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The effect of stage of lactation on daily milk yield, and milk fat and protein content in Tsigai and Improved Valachian ewes

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Abstract

The objective of this study was to analyse the effect of stage of lactation on daily milk yield, and milk fat and protein content in Tsigai and Improved Valachian ewes. Breed lactation curves for daily milk yield, and milk fat and protein content were modelled as a sub-model of the three-trait animal model based on repeated test-day records that were collected by the Breeding Services of the Slovak Republic between 1995 and 2010. Data included 188403 (Tsigai) and 352094 (Improved Valachian) ewe's performance records. Pedigree file included 35484 (Tsigai) and 66994 (Improved Valachian) animals with genetic ties to ewes with milk performance data. The fixed part of the model included parity, litter size and stage of lactation. The effect of days in milk (i.e. stage of lactation) was fitted using Ali and Schaeffer lactation curve. The random part of the model included flock-test day effect, direct additive genetic effect, and permanent environmental effect of ewe nested within lactation. Due to limited number of test-day records in the first and the eighth month of lactation and related difficulties in modelling milk traits in these phases of lactation, the lactation curves were plotted between days 30 and 210. During lactation period the daily milk yield curves were decreasing, while milk fat and protein content were increasing. Because of higher changes at the beginning of lactation balanced with higher changes at the end of lactation in Tsigai and smaller changes at the beginning of lactation balanced with smaller changes at the end of lactation in Improved Valachian, 150d milk yield and average milk fat and protein content were almost the same in both breeds.

Key words: dairy ewes, lactation curves, daily milk yield, milk fat and protein content

Introduction

Tsigai and Improved Valachian are the most spread sheep breeds in Slovakia. Both are multi-purpose breeds (Krupová et al., 2009), well adapted to local climate and environment. Tsigai is one of the oldest native breeds in areas from 500 to 800 m above sea level, mostly in the semi-extensive production system (Krupová et al., 2009), while improved Valachian is mostly kept in mountains and foothill areas more than 800 m above sea level in the extensive/semi-extensive production system. The breed was created with crossing of former Valachian with Texel, Lincoln Longwool and Leicester Longwool, and was recognised in 1982 (Oravcová et al., 2006). The income from breeds is almost equally distributed between milk (cheese) production and production of offspring for slaughter as young animals (Oravcová and Peškovičová, 2008), while wool is just a marginal product.

The importance of ewe's milk market is increasing in Slovakia. Therefore, there is growing

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interest in increase of milk yield and efficiency of milking. Studies analyzing the factors affecting ewe's milk yield and milk composition (Margetín et al., 1996; Čapistrák et al., 2005; Tančin et al., 2011; Antonič et al., 2013) such as breed, age at lambing, parity, litter size as well as studies estimating lactation curves (Oravcová et al., 2006, 2007) were performed. Among factors that affect variation of daily milk yield, milk fat and protein content, the effect of stage of lactation was reported important by Gonzalo et al. (1994), Pavic et al. (2002), Komprej et al. (2012). Various lactation curves based on Wood (1967), Cobby and Le Du (1978), Wilmink (1987) model were firstly used in cattle. Moreover, additional models such as Ali and Schaeffer (1987), Morant and Gnanasakthy (1987), Guo and Swalwe (1995) were developed. Their suitability in ewes was tested by Bilgin et al. (2010).

The first study aimed at quantification of direct additive genetic effect and permanent environmental effect of ewe (Oravcová et al., 2005, 2008) showed that these effects are important sources of variability of milk traits and should be taken into account when fitting lactation curves to milk traits data. Heritabilities of milk traits were estimated between 0.12 and 0.19, and between 0.06 and 0.10 in Tsigai and Improved Valachian breeds, respectively. Variance ratios of permanent environmental effect of ewe were between 0.04 and 0.11, and between 0.02 and 0.11 in Tsigai and Improved Valachian breeds, respectively. The highest variance ratio was found for flock test day effect: between 0.34 and 0.39, and between 0.41 and 0.48 in Tsigai and Improved Valachian breeds, respectively. An influence of the effect of lactation stage which takes into account additional genetic and non-genetic (environmental) factors using the animal model has not been analyzed in Slovakia until now. Also, previous estimation of lactation curves in Slovak ewes considered flock-test day effect as fixed.

