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EFFECT OF NON-GENETIC FACTORS ON STANDARD LACTATION MILK PERFORMANCE TRAITS IN SIMMENTAL COWS*

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Abstract

The effect of systematic and continuous environmental factors on milk performance traits over standard lactations in 2805 Simmental cows was evaluated using the general linear model. The systematic factors included the effect of farm or breeding area, calving season, year of birth, season of birth, lactation group and their interactions. The continuous factor analysed was the effect of age at first conception. The effect of farm, lactation group and calving season on standard lactation milk performance was found to be highly significant (P<0.01), excepting the effect of calving season on milk fat percent in standard lactations which showed statistical significance (P<0.05). The interactions between year and season of birth, farm and calving season, and farm and lactation group had a highly significant effect (P<0.01) on all performance traits studied. Age at first conception, as a continuous factor, had a highly significant effect (P<0.01) on milk yield and milk fat percent, and a non-significant effect on milk fat yield. The model used to correct the performance traits over standard lactations for the effect of systematic factors was highly significant (P<0.01). The variance of the model accounted for 20.06 and 37.31% of the total variance of milk fat yield and milk fat percent, respectively. The resulting coefficients of determination (R^2) ranged from 0.20 for milk fat yield to 0.37 for milk fat percent.

Key words: coefficient of determination, milk performance, Simmental breed, systematic effects

Given the fact that milk performance is a polygenic trait dependent upon genetic and non-genetic factors, its variability is extremely high. Knowledge of genetic and phenotypic parameters is of great importance in the evaluation of the additive genetic value of milk traits in cattle population (Pantelić et al., 2011). Studies on phenotypic

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and genetic variability of performance traits are of high practical importance in that variability underlies selection effects across years and generations.

The cattle breeding procedures used today most commonly employ linear methods and models that combine fixed parameters (viz. year, farm, season, parity), random variables (genetic effect of sire, genetic effect of an individual animal) and continuous variables (viz. age at first conception, age at first calving, etc.) which can be mutually dependent (related) or independent, with or without interactions, depending on the trait analysed. The solution obtained from chosen model represents, in fact, the breeding value of the individual (Bogdanović and Djedović, 2003).

Various reports suggested that the contribution of the non-genetic factors to milk production varies from 22.7 to 50 percent (Hansen et al., 1983; Jovanovac, 1987; Stojić et al., 1995, 1996).

The aim of the study was to examine the influence of fixed and continuous factors on milk production traits in standard lactation under production conditions. This research will serve as a recommendation of optimal models for the correction of production traits and ensure more accurate future determination of the breeding value.

Material and methods

Material

The present research was carried out on 2805 Simmental cows housed in three farms: 1) Zlatiborski Suvati dairy farm, Mt. Zlatibor which provides a free-stall housing system with lying and resting boxes 2) Dobričevo dairy farm, Ćuprija provides tie-stall housing, and 3) Individual tie-stall farms of Kotraža region.

For the present study, the traits studied were standard lactations milk yield (kg), milk fat percent (%) and milk fat yield (%) over standard lactations.

Data preparation for statistical analysis

Milk performance traits of standard lactation were calculated according to the "ICAR standard methods of lactation calculation" based on the data obtained from cow production sheets (ICAR, 2011).

Systematic environmental factors

The following systematic factors were considered in this study:

– *Farm*. The effect of three farm locations was studied: the farm on Mt. Zlatibor (cow no. 578), Dobričevo farm (cow no. 964) and farms in the Kotraža region (cow no. 4513).

– *Lactation groups*. Lactation groups were established in order to equalise the number of animals within different lactations and to reduce variability: group I (first lactation), group II (second lactation), group III (third lactation), group IV (fourth lactation), group V (fifth lactation) and group VI (due to the insufficient number of records, the VI lactation group includes the sixth and all succeeding lactations).

– *Calving season*. I – spring season (March to May), II – summer season (June to August), III – autumn season (September to November) and IV – winter season (December to February).

