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INSTITUTE FOR ANIMAL HUSBANDRY
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EFFECT OF FIXED AND CONTINUOUS ENVIRONMENTAL FACTORS ON MILK PRODUCTION IN THE FIRST THREE STANDARD LACTATIONS IN SIMMENTAL COWS

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Abstract: The effect of non-genetic factors on milk and milk fat production in first three standard lactations was examined in 241 Simmental cows. Milk performance traits in standard lactations (milk and milk fat production and milk fat content) were evaluated in terms of the effect of farm, lactation number, season of birth, season of calving, their interactions and age at first fertilisation.

The mathematical and statistical analysis of data, involving calculation of least squares means, standard errors, analysis of variance and coefficients of determination, was performed according to the general linear model procedure. The effect of farm, lactation group and year of birth on milk and milk fat production was very highly significant ($p<0.001$). The interaction between year of birth and season of birth and the interaction among year of birth, season of birth and season of calving had a significant effect on the variability of milk and milk fat production, whereas season of birth, season of calving and age at first fertilisation did not significantly affect ($P>0.05$) milk and milk fat production. Milk fat content in standard lactations was very highly significantly affected ($P<0.001$) by breeding area and the interaction among year of birth, season of birth and season of calving; significantly affected by year of birth, season of birth and age at first fertilisation; and non-significantly affected by lactation number and season of calving. The coefficient of determination (R^2) was very highly significant ($p<0.001$), ranging from 0.419 for milk fat content to 0.659 and 0.641 for the production of milk and milk fat, respectively, in standard lactations.

Key words: Simmental breed, milk production, milk fat content, season of calving, age at first fertilisation.

Introduction

The cattle breeding procedures used today most commonly employ linear methods and models that combine fixed parameters (year, farm, season, lactation) and random variables (age at first fertilisation or calving, genetic effect of sire, genetic effect of an individual animal, etc.), which can be interdependent (interrelated) or independent, with or without interactions, depending on the trait analysed. The model selected results, essentially, in the breeding value of an individual animal (*Bogdanović et al., 2003*).

Apart from being induced by the effect of genotype, differences in production parameters are also due to the effects of nutrition, care and management, housing system and the human factor. The interrelationship of these factors is characteristic of each individual farm. It is for this reason that differences occur among herds or farms even when animals have similar genetic potential for a particular production level. The classification into regions and breeding areas as a method used in studying the effect of non-genetic factors on either productive, reproductive or functional traits has been employed in numerous experiments mostly showing significant and very significant effects of this systematic non-genetic factor on milk performance traits. *Perišić (1998), Petrović D.M. et al. (2009a, 2009b, 2010, 2012, 2015, 2016, 2017), Petrović M.M. et al. (2009a* and *2009b)* and *Bogdanović et al. (2012)* evaluated the effect of region on milk and milk fat production and milk fat content in Domestic Spotted and Simmental cows, and found significant variations ($P<0.01$) in milk and milk fat yield as induced by the effect of region.

Depending on the level of production, sample size, and mathematical and statistical model, non-genetic discontinuous factors (year, farm, season, lactation) can account for more than 50% of the total variance in milk production *(Stojić et al., 1996).* The same authors, *Stojić et al. (1995),* reported that farm, year and season of calving explained 35.7% of the total variance in milk production. A somewhat lower proportion (22.7%) of the total variance in performance traits attributable to non-genetic factors (farm, year, calving season and lactation number) was found by *Jovanovac* (1987), whereas *Hansen et al. (1983)* determined a considerably higher percentage of about 45% (in terms of the farm-year-season effect).

The effect of season of birth and calving i.e. beginning of lactation as a systematic factor on milk performance traits is reflected through various climatic circumstances and nutrition throughout the year; therefore, it is included in models for the evaluation of the breeding value of dairy animals. As indicated by most authors, milk and milk fat production is maximum during the winter and spring seasons, and minimum during summer and autumn (*Perišić, 1998; Kučera et al., 1999; Cilek and Tekin, 2005; Petrović D.M. et al., 2005* and *2006; Panić 2005;*

Petrović M.M. et al., 2006; Petrović M.M. et al., 2009a; Petrović M.M. et al., 2009b; Lazarević et al., 2013; Nikšić et al., 2013).

