

GENETIC AND ENVIRONMENTAL DISPERSION PARAMETER ESTIMATION BY TEST INTERVAL METHOD IN DAIRY SHEEP ¹

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Genetic and environmental dispersion parameter estimation by test interval method in dairy sheep

Genetic and environmental parameters for 38 983 test-day records of daily milk yield (DMY), fat (FC) and protein (PC) content, collected between 1994 and 2002, were estimated on 3,068 dairy ewes of the three Slovenian breeds. A multivariate restricted maximum likelihood method was used for estimation, where every test-day record was treated as a different trait. Fixed part of the multitrait animal model for DMY, FC, and PC included breed and lambing season as classes, while stage of lactation, parity, and litter size were covariates. Random part of the model contained additive genetic effect and the effects of flock test month and permanent environment over lactations. Heritability estimates for individual test-days were between 0.10 and 0.23 for DMY, 0.09 and 0.18 for FC, and 0.19 and 0.28 for PC. The flock test month effect explained most of the phenotypic variance: 0.18 to 0.41 for DMY, 0.26 to 0.45 for FC, and 0.24 to 0.44 for PC. A lower variance ratio was explained by the permanent environment effect over lactations: 0.09 to 0.15 for DMY, 0.02 to 0.11 for FC, and 0.02 to 0.09 for PC. Additive genetic correlations between individual test-days were high in all three milk traits for adjacent months of lactation. They decreased when the interval between months of lactation increased. The structure of additive genetic correlations showed that the observed milk traits in the different stages of lactation were genetically not the same trait, since the correlations between distant months of lactation were lower than one.

Key words: dairy sheep / milk yield / milk composition / genetic parameters / environmental parameters / test-day records / test interval method / variance-covariance components

Ocena genetskih in okoljskih parametrov disperzije z večlastnostnim modelom z intervali pri mlečnih ovcah

Ocenjevali smo genetske in okoljske parametre za 38 983 meritev na kontrolni dan za količino mleka (DKM) ter vsebnost maščobe (VM) in beljakovin (VB) v mleku pri 3068 mlečnih ovcah treh slovenskih pasem. Meritve so bile zbrane med leti 1994 in 2002. Za oceno parametrov smo uporabili večlastnostno metodo omejenega največjega verjetja, kjer je vsaka meritev na kontrolni dan obravnavana kot druga lastnost. Sistematski del večlastnostnega modela živali za DKM, VM in VB je vključeval pasmo in sezono jagnjitve kot razrede, stadij laktacije, zaporedna jagnjitev in velikost gnezda pa so bili vključeni kot kovariable. Naključni del modela je vseboval aditivni genetski vpliv živali, vpliv skupnega okolja v tropu in vpliv permanentnega okolja živali. Heritabilite za posamezne mesece laktacije so bile med 0,10 in 0,23 za DKM, med 0,09 in 0,18 za VM in med 0,19 in 0,28 za VB. Skupno okolje v tropu je pojasnilo največji del fenotipske variance: 0,18 do 0,41 za DKM, 0,26 do 0,45 za VB in 0,24 do 0,44 za VB. Vpliv permanentnega okolja živali je pojasnil manjši delež variance: 0,09 do 0,15 za DKM, 0,02 do 0,11 za VM in 0,02 do 0,09 za VB. Aditivne genetske korelacije med posameznimi lastnostmi mlečnosti sosednjih mesecev laktacije so bile močne in so se z oddaljevanjem mesecev laktacije zmanjševale. Struktura aditivnih genetskih korelacij kaže, da lastnosti mlečnosti v različnih stadijih laktacije genetsko niso ista lastnost, saj so korelacije med oddaljenimi zapisi manjše od ena.