The objective of this study was to investigate the effect of stage of lactation on daily milk yield, and milk fat and protein content in Tsigai and Improved Valachian ewes taking into account additional fixed and random genetic and environmental factors affecting variability of milk traits. The number of test-day records considerably increased in recent years; therefore, changes in milk traits over time were also investigated.

Material and methods

Test-day records of daily milk yield, and milk fat and protein content were collected by the Breeding Services of the Slovak Republic between 1995 and 2010, following the AC method of ICAR guidelines. The AC method stands for corrected monthly test for evening/morning differences, taking into account the total volume of milk produced by the whole flock over the two milkings concerned (ICAR, 2011). Milk fat and protein content were determined using the automated infrared method and apparatus calibrated against known sample standards (Oravcová et al., 2007). The analysis of daily milk yield was based on 188403 (Tsigai) and 352094 (Improved Valachian) test-day records; at least three test-days per lactation and four flock-test-day measurements were required. Records with daily milk yield lower than 0.1 kg and higher than 3 kg as well as with milk fat and protein content outside the ranges from 2 to 15 % and from 1 to 9 % were deleted. Records for milk fat and protein content were less numerous than records for daily milk yield due to fact that test-day records with no measurements of milk fat and protein content are accepted in national and/or flock evaluation. In Tsigai and Improved Valachian, 167784 and 312829 test-day measurements of milk fat content and 167646 and 312913 test-day measurements of milk protein content were available. The distribution of test-day records of each breed over days in milk is given in Figure 1. The majority of test-day records occurred in the middle of lactation. The shape of distribution was found similar between breeds.

Since the number of test-day records considerably increased in recent years, Wilcoxon test as implemented in NPAR1WAY procedure (SAS Inst. Inc., 2009) was used to investigate differences between daily milk yield, fat and protein content in early (1995-1999) and late period (2006-2010) within each breed.

Milk traits were analysed separately for each breed using the same three-trait animal model:

$$Y = X\beta + Z_f f + Z_a a + Z_p p + e$$

where

- Y is the vector of observations of daily milk yield, and milk fat and protein content

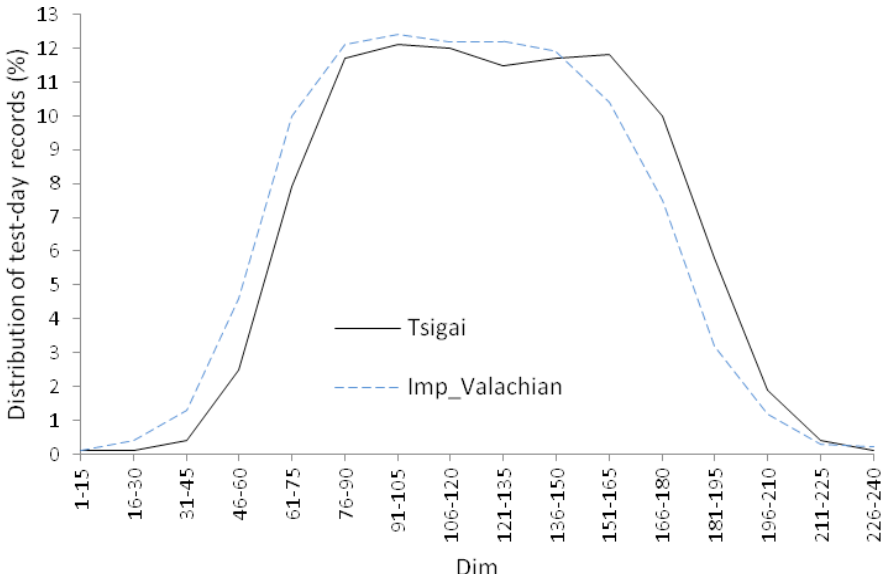

Figure 1. Distribution of test-day records (daily milk yield measurements) over days in milk in Tsigai and Improved Valachian breeds

