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ORIGINAL ARTICLE

Effects of short periods of frequent milking on the persistency of milk yield and SCS in Turkish Saanen goats

Akin PALA and Emrah KOYUNCU

Department of Animal Science, Canakkale Onsekiz Mart University, Canakkale, Turkey

ABSTRACT

The major purpose of this study was to investigate if increasing milking frequency for a short period of 3 weeks had any effects on the persistency of milk yield and the persistency of the somatic cell score (SCS). The methyl green–pyronin method was used for the direct microscopic SCS, converted to SCS for the analyses. Two groups were formed (control, $n = 14$ and treatment, $n = 14$). The treatment group was milked four times a day for 3 weeks after weaning. Both groups were milked twice a day outside this 3-week period, throughout lactation. For the milk yield, persistencies were higher in the treatment group when the distance between the test days was equal to or less than 3 months. The exact opposite was true for the SCS; that is, the treatment group had higher persistencies when the distance between the test days was more than 3 months. Overall, persistencies related to milk yield were higher than persistencies related to SCS. For fat corrected milk yield, treatment persistencies were always higher than the control group persistencies, regardless of the distance between the tests. The same was true for the fat content. Increasing milking frequency for a short period of time (3 weeks) after weaning may help to increase the persistency of the milk yield, fat corrected milk yield and fat content. A 3-D plot of least squares means indicated that the milk yield tended to show a classical lactation curve in lower SCS values while forming an unstable curve in higher SCS values.

Key words: *autoregressive moving average, fat content, persistency, Saanen goats, test day milk.*

INTRODUCTION

The decline in milk yield after peak lactation in dairy animals has been a cause of considerable los of income for the dairy farmer (Stefanon *et al.* 2002). Dairy animals producing milk steadily are preferred to those with a higher production of milk yield at the lactation peak (Wood 1967). Dairy animals with higher persistencies require less feed and reproduction costs and they turn out more profit (Togashi & Lin 2004). In addition, animals with flat curves are less susceptible to metabolic disorders, health and fertility problems, and have more consistent energy requirements throughout lactation (Macciotta *et al.* 2004). Higher peaks can cause stress due to negative energy balance (Loeffler *et al.* 1999) and easing that stress can raise fertility and increase lifetime production (Togashi & Lin 2004).

Increased persistency may also mean decreased SCC due to lower and later peaks and selecting for persistency can help decrease SCC and mastitis in the herd in addition to many other benefits such as increased milk yield. Jensen (2001) reported a genetic correlation between lactation persistency and disease resistance. Paape *et al.* (1992) showed that more frequent milking increases the migration of neutrophils from blood into the mammary gland, providing more efficient mammary gland defense against infections.

Stefanon *et al.* (2002) suggested that manipulative strategies for maximum rate of milk secretion could

Correspondence: Akin Pala, Department of Animal Science, Canakkale Onsekiz Mart University, Canakkale, Turkey. (Email: akin@comu.edu.tr)
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create problems related to welfare and health, but frequent milking, timed appropriately, can improve persistency. This in turn, emphasizes the maintenance of milk secretion during the declining phase of lactation instead of increasing milk production at the peak of lactation. Hickson *et al*. (2006) reported that cows milked twice daily had better persistency than those milked once daily.

In dairy animals, secretory cells become inactive when they are full of milk and they start to regress if they remain inactive for some time (Vetharaniam *et al*. 2003). The cells are more likely to regress when the animals are milked less frequently because they remain inactive for longer periods (Capuco *et al*. 2003). Milk yield declines due to the gradual regression of the epithelium by apoptotic cell death after the peak (Wilde *et al*. 1997). Cows milked once a day lost more mammary tissue after peak, compared to cows milked twice a day (Carruthers *et al*. 1993). In an experiment with mice (Quarrie *et al*. 1996), sealing of the teats halted milk production and stimulated apoptosis, while lactation and cell survival were maintained in the other glands due to the suckling of the pups (Stefanon *et al*. 2002).

In this study, the Saanen dairy goats were milked four times a day for 21 days after weaning to better simulate the kids suckling and to prevent the drop after the peak, improving persistency. Thus, the major objective of this study was to investigate the effects of a 21-day interval of frequent milking on the persistency of milk yield and persistency of the somatic cell score (SCS).