Ključne besede: mlečne ovce / mlečnost/mleko / sestava / genetski parametri / okoljski parametri / zapisi na dan meritve / metoda z intervali / komponente varianc in kovarianc

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1 INTRODUCTION

In Slovenia, three dairy sheep breeds are mostly reared: Bovec breed, Improved Bovec breed (with East-Friesian), and Istrian Pramenka. Milk is processed into cheese and curd that are sold at home or in market halls. Sheep milk production in our climate is explicitly seasonal and coincides with vegetation. Lambings occur between February and April. Test-day records, collected according to ICAR regulations (ICAR, 2009) at monthly intervals are usually missing at the beginning of lactation due to relatively long suckling period (six to seven weeks on average). Considering short lactations in dairy sheep, ewes have on average only three to four test-day records per lactation. Milking period usually starts after the peak of lactation curve has been already reached and when daily milk yield is starting to decrease. Mating season starts in early autumn before lactation is completed, so breeding values should be available before mating season starts.

Genetic evaluations of milk traits in dairy sheep are nowadays mainly performed by application of test-day records (El-Saied *et al.*, 1998a, Serrano *et al.*, 2001, Oravcova *et al.*, 2005, Komprej *et al.*, 2009). Some advantages were found in such modelling of records (Ptak and Schaeffer, 1993, Serrano *et al.*, 2001) in comparison to lactation yields (El-Saied *et al.*, 1998a, El-Saied *et al.*, 1998b, Portolano *et al.*, 2001). The accuracy of genetic evaluations by this approach is higher due to a larger number of records per animal and better modelling of environmental effects on test-day. There is no need to wait until the end of lactation, what enables the selection of animals before new breeding season on records from current lactation. The method thus shortens generation interval (Brežnik, 1999) and increases genetic progress at the same intensity of selection (Swalve, 2000). The genetic analysis could be performed more frequently by this approach, what is important in dairy sheep, where the best animals are selected before the lactation is completed (Brežnik, 1999, Andonov, 1994). Modelling test-day records by the repeatability animal model assumes the common shape of the lactation curve for contemporary group of animals (Ptak and Schaeffer, 1993) and the constant variance along the lactation trajectory. Milk traits are considered to be genetically the same traits during lactation.

The second way of using test-day records directly is multi-trait modelling where lactation is partitioned into intervals containing at most one record per animal. Test-day records in different intervals are treated as different traits (Meyer *et al.*, 1989, Pander *et al.*, 1992, Pander *et al.*, 1993, Swalve, 1995). The method is known as test interval method (TIM) and was described 40 years ago by Everett

and Carter (1968) and Sargent *et al.* (1968). This kind of modelling is frequently used in dairy cows (Meyer *et al.*, 1989, Pander *et al.*, 1992, 1993, Swalve, 1995, Schaeffer and Jamrozik, 1996, Schaeffer, 1998) and seldom in dairy sheep (Baro *et al.*, 1994, Serrano *et al.*, 2001). Recently, the test-interval method was used for dairy buffaloes (Tonhati *et al.*, 2008).

The test interval method also enables estimation of (co)variances between individual test-day records within lactation. Correlations among milk traits, especially yields of milk, fat, and protein, on consecutive test-days are generally high, depending on the length of interval between tests (Ali and Schaeffer, 1987). As mentioned by Vargas *et al.* (1998), the heterogeneity of variances during lactation and the patterns in genetic and phenotypic correlations suggest that a multiple trait approach is more accurate than the repeatability model.

In the present paper, genetic and environmental dispersion parameters for daily milk yield and milk components in Slovenian dairy sheep were determined by the test interval method using test-day records.

2 MATERIAL AND METHODS

2.1 DATA

Data from 3,068 ewes were collected between 1994 and 2002 in 36 flocks according to ICAR regulations by the A4 method (ICAR, 2009). Test-day records for daily milk yield (DMY), fat (FC) and protein (PC) content of Bovec (B), Improved Bovec (IB) and Istrian Pramenka (IP) dairy breeds were obtained from the database of Slovenian breeding programme for small ruminants. The initial set of data contained 41,794 records. Only records without missing values for DMY, FC, and PC, which were collected between the 5th and the 244th day of lactation, were used in the analysis. Furthermore, at least three test-day records were required within lactation. DMY was limited to at least 50 g. FC ranged from 1.5% to 18% and PC between 2.0% and 13%. Records with parity 11 or more were rare and thus discarded. After this editing, 7% of the data were discarded. Thus, the final data set resulted in 38,983 test-day records for all three breeds together (Table 1).