- β is the vector of unknown parameters for fixed effects of parity, stage of lactation (i.e. days in milk) and litter size
- f, a, p are the vectors of unknown parameters for flock-test day effect, direct additive genetic effect, and permanent environmental effect of ewe nested within lactation
- X is the incidence matrix for fixed effects
- Z_f, Z_a, Z_p are the incidence matrices for random flock-test day effect, direct additive genetic effect, and permanent environmental effect of ewe nested within lactation
- e is the vector of residuals

In scalar notation, the model can be presented as follows:

$$y_{ijkl} = P_i + B_j + b_1\left(\frac{DIM_{ijkl}}{150}\right) + b_2\left(\frac{DIM_{ijkl}}{150}\right)^2 + b_3 ln\left(\frac{150}{DIM_{ijkl}}\right) + b_4 ln\left(\left(\frac{150}{DIM_{ijkl}}\right)\right)^2 + f_k + a_l + p_{li} + e_{ijkl}$$

where:

- y_{ijkl} is the observation of daily milk yield, and milk fat and protein content
- P_i is the effect of parity: first (1), second (2) and third and following parities (3+), $\sum_i^3 P_i = 0$
- B_j is the effect of litter size: one (1) and two and more lambs (2+), $\sum_j^2 B_j = 0$
- b_1 to b_4 are the regression coefficients of Ali and Schaeffer (1987) lactation curve
- DIM_{ijkl} are the days in milk involved as covariates in the model
- *150* is the constant which takes into account a shorter length of standardised lactation in ewes than in cows
- f_k is the flock-test day effect with 1583 (Tsigai) and 2304 (Improved Valachian) levels
- a_l is the direct additive genetic effect with 35484 (Tsigai) and 66994 (Improved Valachian) levels
- p_{li} is the permanent effect of ewe nested within lactation with 46283 (Tsigai) and 87 098 (Improved Valachian) levels
- e_{ijkl} is the residual

The fixed part of the model was analyzed using GLM (General Linear Model) procedure (SAS Inst. Inc., 2009) based on Least Squares Method. Covariance components were estimated using the REML (Restricted Maximum Likelihood) method as applied in VCE 6 (Groeneveld et al., 2010). The main effects were described in previous studies of Oravcová et al. (2005, 2006, 2007 and 2008). The model used here was aimed to estimated only one lactation curve for each trait in each breed (i.e. lactation curves were not assumed to differ in shape between parities), taking into account the random part of the model (i.e. direct additive genetic effect and permanent effect of ewe nested within lactation). The model did not employ less significant effects (i.e. age at lambing, number of milkings per day) considered earlier.

Results

The data structure showed the imbalanced frequency of test-day measurements in individual production years: an increase of about 66 % of test-day records in late period (2006-2010) in comparison to early period (1995-1999) of milk performance testing was observed in Tsigai and Improved Valachian ewes. Also, monthly averages of daily milk yield, and milk fat and protein content during lactation differed in each breed between early and late period (Table 1). The lower daily milk yield (0.583 vs. 0.640 kg in Tsigai and 0.562 vs. 0.667 kg in Improved Valachian, respectively) and the higher milk fat content (8.22 vs. 7.29 % in Tsigai and 7.92 vs. 7.51 % in Improved Valachian, respectively) and milk protein content (6.01 vs. 5.86 % in Tsigai and 5.81 vs. 5.82 % in Improved Valachian, respectively) were found in early period. Regardless of breed, highest changes were found in daily milk yield and almost stable milk protein content was found. The average values of daily milk yield, and milk fat and protein content between two periods differed by 9 and 16 %, by 0.93 and 0.41 percentage points and by 0.15 and 0.01 percentage points in Tsigai and Improved Valachian breed, respectively. Daily milk yield was mainly decreasing from the first to the last month of lactation, whereas milk fat and protein content were mainly increasing. Standard deviations followed the pattern of month averages of daily milk yield, and milk fat and protein content (with an increasing number of days in milk these were predominantly decreasing for daily milk yield and increasing for milk fat and protein content).

