Covariance components by a repeatability model in Slovenian dairy sheep using test-day records

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ABSTRACT: The estimation of covariance components for daily milk yield, fat and protein content was performed in three Slovenian dairy sheep breeds (Bovec, Improved Bovec, and Istrian Pramenka). In the period 1994–2002, 38 983 test-day records of 3 068 ewes were collected according to ICAR regulations (method A4). All the available relationships between animals were considered. For that reason, information on 3 534 animals was included. Test-day records were analysed by a multiple-trait repeatability animal model. In its fixed part, the model contained breed and season of lambing as classes. Days after lambing, parity, and litter size were treated as covariates. Days after lambing were modelled with modified Ali-Schaeffer's lactation curve, parity with quadratic, and litter size with linear regression. The random part of the model consisted of flock-test month effect, additive genetic effect, permanent environment effect over lactations, and permanent environment effect within lactation. Covariance components were estimated using the restricted maximum likelihood method (REML). The estimated heritabilities were 0.11 for daily milk yield, 0.08 for fat content, and 0.10 for protein content. A relatively high variance ratio for all milk traits was explained by the flock-test month effect (from 0.27 for daily milk yield to 0.57 for protein content), while ratios explained by both permanent environment effects were lower (up to 0.13). Additive genetic correlations between daily milk yield and fat content, and daily milk yield and protein content were negative and similar (–0.36 and –0.37). A high and positive (0.67) additive genetic correlation between fat and protein content was found. Correlations for environmental effects showed a pattern similar to additive genetic correlations. Genetic parameters estimated in Slovenian dairy sheep showed that genetic progress in milk traits could be achieved using test-day milk records.

Keywords: milk traits; genetic and environmental effects; heritability

In the last few years, the dairy sheep population in Slovenia has increased, mainly due to consumer interest in sheep milk products such as cheese and curd. The population size is estimated to be 5 000 dairy sheep. Almost half of the dairy sheep are reared in flocks in which milk recording is performed (Kompan et al., 2006). Three dairy sheep breeds are mainly used. The autochthonous Bovec (B) breed is used in the western part of Slovenia around the town of Bovec and the Trenta valley. The autochthonous Istrian Pramenka (IP) breed is preserved in the Karst region in the south-western part of Slovenia. A part of the Bovec breed population has been upgraded with the East Friesian breed. The Improved Bovec (IB) breed is also reared in the western part of the country. All three breeds are kept in the traditional environment and reared in a traditional way, except for the part of breed B. Climate conditions are especially different between the regions with breeds B and IP. Most of the breed B breeders take advantage of summer transhumance, and take their animals to mountain pastures.

Sheep milk production in our climate is mostly seasonal. Lambing occurs mainly between February and April. The suckling period lasts approximately two months after lambing. However, there is a considerable variation between and within flocks since breeders often wean the majority of lambs at a particular date and start milking the whole flock of ewes. Thus, milking of ewes starts at different stages of lactation, most often after the peak of the lactation curve is reached. Although test-day records are scarce at the beginning of lactation, Komprej et al. (2003) showed that it is possible to obtain consistent estimates of lactation curves for all periods of lactation. On the other hand, the mating season starts in early autumn before lactation is completed and can last for the entire winter. Breeding values for the selection of parents of the next generation should be available before the mating season starts.

Until a few years ago, the estimation of genetic parameters for milk traits was based on lactation yield in cattle (Danell, 1982; Schaeffer and Jamrozik, 1996), as well as in sheep (El-Saied et al., 1998a,b; Portolano et al., 2001). This approach has some deficiencies. Breeding values are predicted on the basis of only one record (lactation yield) per animal within lactation, which comprises data over lactation. The individual test-day records are not adjusted for specific environmental effects. Genetic evaluation can be performed only when lactation is completed. In the last fifteen years, the repeatability model has been introduced using individual measurements of milk traits (Ptak and Schaeffer, 1993). Such a model has the advantage of modelling individual measurements appropriately. The accuracy of breeding values is higher due to a larger number of records per animal and better adjustments. Furthermore, there is no need to wait until the end of lactation. This approach makes it possible to select animals before the new breeding season starts. A shortened generation interval and higher accuracy of genetic evaluation increases the genetic progress at the same selection intensity. The repeatability model with test-day records was used in French Lacaune dairy sheep by Barillet and Boichard (1994). The model was applied several times to Spanish Churra ewes by Baro et al. (1994), El-Saied et al. (1998a,b,c) and also to Latxa and Manchega sheep by Serrano et al. (2001). It was also used in Slovenian dairy sheep breeds by Brežnik (1999) and in Improved Walachian and Tsigai breeds from Slovakia by Oravcová et al. (2005).