– *Group*. Effect of group was established as year of birth × season of birth interaction (cows that calved from 1996 to 2012 × 4 seasons). Since the effect of group is a large effect with more than 60 levels, Table 1 does not show the distribution of cows born in different years and different seasons.

– *Farm × calving season interaction* (3 farms × 4 calving seasons).

– *Farm × lactation group interaction* (3 farms × 6 lactation groups).

– *Age at first conception*.

Table 1. Presentation of data across different classes of major systematic effects

Farm	Parity	Lactation group	Parity	Season of calving	Parity
I	1968	I (1)	2800	I	2281
(Zlatibor)		II (2)	2297	II	2642
II	3237	III (3)	1715	III	2269
(Dobričevo)		IV(4)	1213	IV	2526
III	4513	V (5)	799		
(Kotraža)		VI (6+7+8+9+10+11+12)	894		

Evaluation of systematic environmental effects

To estimate effects and test hypotheses, the least squares method is used to fit the general linear model. The effect of non-genetic factors on performance traits over standard lactations was evaluated according to the following model:

$$y_{ijkl} = \mu + F_i + L_j + G_k + Cs_l + BCs_{il} + BL_{ij} + b_1(x_1^x – 1) + e_{ijkl}$$

where:

y_{ijkl} – an individual animal of the ith farm, jth lactation group, kth group, lth calving season,

μ – population mean,

F_i – fixed effect of the ith farm (1–3),

L_j – fixed effect of the jth lactation group (1–6),

G_k – fixed effect of the kth group (1–68),

Cs_l – fixed effect of the lth calving season (1–4),

BCs_{il} – fixed effect of the ith farm x lth calving season interaction (1–12),

BL_{ij} – fixed effect of the ith farm x jth lactation group interaction (1–18),

b_1 – linear regression coefficient,

e_{ijkl} – other undetermined error.

As part of further analysis of performance traits over standard lactations, the results of the analysis of variance according to the model used, including the significance of test factors, sum of squares, and percent of the total sum, as well as the coefficients of determination (R^2) for each trait were analysed. Data processing was performed by the GLM procedure of the SAS statistical package (SAS 9.1.3, 2007).

Results

The LS means and effect of systematic factors on milk performance traits over standard lactations is shown in Tables 2 and 3.

Table 2. Least squares means, standard errors of the means and significance of the effect of systematic factors on milk performance traits over standard lactations

Systematic effects		Milk performance traits over standard lactations					
		MYSL (kg)		MFPSL (%)		MFYSL (kg)	
Farm	N	LSM	SELSM	LSM	SELSM	LSM	SELSM
I	1968	4355.00 a	22.08	3.67c	0.004	159.35a	0.84
II	3237	4054.90 b	19.09	3.79b	0.003	153.40c	0.72
III	4513	3964.10 c	16.31	3.91a	0.003	155.03b	0.62
F_{exp}		139.77**		1666.6**		20.53**	
Calving season							
(1)	2281	4143.5 b	21.26	3.79 ab	0.004	156.44 b	0.81
(2)	2642	4010.6 c	19.85	3.78 b	0.004	151.44 c	0.75
(3)	2269	4150.4 b	19.29	3.79 ab	0.004	157.09 b	0.73
(4)	2526	4194.2 a	19.15	3.80 a	0.004	158.74 a	0.73
F_{exp}		23.88**		2.70*		26.20**	
Lactation group							
(1)	2800	3723.7 e	17.24	3.82 a	0.003	141.61 e	0.65
(2)	2297	4061.8 d	19.15	3.79 b	0.004	153.47 d	0.73
(3)	1715	4237.6 b	21.89	3.78 c	0.004	159.78 b	0.83
(4)	1213	4303.6 a	25.37	3.78 c	0.005	162.18 a	0.96
(5)	799	4290.8 a	30.03	3.78 c	0.005	161.81 a	1.14
(6 and onwards)	894	4130.6 c	29.52	3.80 b	0.005	156.70 c	1.12
F_{exp}		152.56**		23.00**		134.12**	
Group							
F_{exp}		6.06**		6.50**		5.87**	

N.S. = Non-significant; *P<0.05; **P<0.01;

Least squares means in columns denoted with different small letters are significantly different (P<0.05) according to Duncan's multiple range test;

MYSL – milk yield over standard lactation; MFPSL – milk fat percent over standard lactation; MFYSL – milk fat yield over standard lactations.

