Factors affecting milk yield and ewe's lactation curves estimated with test-day models

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ABSTRACT: Test-day records of purebred Tsigai, Improved Valachian and Lacaune ewes were analysed with a general linear model in order to investigate the effects of flock-test day, lactation number, days in milk, litter size and month of lambing. In total, 121 576 (Tsigai), 247 902 (Improved Valachian) and 2 196 (Lacaune) test-day records gathered over the period 1995–2005 were included in the analyses. Average daily milk yields were 0.604 ± 0.279 kg (Tsigai), 0.595 ± 0.243 kg (Improved Valachian) and 1.053 ± 0.475 kg (Lacaune). The significant ($P < 0.05$) or highly significant ($P < 0.01$) effects of flock-test day, lactation number (except for Lacaune), days in milk, litter size (except for Lacaune) and month of lambing (either fixed effects or covariates) tested by Fisher's tests were shown. The model explained about 50% of daily milk yield variability, with coefficients of determination as follows: 0.479 for Improved Valachian; 0.487 for Tsigai; 0.537 for Lacaune. Differences in estimated least-squares means were tested using multiple-range Scheffe's tests. A lower daily milk yield was found for the first lactation, single litter and lactations starting in March in comparison with daily milk yield for the second and third lactations (except for Lacaune), multiple litter and lactations starting in January and February (except for Improved Valachian). Ali-Schaeffer regression adopted for sheep was used for the fitting of lactation curve according to breed.

Keywords: Tsigai; Improved Valachian; Lacaune; milk yield; environmental effects; lactation curve

Environmental factors affecting variability in daily milk yield are widely documented in dairy cattle (Ng-Kwai-Hang et al., 1984; Schutz et al., 1990; Dědková and Němcová, 2003; Rekik et al., 2003), goats (Brežnik et al., 1997; Ciappesonni et al., 2004) and sheep (Gonzalo et al., 1994; Cappio-Borlino et al., 1997; Ploumi et al., 1998). Studies investigating environmental factors affecting total lactation or milking period yield in goats and sheep (Margetín et al., 1998; Margetín and Milerski, 2000; Čapistrák et al., 2002) were mostly conducted in Slovakia. New developments in modelling test-day records drew attention to the analyses of successive daily measurements also in Slovakia as many advantages were shown (Swalve, 1998). Moreover, a need for replacing dairy sheep selection programmes by more sophisticated procedures that can distinguish between genetic and environmental factors affecting daily milk traits resulted in the first attempts focused on the quantification of genetic and environmental variance parameters for Slovakian sheep (Oravcová et al., 2005). These analyses showed that the additive genetic effect accounted only for 10% (Improved Valachian) and 20% (Tsigai) of daily milk yield variability, whereas its largest portion (up to 90%) was affected by environmental effects. Accordingly, it is necessary to determine the impact of environmental effects as accurately as possible.

The aim of the present study was to analyse the environmental factors which affect daily milk yield of Tsigai, Improved Valachian and Lacaune ewes

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and to assess the differences in their lactation curves.

MATERIAL AND METHODS

Data

Data from regular milk recording in nucleus and multiplier flocks, representing about 5% of the total number of ewes in Slovakia each year, (see Oravcová et al., 2005 for details on the ICAR reference method applied) over the period 1995–2005 (Tsigai and Improved Valachian) or 1999–2005 (Lacaune) were used in the analyses. There were 121 576 test-day records belonging to 17 202 purebred Tsigai ewes, 247 902 test-day records belonging to 36 548 purebred Improved Valachian ewes and 2 196 test-day records belonging to 362 purebred Lacaune ewes. The first test-day measurements were done mostly from the second to the fourth month after lambing. Three to seven individual daily milk measurements per ewe were performed during lactation. The proportion of three daily milk measurements was low; it varied from 4% (Improved Valachian) to 10% (Tsigai and Lacaune). The proportion of four daily milk measurements was high; it varied from 81% (Tsigai) through 86% (Lacaune) to 91% (Improved Valachian). The remaining proportion of lactations was distributed over five to seven test days. Distribution of days in milk, in which individual test-day measurements were performed, was similar in the three breeds. About 80% of test-day measurements were performed between 60 and 180 days after lambing and were almost equally distributed (about 20%) over each 30-day-period. The remaining proportion of test-day measurements was performed before the 60th and after the 180th day in milk. The number of test-day measurements over days in milk decreased proportionally with the increasing number of lactation. Average number of lactations across breeds varied from 1.5 (Lacaune) through 1.7 (Improved Valachian) to 1.8 (Tsigai) lactations per head. The number of flocks across breeds varied from six (Lacaune) through 47 (Tsigai) to 75 flocks (Improved Valachian).