The first application of the repeatability model with test-day records in Slovenia was performed in dairy goats by Andonov (1994) and Andonov et al. (1998). Brežnik (1999) later applied the repeatability model for covariance component estimation in dairy sheep and also in dairy goats (Brežnik et al., 2000). The number of test-day records in dairy sheep has increased substantially in the last few years. Therefore, the aim of the study was to re-estimate the covariance components using the multiple-trait repeatability animal model for daily milk yield (DMY), fat (FC) and protein content (PC) in Slovenian dairy sheep. The statistical model was also improved by the inclusion of additional effects which are recorded in dairy sheep flocks.

MATERIAL

Data for the analysis of milk traits in Bovec (B), Improved Bovec (IB) and Istrian Pramenka (IP) breeds of sheep were obtained from the Slovenian breeding programme for small ruminants. Test-day records were collected according to ICAR regulations (ICAR, 2005) by the A4 method in 36 flocks. In the period 1994–2002, 38 983 test-day records (Table 2) of 3 068 ewes (Table 1) were analysed. Data were edited before the analysis in order to avoid outliers. It was required that all three measurements (daily milk yield – DMY, daily fat content – FC and daily protein content – PC) be made

Table 1. Number of animals with records and number of animals in pedigree file by breeds

	Breed			
	breeds together	Bovec (B)	Improved Bovec (IB)	Istrian Pramenka (IP)
Ewes with records	3 068	1 957	486	625
Pedigree	3 534	2 244	677	720
Non-base	2 346	1 458	500	440
Base	1 188	786	177	280

Table 2. Descriptive statistics by breeds

Breed	Trait	Number of records	Mean	Standard deviation (SD)
Breeds together	daily milk yield (g)	38 983	1 022	692
	fat content (%)		6.62	1.59
	protein content (%)		5.51	1.07
Bovec (B)	daily milk yield (g)	26 587	1 090	743
	fat content (%)		6.59	1.60
	protein content (%)		5.53	1.14
Improved Bovec (IB)	daily milk yield (g)	6 414	1 010	611
	fat content (%)		6.22	1.32
	protein content (%)		5.33	0.87
Istrian Pramenka (IP)	daily milk yield (g)	5 982	731	408
	fat content (%)		7.20	1.62
	protein content (%)		5.63	0.90

within each test-day. Records collected between the 5th and 244th day after lambing were used for the analysis. Each animal had to have at least three test-day records within lactation. DMY was restricted to at least 50 g. FC could vary between 1.5 and 18% and PC between 2.0 and 13%. Measurements with parity 11 and more were rare and thus discarded. Records with three or more lambs born were treated as one group. The number of measurements decreased about 7% after the edits.

The distribution of test-day records over the lactation is shown in Figure 1. There were some records from the beginning of lactation, but the majority of records were collected in the middle of lactation. In breed B, the suckling period was on average shorter than in the other two breeds, what resulted in shifted distribution of records for the breed. The majority of records in breed B were available from the third to the fifth month of lactation, while in the other two breeds, records were mainly available in the middle and towards the end of lactation.

A pedigree file was set up using all the available relationships between animals and contained 3 534 animals of both sexes (Table 1). Only natural mating took place in the flocks. Two thirds of the animals belonged to breed B. The number of animals summed across breeds was slightly higher than 3 534 because of some common ancestors in breeds B and IB. There were 2 346 (66.38%) animals with at least one ancestor known and 1 188 base animals with both ancestors unknown.