The largest amount of test-day records was collected during the second and the sixth month of lactation (Table 1). The average DMY of all three breeds together was 1022 g with 6.62% FC and 5.51% PC. According to the stage of lactation, the average DMY was decreasing from the first (2,073 g) to the eighth (492 g) month of lactation. Due to negative correlation between DMY and milk components, FC increased from 4.53% to 7.95%

Table 1: Descriptive statistics according to the month of lactation for breeds together
Preglednica 1: Opisna statistika glede na mesec laktacije za vse pasme skupaj

Month of lactation	Number of records	Daily milk yield (g)		Fat content (%)		Protein content, %	
		Mean	SD	Mean	SD	Mean	SD
1	1465	2073	1017	4.53	1.35	4.71	0.49
2	5632	1755	756	5.37	1.03	4.69	0.51
3	7248	1290	581	5.99	1.06	4.90	0.54
4	7619	941	443	6.57	1.18	5.28	0.65
5	7226	714	356	7.15	1.35	5.84	0.90
6	5660	564	304	7.69	1.54	6.40	1.18
7	2855	497	288	7.86	1.60	6.57	1.19
8	1278	492	273	7.95	1.70	6.64	1.10
Together	38983	1022	692	6.62	1.59	5.51	1.07

and PC increased from 4.71% to 6.64% during lactation. The standard deviation (Table 1) decreased from 1017 g to 273 g for DMY and increased from 1.35% to 1.70% for FC and from 0.49% to 1.10% for PC. The variation of DMY thus declined during lactation, while the variation of FC and PC increased at the same time.

The pedigree file contained 3534 animals of both sexes (Table 2), where 2244 animals were from breed B, 677 from breed IB and 720 from breed IP. Considering the fact that some ancestors from breeds B and IB are common, the sum of animals across breeds is not equal to 3534. There were 2346 (66.38%) animals of all breeds with at least one ancestor known, where the majority of data presented breed B. The number of base animals with both ancestors unknown in all three breeds was 1188.

2.2 METHODS

By the test interval method, every test-day record (DMY, FC and PC) is treated as a different trait. Lactation was thus divided into eight intervals (months), where

Table 2: Number of animals with records and number of animals in pedigree file by breeds

Preglednica 2: Število živali z zapisi in število živali v datoteki porekla po pasmah

	Breed			
	Breeds together	Bovec	Improved Bovec	Istrian Pramenka
Ewes	3068	1957	486	625
Pedigree	3534	2244	677	720
Non-base	2346	1458	500	440
Base	1188	786	177	280

each of them presented 30 days of lactation. The first month of lactation presented records measured between the fifth and 34th day of lactation, and the eighth month presented records measured between the 215th and 244th day of lactation. Each animal had at most one record of DMY, FC, and PC on such interval. If a ewe had more than one record in one month, the closest one to the average day of lactation within the month was kept and the other was arranged into other intervals. After arranging the records, an eight trait model was used for DMY, FC, and PC.

Fixed part of the model (Equation 1 for the 1st interval (y_{ijklm}) and Equation 2 for intervals 2–8 (y_{ijklm})) contained breed (B_{ij} , B_{it}), lambing season (LS_{ij} , LS_{it}), stage of lactation (x_{ijklm} , x_{tijklm}), parity (z_{ijklm} , z_{tijklm}), and litter size (w_{ijklm} , w_{tijklm}). In the 1st interval, where the peak of lactation curve is found, the stage of lactation was modelled with quadratic regression, while linear regression was sufficient for intervals from the 2nd to the 8th. Furthermore, parity was modelled with quadratic and litter size with linear regression. Random part of the model included flock-test-month effect as flock-year-month of test-day interaction (fym_{ik} , fym_{tk}), permanent environmental effect over lactations (p_{1il} , p_{til}), additive genetic effect (a_{1il} , a_{til}), and residual (e_{1ijklm} , e_{tijklm}).