In all three breeds, three levels of lactation number (first, second and third), two levels of litter size (single and multiple birth) and three levels of month of lambing (January, February, March) were included in the general linear model used for the analyses. As a small number of lambings occurred in December and April, these subclasses were merged with the subsequent or previous class of month of lambing. The flock-test day effect, used to model management and environmental conditions affecting each daily milk measurement, accounted for 96 (Lacaune), 1 034 (Tsigai) and 1 647 (Improved Valachian) levels. Distribution of records over flock-test day levels was unbalanced; it varied from ten records to 59 (Lacaune), 330 (Tsigai) and 577 (Improved Valachian) records. Stage of lactation was modelled by days in milk considered covariates nested within lactation. Ali-Schaeffer lactation sub-model (Ali and Schaeffer, 1987) adopted for sheep was employed in the analyses.

Statistical model

General linear model (GLM procedure; SAS/STAT 9.1, 2002–2003) was applied to study the influence of factors affecting daily milk yield of ewes. Least-squares means and standard errors were calculated. Statistical significance of the differences between least-squares means was determined using Scheffe's multiple-range tests.

The identical statistical model was considered for all three breeds:

$$y_{ijklm} = \mu + L_i + S_j + M_k + FTD_l + b_{1i}\left(\frac{DIM_{ijklm}}{C}\right) + b_{2i}\left(\frac{DIM_{ijklm}}{C}\right)^2 + b_{3i}\ln\left(\frac{C}{DIM_{ijklm}}\right) + b_{4i}\ln^2\left(\frac{C}{DIM_{ijklm}}\right) + e_{ijklm}$$

where:

y_{ijklm} = individual observation of daily milk yield (kg)
μ = intercept
L_i = fixed effect of lactation number (i =1, 2 and 3)
S_j = fixed effect of litter size (j = 1 and 2+)
M_k = fixed effect of month of lambing (k = 1, 2 and 3)
FTD_l = fixed effect of flock-test day (l = 1 to 1 034 for Tsigai, 1 to 1 647 for Improved Valachian and 1 to 96 for Lacaune)
$b_{1i}, b_{2i}, b_{3i}, b_{4i}$ = regression coefficients associated with *DIM* (days in milk nested within lactation)
C = constant associated with standardised length of milking period in Slovakian sheep (150 days)
e_{ijklm} = random error, $N(0, \delta_e^2)$

Breed lactation curves were constructed on the basis of solutions of the statistical model.

RESULTS AND DISCUSSION

Breeds under study are dual-purpose breeds in the Slovakian sheep husbandry system with about the same income for milk and lamb meat. Mainly Tsigai and Improved Valachian produce lower milk yields than most breeds distributed over Europe and Israel (Table 1). Overall means and standard deviations for daily milk yields calculated for Tsigai, Improved Valachian and Lacaune ewes were 0.604 ± 0.279 kg, 0.595 ± 0.243 kg and 1.053 ± 0.475 kg, respectively. In comparison with the study of Margetín et al. (1998) conducted in the period 1995–1996, the increase of average daily milk yield by 13% (Tsigai) and 24% (Improved Valachian) was observed. Differences were probably a result of different periods of covered and selection done (mainly before the year 2000). Contrariwise, small differences (only 4% for both breeds) observed when daily milk yields of Tsigai and Improved Valachian ewes were compared with previous analyses based on the test-day approach (Oravcová et al., 2005) indicate that the phenotype selection of the last years (since 2000) was not reflected in higher milk yields. Average daily milk yield of Tsigai and Improved Valachian breeds was much lower than daily milk yield of dairy breeds like East Friesian (Hamann et al., 2004), Assaf (Pollot and Gootwine, 2004), Churra (Baro et al., 1994; Gonzalo et al., 1994; El-Saied et al., 1998; Fuertes et al., 1998), and also Bovec, Istrian Pramenka (Komprej et al., 2003), Black-Faced and Blond-Faced Latxa (Gabina et al., 1993), and Sfakia (Kominakis et al., 2001). On the contrary, it was higher in comparison with Florina (Christodoulou et al., 1997) and Cine Type sheep (Karaca et al., 2000) classified as multipurpose breeds. Daily milk yield of Lacaune, although higher than daily milk yield of Tsigai and Improved Valachian, was lower than daily milk yield of comparable breeds reported in the literature – East Friesian (Hamann et al., 2004), Assaf (Pollot and Gootwine, 2004) and Lacaune (Barillet et al., 2001; Berger, 2004). The lower milk yield of Lacaune kept in Slovakia is probably a result of different feeding level and insufficient adaptability to different management and environmental conditions that do not allow the outstanding genetic potential to be manifested.