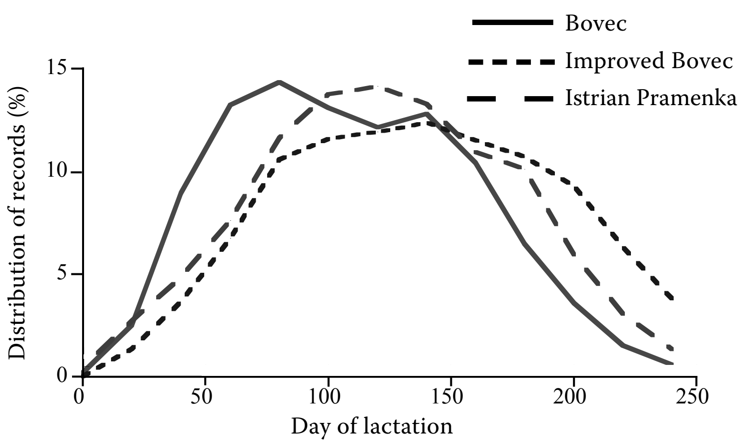

Figure 1. Distribution of test-day records over lactation by breeds

METHODS

Descriptive statistics for data, as well as development of the fixed part of the model were done using the GLM (General Linear Model) procedure in statistical package SAS (SAS, 2001). Fixed effects were included in the model on the basis of significance level (*P*-value), degrees of freedom, and ratio of explained variance. Models with a high ratio of explained variance and a small number of degrees of freedom were favourable. Furthermore, covariance components were estimated by the multiple-trait repeatability animal model using restricted maximum likelihood (REML) using VCE (Variance Covariance Estimation) programme package (Kovač et al., 2002).

Test-day records for DMY, FC, and PC (y_{ijklmn}) were modelled using the three-trait repeatability animal model (Equation 1). Preliminary analyses (Brežnik, 1999; Komprej, 2006) showed that the joint analysis of all three breeds was appropriate due to a small number of data in Improved Bovec and Istrian Pramenka breeds.

The model contained breed (B_i) with three levels and season of lambing (S_j) with 63 levels in the fixed part. Season of lambing was represented as year and month of lambing interaction. Furthermore, days after lambing (x_{ijklmn}), parity (z_{ijklmn}), and litter size as a number of born lambs (w_{ijklmn}) were treated as covariates.

$$y_{ijklmn} = B_i + S_j + \sum_{q=1}^{4} b_{iq}x_q + b_5(z_{ijklmn} - \bar{z}) + b_6(z_{ijklmn} - \bar{z})^2 + b_7(w_{ijklmn} - \bar{w}) + fym_k + a_{il} + p_{il} + l_{ilm} + e_{ijklmn} \quad (1)$$

Days after lambing, nested within breed, were modelled by modified Ali-Schaeffer's lactation curve (Ali and Schaeffer, 1987) with four regression coefficients. Variables which describe the lactation curve are linear (x_1) and quadratic (x_2) terms of the stage of lactation, and linear (x_3) and quadratic (x_4) terms of their transformation by natural logarithm (Equation 2). Instead of the constant 305, the constant 150 was used because lactation in sheep usually ends earlier than in cows.

$$x_1 = x_{ijklmn}/c; \quad x_2 = (x_{ijklmn}/c)^2$$
$$x_3 = \ln(x_{ijklm}); \quad x_4 = (\ln(x_{ijklmn}))^2, \quad c = 150 \quad (2)$$

Simple quadratic and linear regressions provided parsimonious fit for parity and litter size, respectively. The random part of the model contained the effect of flock-test month as flock-year-month of test-day interaction (fym_k), additive genetic effect of the animal (a_{il}), permanent environment effect over lactations (p_{il}), permanent environment effect within lactation (l_{ilm}), and residual (e_{ijklmn}). There were 1 103 levels for the flock-test month effect, 3 068 levels for permanent environment effect over lactations and 8 163 levels for permanent environment effect within lactation. Although many studies treat the flock-test month as fixed, in our study the effect was treated as random due to a small number of records per test-day within some flocks.

The matrix form of the model can be presented as shown in equation 3.