$$y_{ijklm} = B_{ij} + S_{ij} + b_{11}(x_{ijklm} - \bar{x}_i) + b_{12}(x_{ijklm} - \bar{x}_i)^2 + b_{13}(z_{ijklm} - \bar{z}_i) + b_{14}(z_{ijklm} - \bar{z}_i)^2 + b_{15}(w_{ijklm} - \bar{w}_i) + fym_{ik} + p_{1il} + a_{1il} + e_{1ijklm} \quad (1)$$

$$y_{ijklm} = B_{it} + S_{it} + b_{t1}(x_{tijklm} - \bar{x}_t) + b_{t2}(z_{tijklm} - \bar{z}_t) + b_{t4}(z_{tijklm} - \bar{z}_t)^2 + b_{t5}(w_{tijklm} - \bar{w}_t) + fym_{tk} + p_{til} + a_{til} + e_{tijklm} \quad (2)$$

Matrix notation of the multiple trait model can be written as shown in Equation 3:

$$y = X\beta + Z_f f + Z_a a + Z_p p + e \quad (3)$$

where y was a vector of observations on DMY, FC

and PC. Matrix \mathbf{X} was an incidence matrix and $\boldsymbol{\beta}$ a vector of unknown parameters for fixed effects. Vectors of unknown parameters were \mathbf{f} for flock-test-month effect, \mathbf{p} for permanent environment effect over lactation, and \mathbf{a} for additive genetic effect. Corresponding incidence matrices were assigned as \mathbf{Z}_f , \mathbf{Z}_p , and \mathbf{Z}_a . Vector \mathbf{e} was a vector of residuals.

Expected value of observations (Equation 4) was equal to $\mathbf{X}\boldsymbol{\beta}$, while expected values for all random effects were equal to zero.

$$E \begin{bmatrix} \mathbf{y} \\ \mathbf{f} \\ \mathbf{a} \\ \mathbf{p} \\ \mathbf{e} \end{bmatrix} = \begin{bmatrix} \mathbf{X}\boldsymbol{\beta} \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix} \quad (4)$$

Variance components for individual random effects of flock-test-month (\mathbf{F}), permanent environment over lactations (\mathbf{P}), additive genetic effect (\mathbf{G}), and residual (\mathbf{R}) composed phenotypic variance (Equation 5). The structure of individual covariance matrices is presented in equation 6. Matrices \mathbf{I}_f , \mathbf{I}_p , and \mathbf{I}_e are the identity matrices for the effects of flock-test-month, permanent environment over lactations, and residual. The order of the identity matrices is equal to 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 relationship matrix \mathbf{A} . The measurements are correlated within each level for individual random effect, what is shown with variances and covariances in 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, and \mathbf{R}_0 for residual. Symbol Σ^\oplus presents a direct sum. Due to animals with some missing records along lactation trajectory, the matrix of residual is a direct sum of matrices \mathbf{R}_{0k} . Residuals were assumed to be independent and normally distributed.

$$\mathbf{V} = \text{var}(\mathbf{y}) = \mathbf{Z}_f \mathbf{F} \mathbf{Z}_f' + \mathbf{Z}_a \mathbf{G} \mathbf{Z}_a' + \mathbf{Z}_p \mathbf{P} \mathbf{Z}_p' + \mathbf{R} \quad (5)$$

$$\text{var} \begin{bmatrix} \mathbf{f} \\ \mathbf{a} \\ \mathbf{p} \\ \mathbf{e} \end{bmatrix} = \begin{bmatrix} \mathbf{F} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{G} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{P} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{R} \end{bmatrix} = \begin{bmatrix} \mathbf{I}_f \otimes \mathbf{F}_0 & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{A} \otimes \mathbf{G}_0 & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{I}_p \otimes \mathbf{P}_0 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \Sigma^\oplus \mathbf{R}_{0k} \end{bmatrix} \quad (6)$$

Basic statistical analysis was performed using GLM (General Linear Model) procedure by statistical package SAS (SAS, 2001). (Co)variance components for test-day records were estimated by restricted maximum likelihood (REML) from programme package VCE 5 (Variance Covariance Estimation; Kovač *et al.*, 2002) by test interval method. Several runs of VCE 5 from different starting values were performed to ensure that the global maximum of the objective function was achieved.