Following the values given in Table 2, the effects included in the statistical model: lactation number, litter size, month of lambing, flock-test day and, also, covariates associated with days in milk showed a statistically significant ($P < 0.05$) or statistically highly significant ($P < 0.01$) influence on daily milk

Table 1. Literature review of average daily milk yield in various sheep breeds

Source	Breed	Average daily milk yield (l or kg)
Margetin et al. (1998)	Tsigai	0.536
	Improved Valachian	0.482
Oravcová et al. (2005)	Tsigai	0.630
	Improved Valachian	0.620
Gabina et al. (1993)	Latxa Black-Faced	0.820
	Latxa Blond-Faced	0.740
Barro et al. (1994)	Churra	0.845
Gonzalo et al. (1994)	Churra	0.912
El-Saied et al. (1997)	Churra	0.948
Fuertes et al. (1998)	Churra	1.008
Komprej et al. (2003)	Istrian Pramenka	0.708
	Bovec	1.089
Kominakis et al. (2001)	Sfakia	0.704
Hamann et al. (2004)	East Friesian	2.330
Pollot and Gootwine (2004)	Assaf	1.930
Barillet et al. (2001)	Lacaune	1.640
Berger (2004)	Lacaune	1.640
Christodoulou et al. (1997)	Florina	0.470
Karaca et al. (2000)	Cine Type	0.525

Table 2. General linear model for daily milk yield according to breed

	Tsigai		Improved Valachian		Lacaune	
Effects	DF	MS	DF	MS	DF	MS
Lactation No. (L)	2	0.19*	2	0.17*	2	0.10
Litter size (S)	1	7.31**	1	11.32**	1	0.01
Month of lambing (M)	2	0.55**	2	2.77**	2	0.96**
Flock-test day (FTD)	1 033	2.59**	1 646	3.13**	95	1.41**
DIM/C	3	0.23**	3	0.10*	3	0.31*
(DIM/C)2	3	0.22**	3	0.17**	3	0.30*
ln(C/DIM)	3	0.19**	3	0.03	3	0.26
ln2(C/DIM)	3	0.23**	3	0.05	3	0.28*

DF = degrees of freedom; MS = means squares; DIM = days in milk; C = const = 150
*P < 0.05; **P < 0.01 (Fisher's test)

Table 3. General linear model for daily milk yield according to breed – cont

	Tsigai	Improved Valachian	Lacaune
R^2	0.487	0.479	0.537
RSD	0.201	0.176	0.333

R^2 = coefficient of determination; RSD = residual standard deviation

yield, except for lactation number and litter size in Lacaune breed.

According to Table 3, an adjustment for considered effects diminished the variability of daily milk yield by 28% (for Tsigai from 0.279 to 0.201 kg; for Improved Valachian from 0.243 to 0.176 kg) and 30% (for Lacaune from 0.475 to 0.333 kg). The statistical model fitted well for the analyses of daily milk yield in all three breeds. Coefficients of determination (R^2s) were almost identical for the three breeds, varying from 0.479 to 0.537. However, R^2s reported in the literature were mostly higher. In Sarda, Florina and Assaf sheep, Sanna et al. (1994), Christodoulou et al. (1997), and Gootwine and Pollot (2002) reported R^2s from 0.55 through 0.57 to 0.75. In White Shorthaired goats, Margetín and Milerski (2000) reported R^2s from 0.65 to 0.79 (depending on either herd and year or herd-year-season effects involved). Previous analyses of lactation milk yield in Tsigai and Improved Valachian breeds (Margetín et al., 1998) showed lower R^2s (decrease by 10 and 29%). Studies on Creole sheep (Peralta-Lailson et al., 2005) also showed lower R^2s in comparison with the analyses of Slovakian sheep (0.2701 up to 0.4019).