MATERIALS AND METHODS

Two groups of goats were formed to study two different milking frequencies, 2× ($n = 14$) and 4× ($n = 14$) in Turkish Saanen dairy goats. The groups were balanced for parity, body weight and birth type. The 4× (treatment) group was milked four times a day (4×) at 07.00, 10.00, 16.00 and 19.00 hours and the 2× (control) group was milked twice a day (2×) at 07.00 and 19.00 hours for 3 weeks after weaning. Both groups were milked twice a day after the 3-week period, throughout lactation. Test day data included milk per day, milk components and SCS for 7 test days per goat, with each test day ranging around 30 days.

The kids were separated from the goats 3 days after birth. They were allowed to suckle only after the evening milking. Kids reaching 10 kg were weaned. Management and feeding were the same for both groups throughout lactation.

The methyl green–pyronin-Y method (New York modification) was used for the direct microscopic somatic cell count (DMSCC/mL), which excluded RNA and background noise while including the cells that had DNA (Poutrel & Lerondelle 1983; Pachard *et al*. 1992). This type of stain is required in goat milk due to their apocrine milk secretory system.

Ali and Schaeffer (1987) suggested a regression model to account for covariances among test day milk yields in dairy cows and 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 statistical analyses of this study are based on that approach. Repeated statement in PROC MIXED of SAS V8.2 (SAS 1999) was used to fit a lactation curve model and a variance–covariance model to account for the correlations of all the observations from individual goats (Pala & Savas 2006). Akaike's information criteria (Akaike 1974) and Schwarz's Bayesian criteria, also referred to as Bayesian information criteria (Schwarz 1978), were computed and both fitness measures indicated that the first order autoregressive moving average had the highest fit. In addition, hypothesis tests were carried out on the covariance parameters (SAS 1999).

The statistical model was:

$$\mathrm{Y}_{\mathrm{ijklmno}} = \mu + \mathrm{A}_{\mathrm{i}} + \mathrm{B}_{\mathrm{j}} + \mathrm{C}_{\mathrm{k}} + \mathrm{D}_{\mathrm{l}} + \sum_{m=1}^{4} b_{mn} X_m + F_{\mathrm{o}} + \mathrm{e}_{\mathrm{ijklmno}}$$

where;

$\mathrm{Y}_{\mathrm{iklmno}}$ = test day record for daily, or fat corrected daily milk yield, or percentage of fat content of the milk,
μ = overall mean
A_{i} = effects due to milking frequency (2×, 4×)
B_{j} = effects due to parity (1, . . . 5),
C_{k} = effects due to birth type (single, multiple)
D_{l} = effects due to test day (1, . . . 7),
X_{m} = covariates:
C1 = DIM/c where c is constant, set to 300 days,
C2 = $(\mathrm{DIM/c})^2$
$\mathrm{C}_3 = \ln(\mathrm{c/DIM})$
$\mathrm{C}_4 = (\ln(\mathrm{c/DIM}))^2$, the subscript 'n' denotes that the regressions were nested within parity
F_{o} = effects of the subject,
$\mathrm{e}_{\mathrm{ijklmno}}$ = random error.

A second measure of persistence (Pers2) was calculated as the last test day production before dry off, divided by peak production and multiplied by 100 to get the percentage value (Hickson *et al*. 2006). In addition, correlations between persistency and milk yield, persistency and peak milk yield and milk yield and peak milk yield were calculated using the PROC CORR procedure (Hickson *et al*. 2006).

DMSCC/mL was $\log_2$ transformed to SCS using $SCS = \log_2 (SCC/100) + 3$ (Ali & Shook 1980). Mark *et al*. (2002) reported that national data for SCC are $\log_2$ transformed in eight countries, $\log_{10}$ transformed in two countries and $\log_e$ transformed in the UK. These values were analyzed using the first order autoregressive moving average covariance structure.

Milk yield and SCS least squares means were run through PROC G3GRID (SAS 1999) 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 3D plot showed the changes in milk yield and SCS together, throughout lactation.

RESULTS

The autoregressive moving average covariance structure uses gamma (γ) and rho (*p*) values, which in turn generates rows and columns of the persistency matrix. The rho value is the autoregressive parameter while gamma models a moving average component. In overall persistency, the gamma value was 0.596 ± 0.082 ($P < 0.001$) while the rho value was 0.913 ± 0.071 ($P < 0.001$). In the treatment group, the gamma was 0.705 ± 0.108 ($P < 0.001$) and the rho value was 0.900 ± 0.083 ($P < 0.001$). In the control group, gamma was 0.569 ± 0.144 ($P < 0.001$) while the rho value was unity.