3 RESULTS AND DISCUSSION

3.1 PHENOTYPIC VARIANCE

The phenotypic variance for DMY, FC, and PC was composed from (co)variance components for individual random effects of flock-test-month, permanent environment over lactations, additive genetic effect, and residual. Phenotypic variance for DMY (Table 3) was decreasing during the lactation, which is expected, since only the best animals and/or animals from the best flocks had observations at the end of lactation. For FC, the phenotypic variance is firstly decreasing after lambing toward the middle of lactation, and then it is increasing to the end of lactation. This variance is increasing along the lactation period in PC. Treating the flock-test-month effect as random caused the enlargement of the phenotypic variance for the observed milk traits. The effect is usually found in the fixed part of the model (Wilmink, 1987, Meyer *et al.*, 1989). As seen from the literature, most authors treated only the additive genetic effect in the random part of the model in dairy cattle (Danell, 1982, Wilmink, 1987, Meyer *et al.*, 1989) as well as in dairy sheep (Baro *et al.*, 1994, Serrano *et al.*, 2001, Volanis *et al.*, 2002). Some of them (Swalve, 1995, Kominakis *et al.*, 2001, Ilatsia *et al.*, 2006, Tonhati *et al.*, 2008) included the permanent environment effect over lactations in the random part as we did. Besides additive genetic effect, Andonov *et al.* (1998) took into account flock-test-month effect in the random part of the model for (co)variance estimation in Slovenian dairy goats. Due to different models mentioned in the literature, direct comparison of the results from this study is therefore difficult.

3.2 VARIANCE RATIOS

The heritability for DMY (Table 3) increased from the first (0.15) to the fifth month of lactation (0.23). It decreased thereafter (down to 0.10). The largest amount of measurements was collected in the middle of lactation, thus the estimates at this period are more reliable compared to the estimates from early and late lactation. In the last months, only the best animals/flocks were still milked, which would reduce genetic variability. Baro *et al.* (1994) included only the additive genetic effect in the random part of the model for Churra sheep and divided lactation into three intervals (months). They obtained slightly higher heritabilities for DMY (0.24, 0.25, and 0.16), while the trend was similar. The estimates in Bout-sico sheep, where the lactation period was fragmented into eight months and random part of the model also contained permanent environment effect (Kominakis *et*

Table 3: Variance ratios for random effects and phenotypic variance for milk traits during lactation**Preglednica 3:** Deleži variance za naključne vplive in fenotipska varianca za lastnosti mlečnosti med laktacijo

Milk trait	Month of lactation	Phenotypic variance	Heritability	Flock test month	Permanent environment of the animal	Residual
DMY	1	487 345	0.15	0.24	0.12	0.49
	2	303 113	0.18	0.18	0.14	0.50
	3	210 369	0.22	0.21	0.13	0.44
	4	128 514	0.21	0.19	0.15	0.45
	5	84 761	0.23	0.20	0.12	0.45
	6	68 583	0.21	0.26	0.10	0.42
	7	62 565	0.14	0.36	0.09	0.41
	8	63 062	0.10	0.41	0.11	0.38
FC	1	1.716	0.10	0.32	0.11	0.48
	2	1.079	0.09	0.35	0.07	0.48
	3	0.940	0.15	0.26	0.08	0.51
	4	1.142	0.17	0.32	0.05	0.46
	5	1.539	0.16	0.38	0.08	0.38
	6	1.957	0.14	0.36	0.08	0.42
	7	2.208	0.16	0.40	0.06	0.39
	8	2.571	0.18	0.45	0.02	0.35
PC	1	0.204	0.19	0.29	0.06	0.47
	2	0.215	0.25	0.28	0.07	0.40
	3	0.235	0.28	0.24	0.09	0.39
	4	0.361	0.26	0.30	0.06	0.38
	5	0.661	0.20	0.40	0.07	0.34
	6	0.910	0.26	0.33	0.03	0.38
	7	1.055	0.28	0.28	0.03	0.41
	8	1.210	0.22	0.44	0.02	0.32

