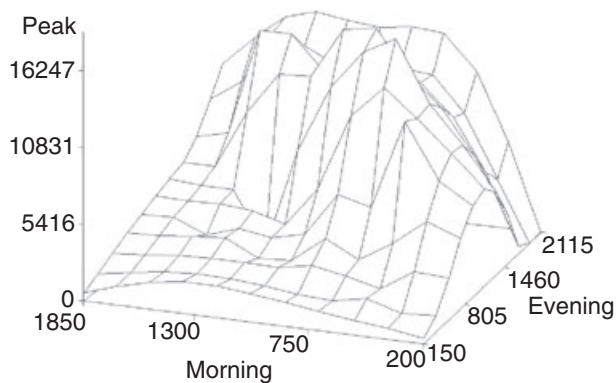
Table 1 Akaike's information criteria and Schwarz's Bayesian criteria fit statistics for different covariance structures for morning, evening and total milk

Covariance structure	Morning		Evening		Total	
	AIC	BIC	AIC	BIC	AIC	BIC
Compound symmetry	15 062	15 069	14 637	14 643	15 110	15 111
Auto regressive	14 969	14 975	14 596	14 601	14 974	14 980
First-order autoregressive moving-average	14 936	14 945	14 562	14 571	14 960	14 969
First-order factor analytic	14 934	15 038	14 753	14 857	15 447	15 548
First-order unstructured	15 628	15 680	15 201	15 253	15 764	15 815
Huynh-Feldt	16 234	16 289	15 143	15 198	15 599	15 653
First-order heterogeneous Toeplitz	15 628	15 680	15 201	15 253	15 764	15 815
Variance components	15 698	15 701	15 195	15 198	15 775	15 779

AIC, Akaike's information criteria; BIC, Schwarz's Bayesian criteria.

Table 3 Regression estimates for effects of different test days on peak milk yield for total daily milk yield, morning milk yield and evening milk yield and their respective *P*-values

Test day	Total milk	<i>P</i> -value	Morning milk	<i>P</i> -value	Evening milk	<i>P</i> -value
Test 1	1.14	0.47	0.30	0.01	-3.04	0.40
Test 2	1.02	0.66	0.37	0.02	3.92	0.26
Test 3	-1.65	0.53	-0.09	0.62	1.15	0.75
Test 4	-0.59	0.79	-0.24	0.31	-2.96	0.48
Test 5	3.58	0.05	0.43	0.02	6.66	0.06
Test 6	-2.36	0.51	0.22	0.58	-5.76	0.24
Test 7	-1.69	0.50	-0.25	0.33	-0.43	0.91
Test 8	4.03	0.34	0.42	0.35	5.29	0.44
Test 9	0.38	0.31	0.31	0.01	0.09	0.86

**Figure 1** Effects of morning milk and evening milk on peak value. X axis, morning milk yield; Z axis, evening milk yield; Y axis, peak milk yield.

standard deviation were small ($P > 0.05$) while the effect of the test day were large ($P < 0.01$). The effect of the morning milk yield on the standard deviation was $b = 0.23 \pm 0.009$ ($P < 0.01$) while the effect of the evening milk yield on the standard deviation was $b = 0.03 \pm 0.016$ ($P = 0.05$). The morning milk yield was higher (938 ± 550 g) than the evening milk yield (835 ± 924 g) and relatively small changes in morning milk apparently affected the standard deviation between the morning milk and the evening milk more than evening milk did.

The effect of the total daily milk yield on the peak milk yield was $b = 1.10 \pm 0.07$ ($P < 0.01$). The effect of the morning milk yield on the peak milk yield was $b = 1.33 \pm 0.09$ ($P < 0.01$) while the effect of the evening milk yield was $b = 1.02 \pm 0.07$ ($P < 0.01$). The average peak yield for the total milk was 3328 ± 2370 mL. The average peak yield for morning milk was 1597 ± 536 mL, lower than that of evening milk, 1799 ± 2112 mL. The higher standard deviation of evening peak milk also indicates that the peak value

of the evening milk deviated more between the goats than the peak values of the morning milk did.

The additional model regressing the peak milk yield on the test days indicated that test day 5 approached significance for the total milk ($P = 0.051$) and the evening milk ($P = 0.055$). The effects of test days 1, 2 and 5 were significant ($P < 0.05$) for the morning milk (Table 3).

Figure 1 shows that the peak daily milk yield increases more with the increasing evening milk. The morning milk does not seem to be as effective as the evening milk in increasing the peak milk yield: rather, it holds the milk yield stable.