Persistency values are given in Table 1 for the treatment group (4×) and the control group (2×) in addition to the overall values. These are calculated from the gamma and the rho values, according to the autoregressive moving average structure. The control group had consistent persistency values for all distances because the rho value was unity for that group.

Differences between the groups were not large ($P > 0.05$) for the second persistency measure (Pers2) in milk yield. Persistency of the control group was 69% and that of the treatment group was 66%, respectively, indicating that the control group had a higher persistency. However, this criterion measures the change from peak to the last test day, which has a 5-month range. This agrees with the results of the first measure of persistency because that criterion also indicated that the control group had higher persistency when the test days taken into consideration were separated by more than 3 months.

Table 1 Persistency values for twice a day milking (2×, control), four times a day milking (4×, treatment) and overall daily milk yields

Distance between test days	2×	4×	Overall
1	0.569	0.705	0.596
2	0.569	0.635	0.544
3	0.569	0.571	0.497
4	0.569	0.514	0.454
5	0.569	0.463	0.414
6	0.569	0.416	0.378

The trend in the milk yield continued in the fat corrected milk yield (Table 2). However, the major difference was that the persistencies were always higher in the treatment group. In other words, the persistencies did not drop below the levels of the control group persistencies after the distance between test days increased to 4 months or more. The gamma values were 0.552 ± 0.091 ($P < 0.001$), 0.681 ± 0.124 ($P < 0.001$) and 0.501 ± 0.153 ($P = 0.001$) for overall, treatment and control group fat corrected milk yields, respectively. The rho values were 0.955 ± 0.048 ($P < 0.001$), 0.957 ± 0.051 ($P < 0.001$) and 0.960 ± 0.100 ($P < 0.001$) for overall, treatment and control group fat corrected milk yields, respectively.

The fat content showed the same trend as the fat corrected milk yield (Table 2). Regardless of the distance between the tests, the persistencies in the treatment group were always higher than those in the control group. The gamma values were 0.365 ± 0.097 ($P < 0.001$), 0.539 ± 0.157 ($P < 0.001$) and 0.365 ± 0.097 ($P < 0.001$) for overall, treatment and control group fat content, respectively. The rho values were 0.876 ± 0.112 ($P < 0.001$), 0.869 ± 0.144 ($P < 0.001$) and 0.876 ± 0.112 ($P < 0.001$) for overall, treatment and control group fat content, respectively.

In overall persistency for SCS, the gamma value was 0.428 ± 0.083 ($P < 0.001$) while the rho value was 0.896 ± 0.071 ($P < 0.001$). In the treatment group, gamma was 0.328 ± 0.126 ($P < 0.001$) and the rho value was 0.984 ± 0.082 ($P < 0.001$). In the control group, gamma was 0.511 ± 0.100 ($P < 0.001$) and rho was 0.797 ± 0.128 ($P < 0.001$). Since gamma represents the correlation when there is only one unit distance between the test days, these results show that

Table 2 Persistency values for twice a day milking (2×, control), four times a day milking (4×, treatment) and overall fat corrected daily milk yields and percentage of fat content

Distance between test days	Fat corrected milk yield			Fat content		
	2×	4×	Overall	2×	4×	Overall
1	0.501	0.681	0.552	0.321	0.539	0.365
2	0.481	0.652	0.528	0.245	0.468	0.319
3	0.462	0.624	0.504	0.187	0.407	0.280
4	0.443	0.597	0.481	0.143	0.353	0.245
5	0.425	0.572	0.459	0.110	0.307	0.215
6	0.408	0.547	0.439	0.083	0.266	00188

Table 3 Persistency values for twice a day milking (2×, control), four times a day milking (4×, treatment) and overall somatic cell scores

Distance between test days	2×	4×	Overall
1	0.511	0.328	0.428
2	0.408	0.323	0.384
3	0.325	0.317	0.344
4	0.259	0.312	0.308
5	0.207	0.307	0.276
6	0.165	0.302	0.247

the control group had higher persistency for SCS when only the succeeding test days are considered. However, the rho value, which is used in calculating persistency in non-succeeding test days, was higher in the treatment group. This is a complete opposite result from the milk yield persistency, where the treatment group had higher persistency when succeeding test days were considered.

Persistency values calculated using SCS are given in Table 3 for the treatment group and control group in addition to the overall persistency values. Overall SCS persistencies ranged from 0.25 to 0.43 for SCS while they ranged from 0.39 to 0.60 for milk yield.