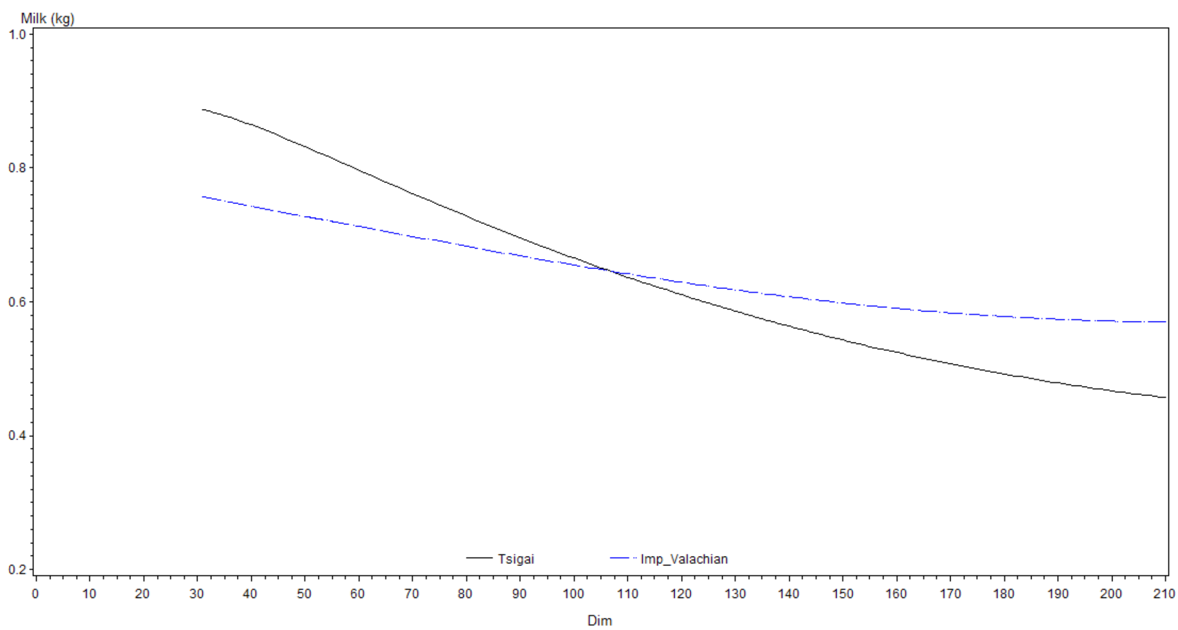

Figure 2. Changes of milk yield during lactation of Tsigai and Improved Valachian ewes

Significant differences found in milk traits between early and late period (Wilcoxon test as implemented in NPAR1WAY procedure SAS Inst. Inc., 2009), gave an opportunity to include data from latest years in the analysis and to re-estimate lactation curves in each breed.

Ali and Schaeffer (1987) lactation curves were used to model milk traits in dependence on days in milk (Figures 2 to 4). Due to limited number of test-day records in the first and the eighth month of lactation and related difficulties in modelling milk traits in these phases of lactation (see Oravcová et al., 2006, 2007 for comparisons), the lactation curves presented here were plotted between days 30 and 210. The lower persistency of milk yield during lactation was found in Tsigai breed (Figure 2): the lower daily milk yield was found at the beginning of lactation and the higher daily milk yield was found at the end of lactation in Improved Valachian breed. As a result of such pattern, 150d milk yield calculated by summarising daily milk yields estimated between days 50 and 200 was almost the same in both breeds i.e. about 96 kg. The day 50 was chosen as a starting point since suckling period takes about 50 days on average and the day 200 was chosen as an ending point since only high productive flocks are milked and recorded in late lactation and most of ewes are dried off in the seventh month of lactation.