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{Z_f f} + \boldsymbol{Z_a a} + \boldsymbol{Z_p p} + \boldsymbol{Z_l l} + \boldsymbol{e} \quad (3)$$

where:

$\boldsymbol{y}$ = the vector of observations for DMY, FC, and PC

$\boldsymbol{\beta}$ = the vector of unknown parameters for fixed effects

f, **a**, **p**, **l** = vectors of unknown parameters for flock-test month effect, additive genetic effect, permanent environment effect over lactations, and permanent environment effect within lactation, respectively

vector $\boldsymbol{e}$ = the vector of residuals

matrix $\boldsymbol{X}$ = the incidence matrix for fixed effects

$\mathbf{Z}_f$, $\mathbf{Z}_a$, $\mathbf{Z}_p$, $\mathbf{Z}_l$ = incidence matrices for random flock-test month effect, additive genetic effect, permanent environment effect over lactations, and permanent environment effect within lactation, respectively

We assumed that the expected value of observations was equal to **Xß** (Equation 4), while the expected values for all random effects were equal to zero.

$$E[\boldsymbol{y}] = \boldsymbol{X\beta} \quad (4)$$

Phenotypic variance (Equation 5) was composed of variance components for individual random effects of flock-test month (**F**), additive genetic effect (**G**), permanent environment over lactations (**P**), permanent environment within lactation (**L**) and residual (**R**).

$$\mathbf{V} = \mathrm{var}(\boldsymbol{y}) = \boldsymbol{Z_f F Z_f'} + \boldsymbol{Z_a G Z_a'} + \boldsymbol{Z_p P Z_p'} + \boldsymbol{Z_l L Z_l'} + \boldsymbol{R} \quad (5)$$

The structure of individual covariance components is seen in equation 6.

where:

matrices $\mathbf{I}_f$, $\mathbf{I}_p$, $\mathbf{I}_l$, and $\mathbf{I}_e$ = the identity matrices for individual random effects and residual

The order of identity matrices is equal to the number of levels for each random variable. Effects and levels for all random effects and residual were assumed to be uncorrelated, except for the additive genetic effect, where the relationship among levels is described by the relationship matrix **A**. (Co)variances among measurements (traits) within each level were presented by matrices $\mathbf{F}_0$ for flock-test month effect, $\mathbf{G}_0$ for additive genetic effect, $\mathbf{P}_0$ for permanent environment effect over lactations, $\mathbf{L}_0$ for permanent environment effect within lactation, and $\mathbf{R}_0$ for residual. Symbol ⊗ is the Kronecker product. Residuals were assumed to be independent and normally distributed.

$$\mathrm{Var}\begin{bmatrix}\mathbf{f}\\ \mathbf{a}\\ \mathbf{p}\\ \mathbf{l}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\mathbf{F} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{G} & \mathbf{0} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{P} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{L} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{R}\end{bmatrix} = \begin{bmatrix}\mathbf{I_f}\otimes\mathbf{F_0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{A}\otimes\mathbf{G_0} & \mathbf{0} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{I_p}\otimes\mathbf{P_0} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{I_l}\otimes\mathbf{L_0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{I_e}\otimes\mathbf{R_0}\end{bmatrix} \quad (6)$$

RESULTS

The average DMY of the total population was 1 022 g with 6.62% FC and 5.51% PC (Table 2). Of all three breeds, breed B had the largest number of test-day records (26 587) and also the highest average DMY (1 090 g). Breeds IB (6 414) and IP (5 982) had a considerably smaller number of records. The lower average for DMY in breed IB (1 010 g) than in breed B is caused by a longer suckling period and consequently, by a larger proportion of records after the peak of lactation. Breed IB may also be less suitable for extensive conditions during winter in comparison with breed B. Breed IP had the lowest average DMY (731 g) among all three breeds. The standard deviation for DMY ranged between 408 g in breed IP and 743 g in breed B. Breed IP had the highest FC (7.20% vs. 6.59% for breed B and 6.22% for breed IB), as well as the highest PC

Table 3. Estimates with standard errors for variance ratios (on diagonal), correlations (above diagonal) and phenotypic variance