In general, persistencies were higher in the control group compared to the treatment group in SCS. In contrast, the treatment group had higher persistencies in milk yield, at least for the closer test days. Because the rho value was close to unity in the treatment group of SCS, persistencies were similar regardless of the distance (Table 3), while there was a small amount of decrease in persistencies as the distance between the test days increased. This means that increasing the distance between the test days did not make much of a difference, as indicated by the rho value. Just as in the milk yield, the tie between the test days changed direction when the distance between the test days reached 4 months. Persistency was higher in the 2× group until the test days were farther apart than 4 months, after which the treatment group had higher persistencies.

Correlations between persistency measures and milk yield were all negative except that between one unit distance persistency and milk yield, when an autoregressive moving average covariance structure was used to calculate persistencies. A compound symmetry covariance structure was also used to calculate persistencies for these between-correlations. The correlation between persistency and milk yield was –0.226 ($P = 0.002$). Correlation between persistency and peak milk yield was −0.364 ($P = 0.057$) and the correlation between milk yield and peak yield was 0.962 ($P < 0.001$).

A 3D plot of milk yield versus SCS was drawn (Fig. 1) using least squares means, which showed the changes in these two traits throughout lactation, as marked by the test day. The figure indicated that the milk yield tended to show a classical lactation curve in lower SCS values. However, the milk yield tended to form a less stable, more zigzagged curve in higher SCS values.

DISCUSSION

The gamma value was higher in the treatment group compared to the control group, which indicates that increased milking frequency increased the correlation between succeeding test days. The rho value was higher in the control group, indicating that test days that are farther apart had slightly higher correlations, compared to those in the treatment, or the 4× group.

The number of mammary cells and rate of their secretion determine milk yield. After the peak, milk yield starts decreasing because of apoptosis and the decreased secretion from the individual cells (Capuco *et al*. 2003; Pala & Savas 2006). Knight and Peaker (1984) reported that in goats, the decreased milk yield after the peak is due to a decreased number of

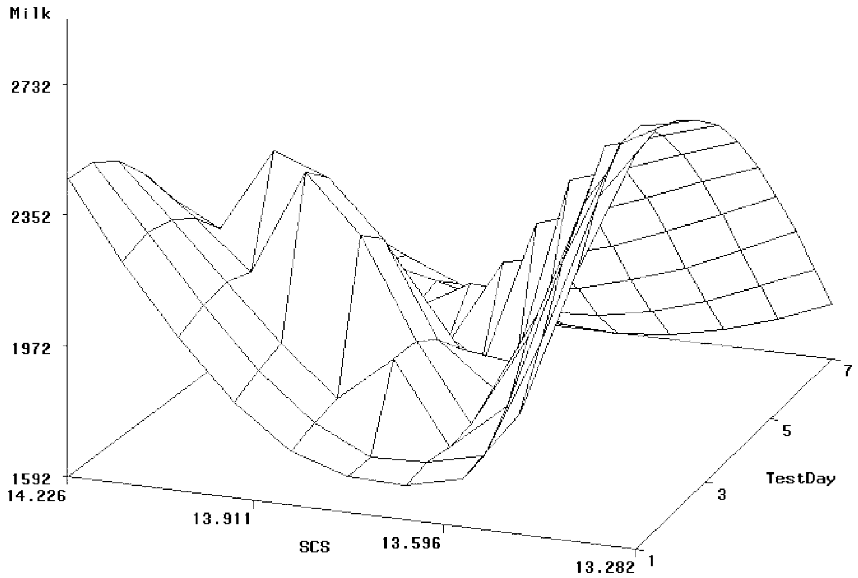

Figure 1 Changes in milk yield and somatic cell score (SCS) marked by the test day throughout lactation. X axis, SCS; Y axis, milk yield (gm); Z axis, test day.

secretory cells, and that in late lactation is due to the decreased activity per cell. The worse persistency is probably because of lost secretory cells, and because existing cells have less secretory activity (Hickson *et al.* 2006). Mammary apoptosis has been detected in the mammary tissue of lactating mice, goats and cattle and frequency of milking is one of the factors that determines the rate of cell death by apoptosis in lactating goats (Stefanon *et al.* 2002), because mammary cell death is stimulated by milk storage (Quarrie *et al.* 1994). Hickson *et al.* (2006) reported that cows milked twice daily produced more and showed more persistency of production than cows milked once daily. In this study, goats milked 4× had more persistency of production than goats milked 2× for test days that are 1, 2 or 3 months apart. The persistency values that favored the 2×, or the control group after the test days, were farther than four or more months. The tie between the test days was higher in the 4× group until the test days were separated by 4 months, after which the control group had higher persistency values (Table 1). This was because rho was higher for the control group compared to the treatment group, which could be because the treatment group had 4× for only 21 days and as the time passes after the application, the effect may diminish and correlation between the test days may be weaker. In contrast, the control group did not have any intervention in terms of milking frequency, which could be the reason the correlations between farther test days are higher in that group compared to those in the treatment group. Increased persistency means that the number of test days required decreases because there are not as many deviations as would emerge from a curve with smaller persistency value (Pala & Savas 2005, 2006).