Table 1. Changes of daily milk yield, and milk fat and protein content by month of lactation in Tsigai and Improved Valachian breed

Breed	Tsigai			Improved Valachian		
Period/Month	Daily milk yield, kg $\overline{x} \pm s$	Fat, % $\overline{x} \pm s$	Protein, % $\overline{x} \pm s$	Daily milk yield, kg $\overline{x} \pm s$	Milk fat, % $\overline{x} \pm s$	Milk protein, % $\overline{x} \pm s$
1995 to 1999						
1	1.066±0.413	6.07±1.26	5.28±0.31	0.579±0.228	7.47±1.38	5.42±0.67
2	0.785±0.373	6.94±1.44	5.28±0.54	0.614±0.292	7.16±1.35	5.36±0.60
3	0.711±0.322	7.15±1.43	5.56±0.59	0.643±0.283	7.16±1.42	5.50±0.57
4	0.696±0.309	7.69±1.37	5.74±0.56	0.643±0.258	7.50±1.21	5.64±0.55
5	0.547±0.254	8.30±1.52	5.86±0.59	0.553±0.200	7.97±1.36	5.73±0.56
6	0.476±0.228	8.85±1.71	6.27±0.68	0.451±0.159	8.79±1.41	6.10±0.62
7	0.410±0.196	9.61±1.95	6.92±0.79	0.379±0.152	9.37±1.52	6.75±0.67
8	0.380±0.298	9.94±2.22	7.42±0.77	0.406±0.144	9.17±1.68	7.11±0.64
Total	0.583±0.302	8.22±1.82	6.01±0.81	0.562±0.248	7.92±1.61	5.81±0.71
2006 to 2010						
1	0.962±0.422	5.44±1.37	5.57±0.50	0.874±0.467	7.01±1.35	5.12±0.53
2	0.788±0.339	6.45±1.37	5.47±0.52	0.719±0.309	6.97±1.14	5.38±0.54
3	0.752±0.329	6.62 1.39	5.62±0.48	0.724±0.276	6.96±1.18	5.65±0.48
4	0.718±0.319	6.93±1.27	5.74±0.46	0.702±0.253	7.14±1.21	5.77±0.46
5	0.598±0.277	7.51±1.39	5.86±0.51	0.627±0.224	7.71±1.23	5.81±0.51
6	0.517±0.250	8.00±1.52	6.17±0.59	0.598±0.205	8.23±1.24	6.09±0.60
7	0.486±0.259	8.29±1.46	6.43±0.66	0.617±0.203	8.39±1.18	6.39±0.63
8	0.414±0.185	8.45±1.50	7.17±0.69	0.622±0.228	7.81±1.20	6.37±0.63
Total	0.640±0.311	7.29±1.51	5.86±0.58	0.667±0.252	7.51±1.31	5.82±0.56
Diff.	++	++	++	++	++	++

N: number of observations; $\overline{x}$ - average; s - standard deviation
Diff. - differences between mean values of milk traits in period 1995-1999 vs. period 2006-2009; ++ - p< 0.01