	Daily milk yield (g)	Fat content (%)	Protein content (%)
Common flock environment			
Daily milk yield (g)	0.27 ± 0.007	–0.13 ± 0.014	–0.06 ± 0.014
Fat content (%)		0.43 ± 0.007	0.61 ± 0.013
Protein content (%)			0.57 ± 0.007
Permanent environment over lactations			
Daily milk yield (g)	0.11 ± 0.007	–0.25 ± 0.043	–0.25 ± 0.051
Fat content (%)		0.05 ± 0.003	0.49 ± 0.031
Protein content (%)			0.03 ± 0.002
Permanent environment within lactation			
Daily milk yield (g)	0.13 ± 0.003	–0.35 ± 0.029	–0.16 ± 0.027
Fat content (%)		0.02 ± 0.002	0.35 ± 0.057
Protein content (%)			0.01 ± 0.001
Additive genetic effect			
Daily milk yield (g)	0.11 ± 0.008	–0.36 ± 0.037	–0.37 ± 0.037
Fat content (%)		0.08 ± 0.003	0.67 ± 0.014
Protein content (%)			0.10 ± 0.004
Residual			
Daily milk yield (g)	0.37 ± 0.004	–0.09 ± 0.004	–0.20 ± 0.004
Fat content (%)		0.42 ± 0.006	0.32 ± 0.004
Protein content (%)			0.29 ± 0.005
Phenotypic variance			
Daily milk yield (g)	176 753	–81.000	–38.000
Fat content (%)		1.607	0.547
Protein content (%)			0.739

in milk (5.63% vs. 5.53% for breed B and 5.33% for breed IB). This was expected since it is known that breeds with low DMY have high FC and PC. The standard deviation for FC and PC ranged from 0.87% in breed IB to 1.62% in breed IP.

Variance components for milk traits in dairy sheep were split into five components. The largest components were estimated for flock-test month effect and residual. Flock-test month effect, as a flock-year-month of test-day interaction, presents different technologies of sheep breeding and feeding manners among flocks including temporary events within the flock on test-day or some days before. The effect explained the largest part of phenotypic variance among all random effects, especially in PC (Table 3). The flock-test month effect accounted for 27% of total variance in DMY, 43% in FC, and 57% in PC.

Variance ratios for permanent environment effect over lactations were low in all milk traits. The value for DMY was 0.11, and only 0.05 for FC and 0.03 for PC. The effect relates to the rearing conditions of the animal from its birth to the first parturition, affecting milk traits in all lactations. As seen from the results, the preparation of ewes for reproductive life is more important in milk yield than in its components.

Additional effects on a particular animal, common to individual lactation, e.g. preparing the animal for individual lactation, are included in permanent environment effect within lactation. The preparation of ewes for individual lactation is also more important in milk yield than in its components. The effect explained a variance ratio that was slightly higher for DMY (0.13) compared to permanent environment effect over lactations, but lower for FC (0.02) and PC (0.01).

Estimates for heritability were low in all milk traits, although the size of the additive genetic variance was relatively high. The heritability estimate for DMY was 0.11. The estimate for FC was slightly lower (0.08) than for DMY, but the heritability for PC was similar (0.10) to heritability for DMY.

The unexplained variance in milk traits is accumulated in residual. The highest residual variance ratio was found in FC (0.42). The ratios were lower in DMY (0.37) and PC (0.29).

Additive genetic correlations (Table 3) between DMY and FC, and DMY and PC were negative as expected, and of similar magnitude (–0.36 and –0.37). A high and positive additive genetic correlation between FC and PC was noticed (0.67). Correlations for environmental effects and for residual between milk traits showed patterns similar to additive genetic correlations. The correlations between DMY and FC, and DMY and PC were low for flock-test month effect, but they were higher for both permanent environment effects. On the contrary, the correlation between FC and PC for flock-test month effect was higher than for both permanent environment effects.

DISCUSSION

Most of sheep milk in our country is home processed into cheese and curd. Besides milk yield, its composition is also an important factor for milk processing. The average DMY of the Bovec (1 090 g), Improved Bovec (1 010 g) and Istrian Pramenka (731 g) sheep population in our study was much lower than DMY of East Friesian dairy breed (2 330 g) reported by Hamann et al. (2004). Daily milk yield in breeds B and IB was comparable to DMY in Churra (1 008 g; Fuertes et al., 1998), Sarda (1 065 g; Carta et al., 2001) and Lacaune (1 074 to 1 112 g; Oravcová et al., 2006) sheep. Lower DMY than in our B and IB breeds were reported for Chios (540 g; Ploumi et al., 1998), Latxa (896 g; Serrano et al., 2001), Manchega (993 g; Serrano et al., 2001), Tsigai (574 to 608 g; Oravcová et al., 2006), and Improved Walachian (577 to 629 g; Oravcová et al., 2006) breeds. In Istrian Pramenka, the average DMY (731 g) was higher than in Chios (540 g; Ploumi et al., 1998), Tsigai (574 to 608 g), and Improved Walachian breeds (577 to 629 g; Oravcová et al., 2006), but lower than in Churra (1 008 g; Fuertes et al., 1998), Sarda (1 065 g; Carta et al., 2001), Latxa (896 g; Serrano et al., 2001), and Manchega (993 g; Serrano et al., 2001) sheep.