al., 2001), ranged between 0.15 in the eighth month and 0.24 in the fifth month of lactation. Mid-lactation yields were also more heritable than those at the beginning and at the end of lactation. Higher estimates for DMY compared to our results were found by Serrano *et al.* (2001) in Latxa (0.20 to 0.33) and Manchega sheep (0.17 to 0.26) who divided lactation period into four months. Especially high heritabilities (0.41 to 0.47) were reported by Volanis *et al.* (2002) in Sfakia breed. A similar trend of heritability estimates for DMY compared to our results was reported by Andonov *et al.* (1998) in Slovenian dairy goats. The heritability increased from 0.18 in the third to 0.20 in the fifth month, and then declined down to 0.16 in the eighth month of lactation. The trend of heritability estimates for DMY in our research was also in accordance with dairy cows (Danell, 1982, Wilmlink, 1987, Meyer *et al.*, 1989, Pander *et al.*, 1992, Swalve, 1995) and dairy buffalo (Tonhati *et al.*, 2008), where estimates in the middle

of lactation were higher than in early or late lactation. Relatively constant heritability estimates for DMY (0.25 to 0.30) during lactation were reported for dairy cows by Ilatsia *et al.* (2006). Our heritability estimates for DMY are mostly lower in comparison to the literature, but there are differences in the models, differences in the (co) variance structure, and also lack of pedigree data could be the reason for the obtained results. Actually, the pedigree is a source of information that enables the division of permanent environment and additive genetic effect.

Flock-test-month effect explains a relatively large amount of the phenotypic variance. This effect presents different technologies of sheep breeding and feeding manners among flocks including temporary events within flock on test-day or some days before, what is expressed in variance ratio for the effect. Flock-test-month effect presented about 20% of phenotypic variance in DMY from the beginning to the middle of lactation. The

percentage rapidly increased toward the end of lactation up to 41%. Andonov *et al.* (1998) reported about the oscillation of the variance for flock-test-month effect across lactation in Slovenian goats. The percentage amounted from 29% in the fourth month to 36% in the seventh month of lactation.

Variance ratio for DMY explained by the permanent environment effect over lactations ranged between 0.09 in the seventh month and 0.15 in the fourth month of lactation. The ratio slightly increased from the beginning to the middle of lactation and reduced thereafter. This effect relates to the rearing conditions of the ewe from its birth to the first parturition, affecting milk traits in all lactations. Results indicate that preparation of the ewes for reproductive life is more important in milk yield than in its components. In Boutsico sheep Kominakis *et al.* (2001) explained higher ratio for this effect, except in the first and in the third month of lactation. The ratio was between 0.08 in the early lactation and 0.42 in the eighth month. Tonhati *et al.* (2008) obtained smaller oscillation in the permanent environment variance ratio for DMY in dairy buffalos, which were between 0.10 and 0.20 across lactation.

Residual presented the largest (co)variance component among all components observed. In the first two months of lactation, it was around 50%. It declined toward the end of lactation and was less than 40% in the last month. In study by Andonov *et al.* (1998) in Slovenian goats, the ratio for residual firstly decreased from 0.52 in the third month to 0.46 in the fifth month, and then it increased to 0.54 in the sixth month of lactation. The ratio then decreased again toward the last month of lactation to 0.52. The ratio for residual was especially high in Boutsico sheep (Kominakis *et al.*, 2001), which ranged from 0.62 in the fourth month to 0.81 in the eighth month of lactation. It oscillated along lactation period. High values (0.50 to 0.75) were obtained also in dairy buffalo by Tonhati *et al.* (2008), where the ratio firstly reduced from the first to the third month of lactation and it arised thereafter. Neither Kominakis *et al.* (2001) nor Tonhati *et al.* (2008) did include flock-test-month effect in the random part of the model, which could reduce the unexplained ratio of variance in the observed milk traits.