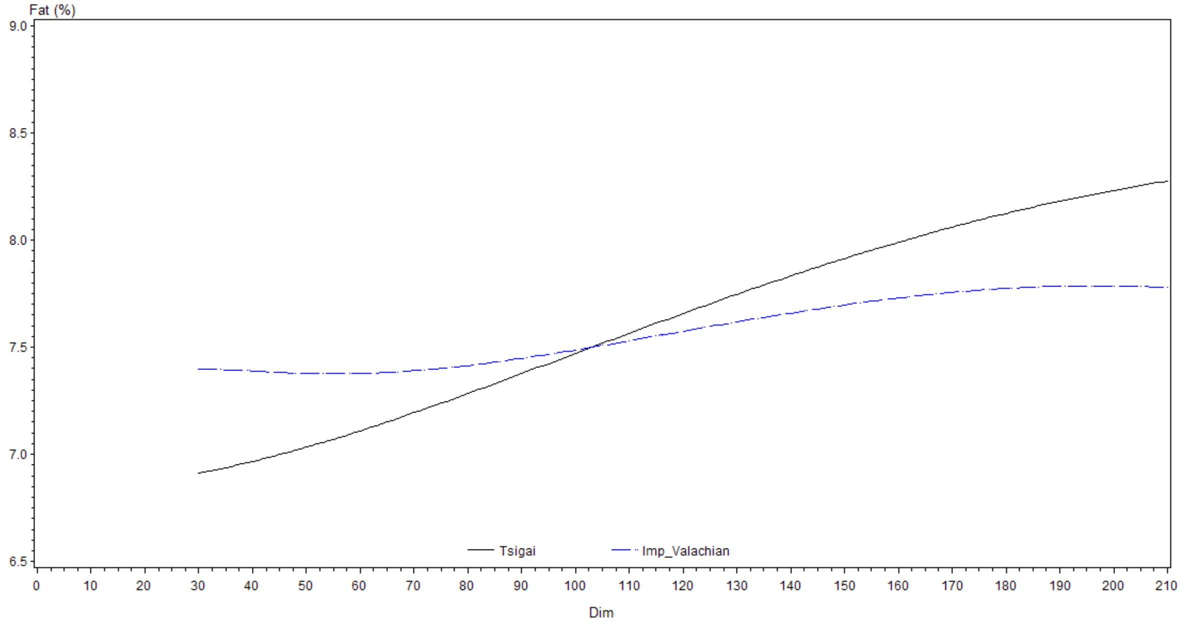

Figure 3. Changes of milk fat content during lactation of Tsigai and Improved Valachian ewes

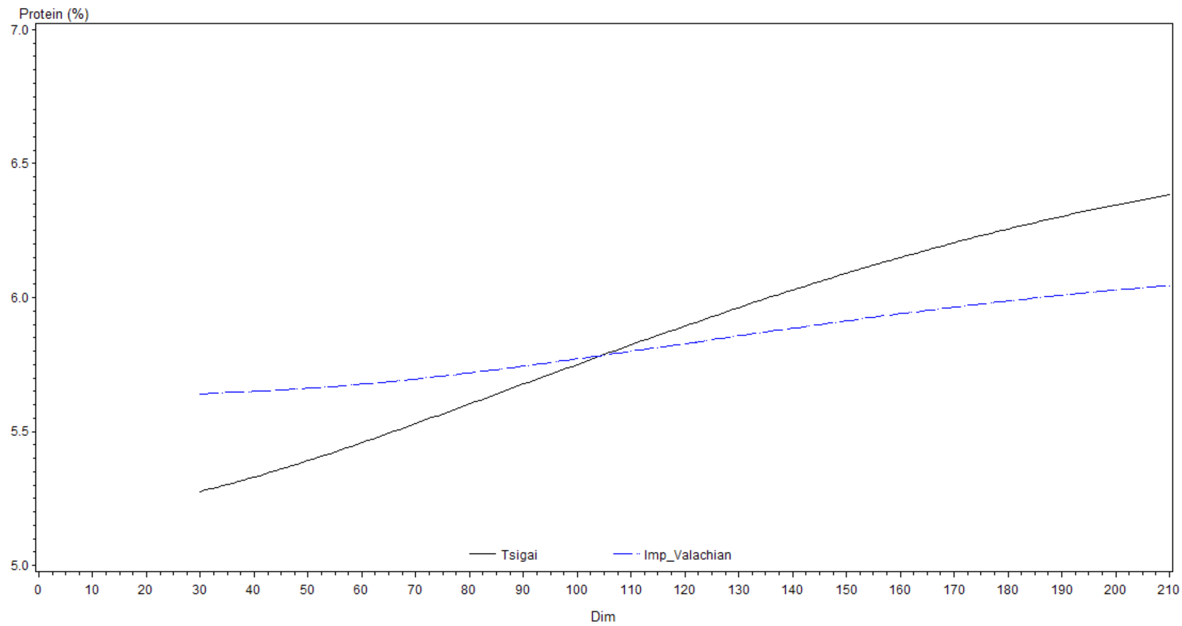

Figure 4. Changes of milk protein content during lactation of Tsigai and Improved Valachian ewes