DISCUSSION

There is a tendency to give one overall value to measure repeatability and persistency within correlation and other numerous estimates in literature. This approach is more user-friendly while it hides more detailed information. For example, a repeatability value gives an overall estimate of correlation among parities while it is not precisely an estimate of the correlation between lactation 1 and lactation 2, or between lactation 3 and lactation 5. Similarly, an overall persistency estimate may be insufficient to provide enough information to the researcher due to the shape of lactation. In this study, the within correlations were presented in the form of a matrix calculated by the first order autoregressive moving-average model, instead of assuming all correlations among the test days are equal and calculating one value. A compound symmetry method assumes these correlations and variations are all equal. Though the model used here makes fewer assumptions about the dependencies, it still carries out the assumption that correlations of test days equally further apart are the same. For example, it assumes that the correlation between test

day 1 and test day 2 is the same as that between test day 4 and 5, or 8 and 9. A better method, 1 with no assumptions would be the unstructured method. However, that method did not converge for this data set, because there were too many parameters. This indicates that increasing the sample size in studies like this not only increases the test reliability but it also provides the means to employ better methods. Another approach to calculating persistencies is to divide succeeding test days and analyze them using a multivariate approach. This method assumes that test days further apart have the same correlation with test days of equal distances. For example, it assumes the correlation between test day 1 and 2 is the same as that between test day 1 and 5. It is expected in biology studies that closer observation days have stronger relationships or correlations compared to observation days further apart.

Norman *et al.* (1999) reported that intervals between tests have lately increased. The intervals between tests may be increased as the correlations between the test days increase. In other words, if persistency is used as selection criterion, fewer tests may be required, and thus, the testing intervals may be increased. The values in Table 2 indicate that succeeding tests have strong correlations (0.77 for total milk) while, for example, those three tests apart have weaker (0.57) correlations and those nine tests apart have the weakest (0.27) correlations.

Pala and Savaş (2005), who used 3 years of data and a compound symmetry structure reported that the morning milk yield was higher than the evening milk yield while the morning milk persistency values were lower compared to the evening milk values. In contrast, this study with 4 years of data and a more detailed covariance structure with fewer assumptions indicated that the persistency values were higher overall and evening the milk had lower overall persistency than the morning milk.

The effect of morning milk yield on standard deviation ($b = 0.23$) being higher than the effect of evening milk yield on standard deviation ($b = 0.03$) seems to suggest that morning milk had more variance and thus should have less persistency. However, the morning milk yield was higher (938 mL) than the evening milk yield (835 mL). Thus, changes in morning milk yield affected the difference between the morning and evening milk yield more compared to the changes in the evening milk yield, because the morning milk volume was larger. However, the variance of the morning milk was smaller compared to the

evening milk. Looking at the effects of the morning milk alone, and then looking at the effect of the evening milk and comparing them does not give an idea about the persistency of these milk yields. Instead, it gives an idea on how these milk yields affect the difference between the morning and evening milk yields. According to this, the morning milk yield changed the difference more due to its higher volume compared to the evening milk. However, when evaluated within itself, the persistency of the morning milk yield was higher compared to the evening milk (Table 2). The morning milk had a larger volume and higher persistency compared to the evening milk. In contrast, Togashi and Lin (2004) reported a negative correlation between lactation milk yield and persistency.

The effect of the morning milk yield on the peak milk yield was higher compared to the evening milk yield, probably because of the larger volume of the morning milk yield and its higher persistency. Increased persistency means that the peak value may be flattened. Since the peak value of the morning milk was lower than that of the evening milk (1597 mL of morning milk versus 1799 mL of evening milk) this means that morning milk contributes more to the flatness of the lactation curve. The peak values differed greatly for each animal, especially for the evening milk. Zwald *et al.* (2001) concluded that the important environmental descriptors causing the re-ranking of dairy sires between countries were relative peak milk yield, herd size, temperature and standard deviation of milk yield (Hayes *et al.* 2003). The relative peak milk yield is defined by the highest test-day milk production of a heifer divided by its average test-day milk production (Calus & Veerkamp 2003). Lin and Togashi (2005) used various selection strategies for improving lactation milk without decreasing persistency. The index subject to the restriction of zero gain at DIM 60 yielded the greatest persistency, but achieved the smallest response in the estimated breeding value of the lactation. They suggested that it is impractical to increase persistency by inhibiting change in the peak yield. The figures indicated that the morning milk yield levels out fluctuations of peak milk yield. This agreed with the persistency findings and the analysis of the milk yields on the peak values.

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