The extent to which the environmental effects influenced daily milk yield of analysed breeds is summarized in Table 4. Trends in least-squares means (LSMs) for the first, second and third lactation were similar (except for Lacaune) to those reported in literature with the significantly lowest daily milk yield of primiparous ewes that increased along with the increasing number of lambings (0.034 and 0.052 kg higher in the third lactation than in the first lactation for Tsigai and Improved Valachian, respectively). The findings for these two breeds agree with findings of Cappio-Borlino et al. (1997) and Ruiz et al. (2000). Lacaune breed showed a balanced milk yield over successive lactations with non-significant (P > 0.05) differences that were lower than 4%. Differences in the first three lactations found for the remaining two breeds (less than 10%) were in accordance with findings of Gonzalo et al. (1994), Christodoulou et al. (1997), El-Saied et al. (1998) and Margetín et al. (1998). However, Cappio-Borlino et al. (1997), Margetín and Milerski (2000) and Ciappesoni et al. (2004) found differences in the first three lactations between 13 and 17% for Valle del Belice ewes; 11 and 15% and 18 and 25% for White Shorthaired goats kept in Slovakia and the Czech Republic.

A lower daily milk yield was recorded in ewes lambing singles in comparison with ewes lambing multiples (P < 0.01 for Tsigai and Improved Valachian; P > 0.05 for Lacaune). Differences in daily milk yield between the ewes lambing singles and multiples were 0.020 (Tsigai), 0.019 (Improved Valachian) and 0.001 kg (Lacaune) in favour of daily milk yield associated with multiples. These findings are in agreement with Gabina et al. (1993) and

Table 4. Least-squares means and standard errors for daily milk yield according to breed

Effect/Breed	Tsigai		Improved Valachian		Lacaune	
	n	$\mu \pm S_{\mu i}$	n	$\mu \pm S_{\mu i}$	n	$\mu \pm S_{\mu i}$
Lactation (kg)						
First (1)	50 008	0.574 ± 0.0013	10 4566	0.577 ± 0.0008	1 192	1.112 ± 0.0132
Second (2)	43 204	0.599 ± 0.0013	91 005	0.628 ± 0.0009	607	1.118 ± 0.0168
Third (3)	28 364	0.608 ± 0.0015	52 331	0.629 ± 0.0010	397	1.074 ± 0.0209
Multiple-range tests		1:2**, 1:3** 2:3**		1:2**, 1:3**		
Litter size						
Single birth (1)	95 297	0.583 ± 0.0010	20 0631	0.610 ± 0.0006	1 514	1.101 ± 0.0138
Multiple birth (2)	27 885	0.603 ± 0.0015	47 271	0.629 ± 0.0010	682	1.102 ± 0.0149
Multiple-range tests		1:2**		1:2**		
Month of lambing						
January (1)	37 602	0.594 ± 0.0018	34 961	0.599 ± 0.0015	361	1.122 ± 0.0325
February (2)	73 513	0.599 ± 0.0010	17 5660	0.616 ± 0.0006	1 273	1.145 ± 0.0129
March (3)	10 461	0.587 ± 0.0032	37 281	0.617 ± 0.0015	562	1.036 ± 0.0282
Multiple-range tests		2:3**		1:2**, 1:3**		2:3**

*$P < 0.05$; **$P < 0.01$ (Scheffe's test)

Gonzalo et al. (1994) and reflect the stimulus of litter size. Breeds under study are of lower fertility; ewes mostly produce singles, and there occurred about 22 (Tsigai), 20 (Improved Valachian) and 31% (Lacaune) of lactations with multiple births.