The results show that all systematic factors along with calving season had a highly significant effect on variability of milk performance traits over standard lactations. Milk production was the highest on Farm 1 (4355 kg) and the highest milk fat percent was obtained on Farm 3 (3.91%). Winter born cows produced higher milk yields compared to cows born in the other three seasons (4194.2 kg vs. 4143.5 kg, 4010.6 kg, 4150.4 kg), whereas the milk fat percent was almost uniform, showing somewhat higher values in winter born cows. Milk production increased with cow age; the highest milk yield in Simmental cows was in lactation IV (4303.6 kg), but gradually decreased thereafter. Milk fat percent was found to be the highest in lactation I cows (3.82%) and decreased across lactations with increasing milk yield.

Table 3. Significance of the effect of interactions between systematic factors and age at first conception on milk performance traits over standard lactations

Effects	MYSL (kg)	MFPSL (%)	MFYSL (kg)
	Milk performance traits over standard lactations		
Farm × Calving season			
F_{exp}	9.39**	4.60**	9.82**
Farm × Lactation groups			
F_{exp}	49.41**	4.10**	49.87**
Age at first conception			
F_{exp}	26.31**	29.22**	2.20NS

N.S. = Non-significant; *P<0.05; **P<0.01; MYSL – milk yield over standard lactation; MFPSL – milk fat percent over standard lactation; MFYSL – milk fat yield over standard lactations.

Table 4. Analysis of variance for milk performance traits over standard lactations – significance of factors, sums of squares and percent of the total sum and coefficients of determination (R^2)

Traits	Degrees of freedom	Source of variation	MYSL (kg)	MFPSL (%)	MFYSL (kg)
Farm		significance of factors	**	**	**
	2	sums of squares	368 346 700	91.700	110 284
		percent of the total sum	5.36	32.91	1.18
Calving season	3	significance of factors	**	*	**
		sums of squares	46 946 220	0.100	74 327
		percent of the total sum	0.68	0.04	0.79
Lactation groups	5	significance of factors	**	**	**
		sums of squares	533 561 300	2.300	695 137
		percent of the total sum	7.76	0.83	7.41
Group		significance of factors	**	**	**
	67	sums of squares	392 188 300	8.600	545 015
		percent of the total sum	5.71	3.09	5.81
Farm × Calving season		significance of factors	**	**	**
	6	sums of squares	31 883 460	0.500	47 792
		percent of the total sum	0.46	0.18	0.51
Farm × Lactation group	10	significance of factors	**	**	**
		sums of squares	266 288 200	0.700	386 194
		percent of the total sum	3.87	0.25	4.12
Age at first conception		significance of factors	**	NS	**
	1	sums of squares	14 267 020	0.040	22 777
		percent of the total sum	0.21	0.01	0.24
Model		significance of factors	**	**	**
	94	sums of squares	1 653 481 000	103.940	1 881526
		percent of the total sum	24.06	37.31	20.06
Residual variance	9623	sums of squares	5 218 790 000	174.678	7 500 520
		percent of the total sum	75.94	62.69	79.94
R^2	-		0.241	0.373	0.201

N.S. = Non-significant; *P<0.05; **P<0.01; MYSL – milk yield over standard lactation; MFPSL – milk fat percent over standard lactation; MFYSL – milk fat yield over standard lactations.

The results of analysis of variance for milk performance traits over standard lactations are shown in Table 4.