Changes of milk fat and protein content during lactation were similar in Tsigai and Improved Valachian ewes; milk fat and protein content between days 50 and 200 of lactation did not differ more than by 0.10 percentage points. Similarly to daily milk yield, changes of milk fat and protein content were found lower in Improved Valachian breed (Figures 3 and 4). In total, daily milk yield decreased by 44 and 21 %; milk fat content increased by 1.20 and 0.41 percentage points; milk protein content increased by 0.95 and 0.37 percentage points between days 50 and 200 of lactation in Tsigai and Improved Valachian.

Discussion

The number of ewes included in milk performance testing in Slovakia was gradually increased. There were 4162 (Tsigai) and 8102 (Improved Valachian) ewes recorded in early period (1995-1999), and 11500 (Tsigai) and 19651(Improved Valachian) ewes in late period (2006 to 2010). Daily milk yield, and milk fat and protein content found in both breeds and both periods fell in the range reported in literature (see Oravcová et al., 2006, 2007 for comparisons): daily milk yield was similar to the lower values of daily milk yield found in literature; milk fat and protein content were similar to the higher values of milk fat and protein content found in literature. An increase of daily milk yield between early and late period was accompanied with a decrease of milk fat and protein content in both breeds. This decrease indicates that nutritional value of ewe's milk, as milk fat and protein content is concerned, is changing to a lower extent. When breeders are willing to avoid the decrease of milk fat and protein content in future, selection will have to be aimed not only at increasing milk yield but also increasing milk composition.

In contrast to previous studies of Oravcová et al. (2006, 2007), coefficients of Ali and Schaeffer (1987) lactation curve were not considered nested within parities and only one lactation curve for each milk trait in each breed was estimated here. This approach appeared to describe milk traits according to stage of lactation sufficiently, though some limitations to describe the beginning and the end of lactation curves occurred. Lactation curve for daily milk yield showed the decreasing trend with an increasing number of days in milk. This shape was less visible in previous study of Oravcová et al. (2006) where no animal model was applied and almost stable or even slightly increasing daily milk yields at the end of lactation in both breeds were found. In comparison to Tsigai, smaller changes of milk traits were found during lactation in Improved Valachian (21 vs. 44 %).

Based on comparisons between lactation curves, higher changes of milk traits during lactation, or similar to those in Tsigai, were reported in literature. For instance: Gonzalo et al. (1994) and Fuertés et al. (1998) found milk yield decreasing by 70 % between days 45 and 150 of lactation in Churra ewes. Carta et al. (1995) reported the decrease of daily milk yield in Sarda breed by 65 % between days 30 and 270 of lactation which corresponded to the decrease of daily milk yield about 30 % between days 30 and 150 of lactation. Ruiz et al. (2000) reported the lower decrease of daily milk yield between days 50 and 160 of lactation (36 % as a result of the higher persistency) in the first parity Latxa ewes when comparing ewes of different parities.