The heritability estimates for FC slightly increased from early toward the late lactation (Table 3). The lowest heritability for FC was found in the first two months (around 0.10). It increased almost two times to the last month (up to 0.18). Much higher heritability estimates for FC were shown by Volanis *et al.* (2002) in Sfakia sheep breed, which were in the range from 0.32 in the first to 0.52 in the fourth month of lactation. Our estimates were lower compared to the estimates in Slovenian dairy goats by Andonov *et al.* (1998), where the heritability in-

creased from the third (0.16) to the fifth month (0.29) of lactation, and it reduced thereafter. Danell (1982), Wilmink (1987), Meyer *et al.* (1989), Pander *et al.* (1992), and Swalve (1995) obtained the highest heritabilities for FC in dairy cows in the middle of lactation and the lowest at the beginning and at the end of lactation. The estimates from our study were lower than those in dairy cows.

Relatively a high variance ratio for FC was explained by the flock-test-month effect. Except the lowest variance ratio in third month of lactation (0.26), the estimates for this effect increased during lactation (to 0.45). The estimates were higher in comparison to the estimates by Andonov *et al.* (1998) found in Slovenian dairy goats, where the ratio for flock-test-month effect varied from 0.13 to 0.27. Due to treating the effect as fixed, no other results were found in the literature.

The variance ratio for FC explained by the permanent environment effect over lactations diminished from the beginning (0.11) toward the end of lactation (0.02). The unexplained variance ratio in FC oscillated according to the month of lactation. Nevertheless, it decreased from the first to the last month of lactation (0.47 to 0.32).

In PC, the heritability estimates accounted from 0.19 in the first to 0.28 in the third and in the seventh month of lactation (Table 3). The estimates oscillated during lactation. The estimates for PC were in accordance with those in Manchega sheep breed reported by Serrano *et al.* (2001), only that their heritability estimates arised in the early lactation and they declined after that. Much higher heritability estimates for PC were shown by Volanis *et al.* (2002) in Sfakia sheep breed, which were 0.44 in the first and 0.55 in the fourth month of lactation. Furthermore, Meyer *et al.* (1989) obtained higher heritabilities for PC in dairy cows with the highest value in the middle of lactation (0.49) and lower (0.23) at the beginning and at the end of lactation. On the other hand Danell (1982) obtained a slightly lower heritability for PC in dairy cows, while the estimates by Wilmink (1987) in first lactation cows were lower at the beginning and at the end of lactation compared to our study, but slightly higher in the middle of lactation. Pander *et al.* (1993) estimated genetic (co)variances in dairy cows, but only for every second test day. However, the heritability estimates for PC were the highest in mid lactation and they were much higher in comparison to our results.

Variance ratio for the flock test month effect oscillated and ranged between 0.24 in the third to 0.44 in the last month of lactation (Table 3). Permanent environment effect over lactations explained much lower variance ratio in PC (0.02 to 0.09). The percentage firstly increased from lambing to the third month of lactation, and then it decreased. Variance ratio in PC for residual

was high (0.47), especially in the early lactation. The ratio decreased to 0.32 at the end of lactation.

3.3 CORRELATIONS

Additive genetic correlations for DMY between adjacent months of lactation (Table 4) were high (0.95 to 0.98). The correlations decreased as the interval between months of lactation increased. The lowest additive genetic correlation for DMY (0.37) was estimated between the first and the last month of lactation. The structure of additive genetic correlations shows that DMY in the different stages of lactation is genetically not the same trait, since the correlations between distant months of lactation are lower than one. Results were in accordance with additive genetic correlations in Latxa and Manchega breeds, where Serrano *et al.* (2001) estimated the highest additive genetic correlations between adjacent months of lactation (0.87 to 0.97) and lower between distant months (0.46). Volanis *et al.* (2002) also published high additive genetic correlations for DMY between adjacent months (0.78 to 0.96) in Sfakia sheep, which reduced with increasing time interval among test-days (0.71 between the first and the fourth). The additive genetic correlation between the first and the second month of lactation in Boutsico breed was 0.99 (Kominakis *et al.*, 2002). With increasing time interval among test-days, the correlations slightly decreased, thus the lowest additive genetic correlation was estimated to 0.45, and was higher for 0.08 from ours. High additive genetic correlations for DMY between adjacent months of lactation were found also by Danell (1982) and Meyer *et al.* (1989) in dairy cows. The correlations decreased (to 0.22) when the interval between months of lactation increased. In the study of Pander *et al.* (1993), where estimates for every second test-day were reported, genetic correlations between distant months of lactation were still relatively high (up to 0.70). The additive genetic correlations for DMY between adjacent test-days estimated in the study of Ilatsia *et al.* (2006) in dairy cows were much lower (to 0.50) in comparison to our results. The correlations did not decrease with the increasing time interval among test-day records.