The model used for estimation of the non-genetic component of the variance for milk performance traits over standard lactations manifested a high statistical significance (P<0.01), indicating the significant effect of the analysed factors on the variability of milk performance traits over standard lactations in Simmental cows.

Discussion

The effect of farms on all milk performance traits was highly significant (P<0.01). The high intensity of the production technology used on the Zlatibor and Dobričevo farms resulted in higher milk and fat yields as compared to individual farms in the Kotraža region. The cows on the Zlatiborski Suvati farm gave the highest milk and fat yield, which was attributable to the more favourable effect of the free-stall housing system on performance traits as compared to the tie-stall system employed on the Dobričevo farm. Milk fat percent, in line with the lowest milk performance, was highest in cows in the Kotraža region (LSM=3.91) and lowest in cows on Mt. Zlatibor (LSM=3.67) that had the highest milk performance. Most of the authors have reported significant effects of farm on milk and fat yield over standard lactations (Panić, 2005; Lazarević et al., 2013; Nikšić et al., 2013). The effect of farm on milk fat percent gave contrasting results in different studies. Contrary to the present finding Petrović et al. (1997 and 2006), Perišić (1998) and Panić (2005) report non-significant effects of this systematic factor on milk fat percent.

Calving season had a highly significant effect (P<0.01) on all milk performance traits over standard lactations except for milk fat percent which was significantly affected (P<0.05) by calving season. Therefore, the effect of calving season should be included in the model used to evaluate the breeding value of dairy cows. Most authors (Kucera et al., 1999; Cilek and Tekin, 2005; Petrović D.M. et al., 2006; Panić, 2005; Lazarević et al., 2013; Nikšić et al., 2013) reported significant effects of calving season on milk and fat yield over standard lactations. However, Chladek and Kucera (2000) and Pantelić et al. (2005) found a non-significant effect (P>0.05) of the factor analysed. The highest milk and fat yields along with the highest milk fat percent were produced during the winter season and the lowest during the summer season. The highest milk yield during the winter season resulted from the fact that the test cows used their biological potential for high milk production during the first three to four months of lactation, with the period considerably prolonged due to the favourable effect of green forage in the spring and summer seasons. Maximum winter or spring season and minimum summer or autumn season were also reported by Petrović D.M. et al. (2006), Lazarević et al. (2013) and Nikšić et al. (2013).

The effect of lactation number on all milk performance traits was found to be highly significant (P<0.01). Milk and milk fat production over lactations increased with increasing cow age, the lowest being in the first lactation, and the maximum in the fourth lactation, followed by a slowly decreasing tendency. In contrast to milk and milk fat production, milk fat percent (LSM=3.82%) was the highest in lactations that had the lowest milk yield (lacatation 1), and decreased with increasing milk yield. Highly significant effects of parity on milk and fat yield over standard lactations were reported by most authors: Panić (2005), Pantelić et al. (2005), Petrović D.M. et al. (2006), and Lateef et al. (2008). Moreover, most authors agree that lactation number had a non-significant effect on milk fat percent (Perišić, 1998; Panić, 2005), in view of the fact that this trait is more affected by genetic factors.

Group defined as year of birth × season of birth, farm × calving season and farm × lactation group interactions exhibited a highly significant effect ($P<0.01$) on all milk performance traits over standard lactations. Therefore, the inclusion of both these individual systematic factors and their interactions into the models used to estimate the breeding value of cows was found to be justified. The contribution of the variances of the interactions of systematic factors to the total variance of productive traits of standard lactations for certain traits exceeded 4% (influence of interaction farm × lactation group on milk fat yield over standard lactations), which is an important factor in improving the accuracy of the model used to evaluate the breeding value of cows. Stojić (1996) observed that the effect of farm-year-season was the most dominant effect for all milk performance parameters in a standard lactation ($P<0.01$). A study conducted by Petrović M.M. et al. (1997) on active Simmental cattle population in Serbia suggested that the farm × calving season interaction contributed to highly significant variations in milk and fat yield ($P<0.01$).