As for the lambing month effect, Improved Valachian ewes with lactations starting in January and February produced daily milk yield (0.599 and 0.616 kg) which was lower than daily milk yield of ewes with lactations starting in March (0.617 kg). An opposite trend was observed for the remaining breeds (Tsigai and Lacaune). For Tsigai, a significant difference ($P < 0.05$) was found between lactations starting in February and March (0.599 vs. 0.587 kg). For Lacaune, there was a highly significant ($P < 0.01$) difference between lactations starting in February and March (1.145 vs. 1.036 kg). A lower daily milk yield found for lactations starting in January and February (Improved Valachian) is in agreement with findings of Ciappesoni et al. (2004) for White Shorthaired goat, who explained this fact by poor quality feeding and change from winter to summer ration. An opposite trend in Tsigai and Lacaune (milk yield lower for lactations starting in March) is in agreement with findings of Cappio-Borlino et al. (1997) for Valle del Belice.

Lactation curves according to breeds are given in Figure 1, 2 and 3. The peak of lactation curves occurred in about 20–40 days after lambing (except for the first lactation in Tsigai with the peak at an

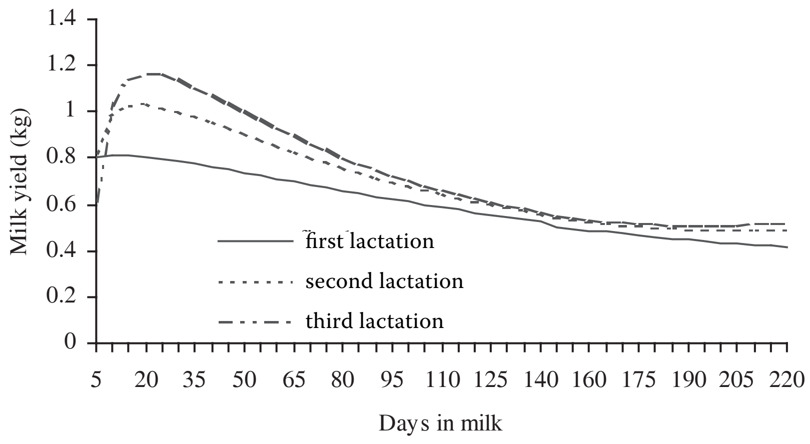

Figure 1. Lactation curves estimated for Tsigai breed

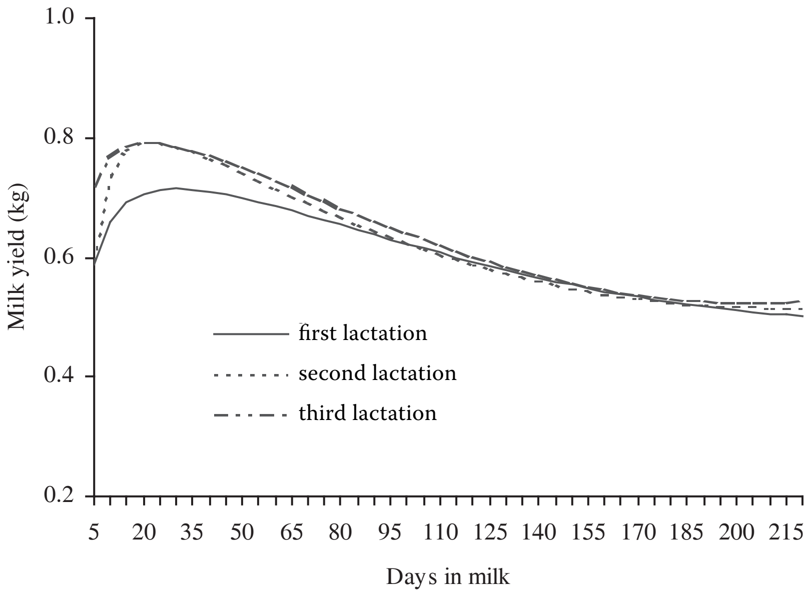

Figure 2. Lactation curves estimated for Improved Valachian breed

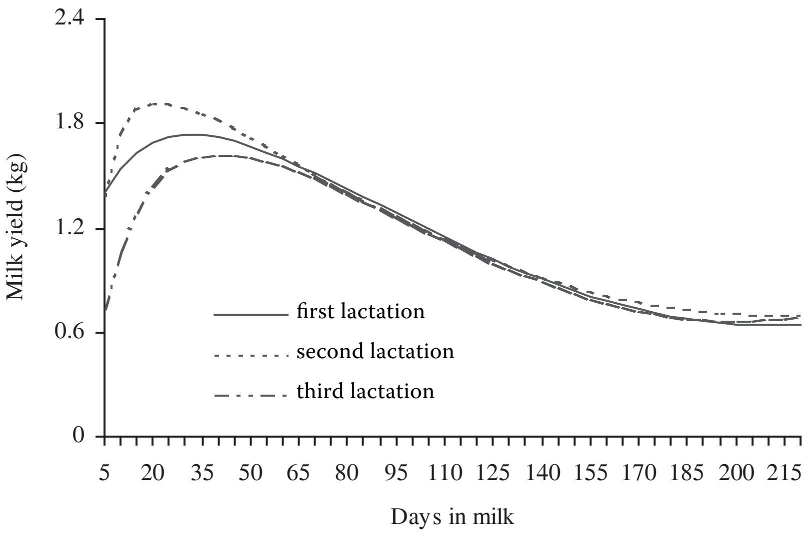

Figure 3. Lactation curves estimated for Lacaune breed

earlier stage). After the peak is achieved (more or less visible in dependence on the breed), the pattern with progressively decreasing daily milk yield until the end of lactation can be observed (see Alderman and Cottrill, 1995; Komprej et al., 2003; Peralta-Lailson et al., 2005, for a comparison with dairy and suckler cows, Slovene sheep and black variety of Creole sheep). Contrariwise, Carta et al. (1995) and Peralta-Lailson et al. (2005) reported only a decreasing shape of lactation curve for Sarda dairy sheep and White and Brown varieties of Creole sheep.

A decrease in daily milk yield between the beginning and the end of lactation differed in the particular breeds (6% per 30-day-period for Improved Valachian; 10 to 13% for Tsigai and Lacaune). Smaller differences in lactation stages found for Improved Valachian, built as a composite breed of former Valachian with Texel, Lincoln Longwool and Leicester Longwool, correspond with small differences in lactation stages in suckler cows (Alderman and Cottrill, 