Additive genetic correlations for FC and PC followed similar pattern compared to DMY (Table 4). For FC, the correlations between adjacent months of lactation ranged between 0.82 and 0.98. The correlations declined with the extending interval between test-days (to 0.49). They slightly increased between the months from early and late lactation (to 0.58), what could be the result of very few ewes from the best flocks with observations at the end of lactation. Between adjacent months of lactation the additive genetic correlations for PC were

Table 4: Additive genetic correlations for milk traits during lactation

Preglednica 4: Aditivne genetske korelacije za lastnosti mlečnosti med laktacijo

Milk trait	Month of lactation	2	3	4	5	6	7	8
DMY	1	0.97	0.86	0.76	0.65	0.61	0.46	0.37
	2		0.95	0.89	0.81	0.76	0.62	0.56
	3			0.98	0.94	0.90	0.81	0.78
	4				0.99	0.95	0.87	0.86
	5					0.98	0.92	0.92
	6						0.97	0.95
	7							0.98
FC	1	0.95	0.71	0.63	0.54	0.49	0.59	0.58
	2		0.82	0.70	0.57	0.48	0.56	0.64
	3			0.95	0.87	0.77	0.64	0.81
	4				0.94	0.87	0.75	0.86
	5					0.98	0.83	0.90
	6						0.87	0.90
	7							0.95
PC	1	0.90	0.78	0.58	0.43	0.25	0.18	0.09
	2		0.96	0.81	0.66	0.49	0.41	0.35
	3			0.94	0.81	0.64	0.55	0.55
	4				0.94	0.79	0.64	0.71
	5					0.95	0.80	0.85
	6						0.91	0.90
	7							0.96

all above 0.90. The correlations for PC rapidly decreased with rising distance between test-days, down to 0.09 between the first and the last month of lactation. The correlations for FC in Sfakia sheep breed, obtained by Volanis *et al.* (2002), were mainly higher compared to our study, while some of them were similar to our estimates. They estimated the lowest additive genetic correlation between the first and the fourth month (0.79 for FC and 0.85 for PC), and the highest between the first and the second month of lactation (0.99). In dairy cows, the additive genetic correlations for FC between adjacent months (Danell, 1982) were similar to ours, but they were slightly lower for PC (0.71 to 0.86). Pander *et al.* (1993) also estimated high additive genetic correlations between adjacent months of lactation in bimonthly test-day analysis. All the additive genetic correlations in the cited studies diminished with the increasing interval between test-days. A larger range (0.61 to 0.99) of additive genetic correlations for PC between adjacent months was published by Serrano *et al.* (2001) in Manchega sheep breed for

four months of lactation. The correlations decreased up to 0.50 with the rising distance between test-days.

4 CONCLUSIONS

Milk traits in three Slovenian dairy sheep breeds were studied by the test-interval method. Heritability estimates for DMY were the highest in the middle of lactation, and lower at early and late lactation. For FC, the estimates increased from the beginning to the end of lactation, while heritability in PC increased after lambing, and then oscillated toward the end of lactation. Heritability estimates for DMY, FC, and PC were lower in comparison to the literature. Differences in estimates appeared mainly due to fitting flock-test-month effect as random and due to inclusion the permanent environment effect over lactations into the model. Additive genetic correlations between adjacent months of lactation were high, close to one, in all three milk traits. They decreased when the interval between months of lactation increased. The structure of additive genetic correlations showed that the observed milk traits in different stages of lactation genetically are not the same traits, since the correlations between distant months of lactation were lower than one. A further research is required to study the use of random regression models in genetic evaluation, which allow the estimation of the lactation curve within animal.

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