Daily milk yield in multiparous Valle del Belice ewes decreased by 50 % between days 50 and 225 of lactation (Cappio-Borlino et al., 1997); the decrease of daily milk yield was slightly lower in primiparous ewes. Daily milk yield in Boutsico breed decreased by 70 % between days 24 and 248 of lactation (Kominakis et al., 2002). Komprej et al. (2012) found daily milk yield decreasing by 60 and 70 % between days 45 and 150 of lactation in Improved Bovec and Bovec, respectively. Daily milk yield in Pag ewes decreased by 43 and 75 % (ewes of South-West and North-East of Pag island were compared) between days 20 and 180 (Barać et al., 2012). Daily milk yield in Istrian ewes decreased by 41 % between days 20 and 180 (Vrdoljak et al., 2012). Peralta-Lailson et al. (2005) found the decrease of daily milk yield between the beginning and the end of lactation varying from 62 to 78 % in the varieties of Creole breed of Chiapas-Mexico.

The decrease of daily milk yield as lactation progressed was also referred by El-Saied et al. (1998) in their study on Churra ewes. Similarly to findings in this study, the increase of milk fat and protein during lactation (either the decrease of milk composition at the beginning of lactation was observed or not) was referred by Gonzalo et al. (1994), El-Saied et al. (1998), Fuertés et al. (1998), Komprej et al. (2012). In Pag and Istrian ewes, the increase of milk fat and protein content during lactation was referred by Vrdoljak et al. (2012).

Conclusions

The analysis showed that the effect of stage of lactation influenced variability of ewe's daily milk yield, and milk fat and protein content. Higher changes of milk traits during lactation were found in Tsigai. Nevertheless, 150d milk yield and average milk fat and protein content were almost the same in both breeds due to fact that higher changes at the beginning of lactation were balanced with higher changes in the end of lactation in Tsigai and smaller changes in the beginning of lactation were balanced with smaller changes at the end of lactation in Improved Valachian.

Since milk price is independent of amount of milk fat and protein content (the only requirement is to meet given minimal values), selection in Slovak sheep is aimed at increasing milk yield. Such selection is consequently accompanied with a decrease of milk fat and protein content as comparison of traits between early and late period of milk performance testing in Slovakia showed. When breeders are willing to avoid a further decrease of milk constituents, they should think about the change of this trend.

Acknowledgements

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Utjecaj stadija laktacije na dnevnu proizvodnju mlijeka, udjele mliječne masti i bjelančevina u ovaca pasmine cigaja i Valachian

Sažetak

Svrha ovog istraživanja bila je analizirati utjecaj stadija laktacije na dnevnu proizvodnju mlijeka, udjele mliječne masti i bjelančevina u ovaca pasmine cigaja i Valachian. Laktacijske krivulje za dnevnu proizvodnju mlijeka, mliječne masti i bjelančevina modelirane su kao pod-model životinjskog modela (za 3 svojstva) temeljenog na testnim mjerenjima koje su prikupljene od uzgojne službe Republike Slovačke između 1995. i 2010. Ukupno je analizirano 188.403 podataka (za cigaja pasminu) i 352.094 podataka (za Valachian pasminu). Podaci o karakteristikama mliječnosti uzeti su za ukupno 35.484 ovaca pasmine cigaja, i 66.994 ovaca pasmine Valachian. Fiksni dio modela uključivao je redni broj laktacije, veličinu legla i stadij laktacije. Učinak stadija laktacije utvrđen je pomoću Ali-Schaeffer laktacijske krivulje. Nasumični dio modela uključuje utjecaj testnog dana, direktni aditivni genetski efekt i trajan utjecaj okoliša na laktaciju. Zbog ograničenog broja dnevnih kontrola u prvom i osmom mjesecu laktacije i sličnih poteškoća u modeliranju osobina mliječnosti u tim fazama laktacije, laktacijske krivulje prikazane su između 30 i 210 dana. Proizvodnja mlijeka prema laktacijskim krivuljama smanjivala se prema kraju laktacije, dok su se koncentracije mliječne masti i proteina povećavale. Tijekom 150-dnevne proizvodnje mlijeka, u obje pasmine je zabilježena gotova jednaka količina mlijeka, te koncentracija mliječne masti i proteina.

Ključne riječi: mliječne ovce, laktacijske krivulje, dnevna proizvodnja mlijeka, udjel mliječne masti i proteina

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