1995). Smaller differences in lactation stages, however, may also be associated with the level of feeding. Improved Valachian breed is kept in hilly locations of northern Slovakia and fits well the less favourable environment of extensive production systems. Poor quality feeding, mainly at the beginning of lactation, may be responsible for relatively low milk yield on the first test days, although a lower amount of data is available for this stage of lactation (suckling period of about 54–55 days in the three breeds). On the other hand, pasture of higher quality during late spring and summer may be responsible for relatively high milk yield at the middle and end of lactation.

Almost identical milk yield at the end of lactations in Improved Valachian (from 0.50 to 0.53 kg) and Tsigai (0.42 to 0.52 kg) may be caused by similarity in the production level of these breeds. With regard to the milk production level at the beginning of lactations, the shape of lactation curves brings the evidence of lower persistency in Lacaune breed (milk yield varying between 1.50 and 1.90 kg at the peak vs. milk yield varying between 0.64 and 0.69 kg at the end of lactation). Moreover, the shape of lactation curves in the three breeds showed that the ewes in the first lactation, although producing at a lower level than older ewes, had higher persistency.

The analyses revealed that the structure of data in test-day measurements of Slovakian ewes is inappropriate to produce solutions for more complicated models (days in milk modelled within litter size and month of lambing effects). The analyses also revealed that coefficients of determination and residual standard deviations showed stability and changed minimally with the models used. When the investigated effects were evaluated separately, the highest influence of flock-test day effect was proved. When variant combinations of effects were considered, their proportion in total variability of daily milk yield differed between the models used.

CONCLUSION

Results of the present study highlight the relevant factors affecting variability of daily milk yield and give useful information on its main features in various sheep breeds. Although the results did not confirm statistical significance of all environmental effects studied in milk yield of Lacaune, they provide reasonable findings about milk performance of this breed under Slovakian production conditions. Differences in the shapes of lactation curves between breeds are of particular interest.

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