The second measure of persistency indicated that, though the differences between the groups were not large ($P > 0.05$), the persistency of the control group was 3% higher than that of the treatment group. This criterion measures the change from the peak to the last test day. The peak occurred during the second test day and the last test day was the 7th test day. The repeated analyses using an autoregressive moving average structure indicated that the control group had higher persistency when the test days were far apart. Because there is a five-unit distance between the peak and the last test day, it is expected that this measure of persistency indicates that the control group had higher persistency while a closer look with more detailed analysis, such as the first persistency measure in this article, provides a more detailed conclusion and a better resolution. The repeated analyses showed that the control group had higher persistency for tests that are farther apart than 3 months, while treatment group had higher persistency for test days closer together, namely only one, two or three test days apart.

For fat corrected milk yield, the treatment group had higher persistencies compared to the control group, regardless of the distance between the test days. This indicates that the fat content of the milk balances out the inconsistencies in milk yield, improving persistency in the treatment group. This improvement was observed especially when the distance between test days was more than 3 months. Because the animals in the treatment group were milked more frequently for 3 weeks after weaning, they could have the fat content decreased, while keeping the milk yield steady. Salama *et al*. (2003) reported that goats milked once a day had a significantly higher fat percentage than those milked twice a day. The decrease in fat content may have helped persistency during peak lactation. In addition, the persistency of the treatment group for fat content was higher than that of the control group.

Overall persistency values were higher for milk yield compared to SCS persistency values. This indicates that somatic cells are harder to predict compared to milk yield and they require more tests for reliable estimates.

The correlations indicated that increasing milk yield decreases persistency. Increased peak milk yield decreases persistency as well and there is an almost linear relationship between the peak yield and milk yield. Dairy animals producing milk steadily are preferred to those with a higher production of milk yield at the lactation peak (Wood 1967). Pala and Savas (2006) reported that a higher peak means decreased persistency, but Calus *et al*. (2005) reported a correlation of 0.84 between persistency and peak milk yield. Togashi and Lin (2004) reported a negative correlation between lactation milk yield and persistency. In a study by Hickson *et al*. (2006), the correlations between peak yield and persistency were negative, which means that cows with flatter lactation curves have greater persistency than cows that show a large decline in production after peak.

The 3D plot showed that the milk yield curve was more stable when the SCS values were low. The unstable curve of the milk yield could be because deteriorating udder health, as indicated by the high SCS, may interfere with the natural, classical lactation curve because there is a negative genetic correlation between SCS and milk yield (De Vliegher *et al*. 2005).

Persistency, as defined in this study, is the flatness of the lactation curve, or the correlation among the test days. As persistency increases, fewer test days are required to estimate the lactation milk yield (Pala & Savas 2005, 2006). There are several definitions of persistency. One of them divides succeeding test days and uses the ratio as the persistency value. The other uses variance–covariance structures. The second is a more elaborate approach and does not require assumptions, such as that all distances are correlated equally. Another definition is the ratio of peak value to the last test value, which was used in this article. This persistency measure does not take the differences between the test days into consideration. As this study showed, the differences between farther apart test days may be high while test closer together may have higher persistencies. Though efforts in manipulating persistency seem to be focused on parameters such as peak value, peak value by itself, even along with the last test day, may sometimes fail to provide the whole picture. Measuring the persistency or flatness of the curve in more detail requires methods such as the first persistency measure in this study.

Increasing milking frequency for a short period of time (3 weeks) after weaning may help increase persistency of the milk yield, fat corrected milk yield and fat content. The milk yield tended to show a classical lactation curve in lower SCS values while forming an unstable curve in higher SCS values. Increasing milk yield decreases persistency. Increased peak milk yield decreases persistency as well. However, using methods based on peak milk yield may not give enough detail to provide the whole picture of persistency, and covariance structures should be used to get a better resolution.

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