Age at first conception had a statistically highly significant ($P<0.01$) effect on milk and fat yield, and a non-significant effect on milk fat percent. Lin et al. (1988) and Perišić et al. (2002) reported significant ($P<0.05$) and highly significant ($P<0.01$) effects of age at first conception, as a fixed factor, on the milk yield and fat milk yield in first and standard lactation with the effect subsequently diminishing, resulting in a non-significant effect of age at first conception on milk performance in the second and third lactations. However, a non-significant effect of age at first conception on milk performance traits over standard lactations was observed by Djurdjević et al. (2002) and Petrović D.M. et al. (2006).

The percent contribution of the variability of standard lactation performance traits induced by the effect of farm to the total variance ranged from 1.18 to 32.91% in milk fat yield and milk fat percent, respectively. Calving season had considerably lower effect on the variability of milk performance traits over standard lactations. Effect of this factor, the variance of performance traits contributed less than 1 percent to the total variance of all performance traits over standard lactations. A higher percent contribution of variance in standard lactation performance traits of above 3 percent, as induced by the effect of calving season, was observed by Petrović D.M. et al. (2006). Mchau and Syrstad (1991) reported similar values in milk production control in Norway that month of calving contributed 2–3 percent to the total variability of performance traits.

The percent contribution of the variance of performance traits over standard lactations to the total variance, as induced by the effect of lactation order, was above 7 percent, excepting milk fat percent with the percent contribution of as low as 0.83 percent. A considerably higher contribution (18.19 and 29.43) of the variance of milk fat content and milk yield affected by lactation group was reported by Petrović D.M. et al. (2006).

The variances of the interactions between systematic factors (farm × lactation group) contributed more than 4 percent to the total variance of performance traits over standard lactations for milk fat yield over standard lactations. Similar results were reported by Petrović D.M. et al. (2009). The variance caused by the effect of age at first conception had the lowest contribution to the total variance of performance traits over standard lactations – far less than 1%, this finding being confirmed by Petrović D.M. et al. (2006).

The model used to correct all performance traits over standard lactations for the effect of systematic factors and their individual interactions was highly significant ($P<0.01$), suggesting adequate selection of the systematic factors included in the model and the necessity to correct standard lactation performance traits for their effect. The non-genetic factors included in the model caused 20.06% variability in milk fat yield to 37.31% variability in milk fat percent relative to their total variability.

The calculated coefficients of determination, indicating the level of variation in the performance traits over standard lactations that can be explained by the model, ranged from 0.201 for milk fat yield to 0.37 for milk fat percent, which showed that the variability of the traits was affected not only by genetic factors but also by a large number of other non-genetic factors that were not analysed or included in the model used in this study, but will be covered by further research.

Conclusions

From the analysis of fixed and continuous effects on milk production traits in standard lactation in Simmental cows raised under average farm production conditions in Serbia, it can be concluded that:

– The effect of farm, lactation group and calving season and their interactions on performance traits over standard lactations was significant ($P<0.01$), excepting the effect of calving season on milk fat percent over standard lactations showing statistical significance ($P<0.05$).

– Age at first conception showed a statistically highly significant ($P<0.01$) effect on milk yield and milk fat percent, and a non-significant effect ($P>0.05$) on milk fat yield.

– The model used to correct performance traits over standard lactations for the effect of systematic factors was highly significant ($P<0.01$). The percent contribution of the model variance to the total variance of the traits analysed ranged from 20.06 percent for milk fat yield to 37.31 percent for milk fat percent.

– The coefficients of determination obtained by means of the model (R^2) ranged from 0.201 for milk fat yield to 0.37 for milk fat percent.

Given that the non-genetic effects, both fixed and continuous, mostly showed a highly significant effect on milk performance traits and caused their highest variation, they should be included in the models for estimating the breeding value of milk cows, i.e. performance traits should be corrected for the effect of these non-genetic factors.

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