In general, the average FC and PC in all three Slovenian breeds were lower in comparison to the previously mentioned sheep breeds observed by Ploumi et al. (1998), Carta et al. (2001) and Oravcová et al. (2007). Contrary, all three observed breeds had higher FC and PC in milk than East-Friesian sheep reported by Hamann et al. (2004).

Phenotypic variance in our study consisted of variance components for flock-test month effect, additive genetic effect, permanent environment effect over lactations, permanent environment effect within lactation, and residual. Due to the large variation in flock size, the flock-test month effect was included in the random part of the model as previously done by Brežnik (1999), Komprej et al. (2003) and Oravcová et al. (2005), causing the enlargement of phenotypic variance. Exact quantification of this enlargement is difficult, since it is not possible to obtain reliable estimates of variance components with flock-test month effect in the fixed part of the model. However, the size of variance due to flock-test month effect provides information about the enlargement of phenotypic variance. Thus, our model was not directly comparable with most of the results from the literature, where the flock-test month effect is mainly treated as fixed (Baro et al., 1994a; El-Saied et al., 1998a; Serrano et al., 2001). Additionally, only permanent environment effect over lactations was found in models of El-Saied et al. (1998a,c), Serrano et al. (2001) and Hamman et al. (2004), but no permanent environment effect within lactation. As seen in Table 3, the effect was not negligible regarding the phenotypic variance ratio explained for the effect, especially in DMY. The withdrawal of permanent environment effect within lactation from the model for DMY increased the variances for permanent environment effect over lactations and for the residual. Furthermore, variance components are rarely reported in literature, making the direct comparison of results more difficult.

The analysis of test-day records for milk traits in three Slovenian dairy sheep breeds showed lower heritability estimates for DMY and FC and similar estimates for PC (Table 3) in comparison to the previous study on Slovenian data by Brežnik (1999), who reported 0.20 for DMY, 0.11 for FC, and 0.10 for PC. The data set has enlarged and the pedigree data has improved since the previous analysis. Differences in the random part of the models caused differences in estimates. Preliminary analysis of the same population (Komprej et al., 2003) showed twice as high heritability for DMY (0.25) and also higher heritabilities for FC (0.14) and PC (0.12). The older estimates were acquired by a model not containing the permanent environment effect over lactations. When this effect was left out, a large part of that component was embodied with the additive genetic effect and a smaller part with the permanent environment effect over lactation. In FC and PC, the variance was mainly distributed into additive genetic effect and flock-test month effect. A considerably higher heritability estimate for DMY (0.34) and a slightly higher one for PC (0.13) in the Churra breed were found by Baro et al. (1994a), whose model contained flock-test month effect in the fixed part, but did not treat permanent environment effect within lactation. Other authors (El-Saied et al., 1998a; Serrano et al., 2001; Hamman et al., 2004) also estimated higher heritabilities for DMY. The estimates were in the range between 0.14 and 0.21. No permanent environment effect within lactation was treated in the models of the quoted authors. Hamman et al. (2004) reported a similar value for FC (0.09) and a higher one for PC (0.20) when compared to our study. On the other hand, the heritability for DMY in three Slovenian sheep breeds agrees with findings of Oravcová et al. (2005) in the Improved Walachian breed (0.10), while slightly lower heritabilities were found for FC (0.06) and PC (0.07). Their heritabilities estimated in the Tsigai breed were higher for DMY (0.19), as well as for FC (0.12) and PC (0.17).

The flock-test month effect explained the relatively large ratio of the phenotypic variance in DMY, and especially in FC and PC (Table 3). Slightly lower values for DMY (0.24 and 0.25), but higher ones for FC (0.53 and 0.46) and PC (0.65 and 0.61) were found by Brežnik (1999) and Komprej et al. (2003) in previous studies on Slovenian data. The variance ratio for flock-test month effect in the Improved Walachian breed (Oravcová et al., 2005) was higher for DMY (0.41) and FC (0.48), but lower for PC (0.46). In the Tsigai breed from the same analysis, the flock-test month effect accounted for a higher variance ratio for DMY (0.34), but lower for FC and PC (0.39).

The permanent environment effect over lactations explained a minor, but not negligible variance ratio, especially in DMY (Table 3). Considering only additive genetic effect and permanent environment effect over lactations, El-Saied et al. (1998a,c) published higher variance ratios for DMY (0.30 and 0.36). A substantially higher variance ratio for the effect was estimated for PC (0.22) by El-Saied et al. (1998c). Hamman et al. (2004) obtained a higher variance ratio for DMY (0.15) in East Friesian sheep. The ratio was lower for FC (0.01), but similar for PC (0.03). Variance ratios in our study are mostly lower than in the literature, mainly due to additional random effects in the model.

The variance ratio for permanent environment effect within lactation was slightly higher for DMY and lower for FC and PC (Table 3) than the ratio for the effect over lactations. The estimates were similar to those obtained by Brežnik (1999) and Komprej et al. (2003). A similar variance ratio (0.14) for DMY was published by Oravcová et al. (2005) in the Improved Walachian breed, while the ratio was slightly lower (0.11) in the Tsigai breed. The same variance ratio was obtained for FC in the Improved Walachian breed and slightly higher (0.04) in the Tsigai breed. The ratio for PC was higher (0.04) in both breeds in comparison with our results.

Additive genetic correlations were negative between DMY and FC, and DMY and PC, but positive between FC and PC (Table 3) as expected. Previous correlation estimates for additive genetic effect in the Slovenian population of sheep (Brežnik, 1999) were lower between DMY and FC (–0.29), DMY and PC (–0.31), as well as between FC and PC (0.63). Lower additive genetic correlations between DMY and FC (from –0.29 to –0.23), DMY and PC (from –0.30 to –0.27), and FC and PC (from 0.57 to 0.58) were published by Oravcová et al. (2005) for the Improved Walachian and Tsigai breeds, respectively. Conversely, Hamann et al. (2004) estimated a slightly positive additive genetic correlation in East Friesian sheep between DMY and FC (0.08), while the additive genetic correlation between DMY and PC was negative (–0.13), but lower than in our population of sheep. These authors estimated a considerably lower additive genetic correlation (0.23) between FC and PC than we did.

Environmental correlations between milk traits showed a pattern similar to additive genetic correlations (Table 3). Correlations for flock-test month effect were higher in a previous analysis by Brežnik (1999) than in the current research. Between DMY and FC, and DMY and PC, the correlations were –0.43 and –0.27, respectively. The correlation between FC and PC was 0.67. Higher correlations for flock-test month effect (–0.31) were evaluated in the Improved Walachian and Tsigai breeds between DMY and FC by Oravcová et al. (2005), while the correlations between DMY and PC were close to zero (–0.01 and 0.05). In the Improved Walachian (0.39), as well as in the Tsigai breed (0.25), correlation estimates between FC and PC were lower, compared to our estimates. The estimates for permanent environment effect within lactation were lower than correlations obtained in Slovenian dairy sheep by Brežnik (1999), who reported –0.39 between DMY and FC, –0.25 between DMY and PC, and 0.45 between FC and PC. Considerably lower correlations for the effect were estimated in the Improved Walachian and Tsigai breeds (Oravcová et al., 2005) between DMY and FC and between DMY and PC (from –0.13 to 0.05). On the other hand, similar or even higher correlations compared to our study were estimated between FC and PC (from 0.36 to 0.45) in these two breeds.

CONCLUSIONS

Flock-test month effect treated as random increased the phenotypic variance. The effect accounted for the largest phenotypic variance ratio in all three milk traits. Both permanent environment effects presented lower, but not negligible variance ratios.

The heritability estimates for DMY, FC and PC in three dairy sheep breeds were lower than those obtained in the previous studies on Slovenian data. They were also lower in comparison to estimates from other studies. Differences appeared mainly because this model included two different permanent environment effects which have never been used together in other studies. Nevertheless, genetic parameters estimated in Slovenian dairy sheep showed that genetic progress in milk traits could be achieved using test-day milk records.

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