Most domestic and foreign authors indicate significant and highly significant effects of lactation number i.e. lactation group on the expression of production traits. Namely, maximum milk production is dependent on the intensity of breeding in the period from the third until the fifth lactation (*Mchau and Syrstad, 1991; Tarkowski et al., 1994; Gaydarska et al., 2001; Đurđević, 2001; Pantelić et al., 2005; Petrović D.M. et al., 2005, 2006 and 2010)*. Milk production is lowest in the first lactation due to insufficient body development of animals, whereas a drop in production after the third i.e. fifth lactation often occurs due to health disorders.

There is general agreement among most researchers that milk and milk fat yield in standard lactations increases with increasing age at first fertilisation *(Fiss and Wilton, 1989; Michel et al., 1989; Perišić, 2002; Petrović D.M. et al., 2005 and 2006)*.

Material and methods

The effect of non-genetic factors on milk performance traits in the first three standard lactations was evaluated in 241 Simmental cows born between 1998 and 2010, and raised in three breeding areas (Kraljevo, Jagodina and Niš).
Milk and milk fat production in standard lactations was examined in terms of the effect of the following environmental factors:

- ***Breeding area*** i.e. the effect of three locations (1 – Kraljevo, 2 – Jagodina and 3 – Niš).
- ***Lactation number*** i.e. the effect of the first three lactations.
- ***Year of birth.*** To equalise the number of animals across different years of birth as much as possible and reduce variability, cows were grouped according to year of birth (group I – cows born between 1999 and 2004; group II – cows born between 2005 and 2006; group III – cows born in 2007; group IV – cows born between 2008 and 2010)
- ***Season of birth*** i.e. the effect of four seasons (I-spring, II-summer, III-autumn, IV-winter).
- ***Season of calving*** i.e. beginning of lactation (I-spring, II-summer, III-autumn, IV-winter).
- ***Interaction between year of birth*** (cows that calved between 1999 and 2010) ***and season of birth*** (I-spring, II-summer, III-autumn and IV-winter)***)***.
- ***Interaction among year of birth*** (4 groups) ***season of birth*** (4 seasons) ***and season of calving*** (4 seasons).
- ***Age at first fertilisation.***

The mathematical and statistical analysis of data, involving calculation of least squares means (LSM), standard error of the mean (SE_{LSM}), analysis of variance (F_{exp}) and coefficient of determination (R^2), was performed following the general linear model:

$$\mathbf{y}_{ijklm} = \mu + \mathbf{B}_i + \mathbf{L}_j + \mathbf{Y}_k + \mathbf{Sb}_l + \mathbf{Sc}_m + \mathbf{SbY}_{lk} + \mathbf{SbYS}_{Clkm} + \mathbf{b}_1(\mathbf{x}_1 - \bar{x}_1) + \mathbf{e}_{ijklm},$$ where:

$\mathbf{y}_{ijklm}$– an individual animal of $\mathbf{i}^{th}$ breeding area, $\mathbf{j}^{th}$ lactation group, $\mathbf{k}^{th}$ year of birth, $\mathbf{l}^{th}$ season of birth and $\mathbf{m}^{th}$ season of calving.
μ – population mean at equal proportions of all classes of effects (B, L,Y, Sb, Sc,SbY, SbYSc),
$\mathbf{B}_i$ – fixed effect of i^{th} breeding area (1-3),
$\mathbf{L}_j$ – fixed effect of j^{th} lactation (1-3),
$\mathbf{Y}_k$–fixed effect of k^{th} year of birth (1-4),
$\mathbf{Sb}_l$ –fixed effect of l^{th} season of birth (1-4),
$\mathbf{Sc}_m$ –fixed effect of m^{th} season of calving (1-4),
$\mathbf{SbY}_{lk}$–fixed effect of the interaction between l^{th} season of birth and k^{th} year of birth (1-16)
$\mathbf{SbYSc}_{lkm}$ –fixed effect of the interaction among l^{th} season of birth, k^{th} year of birth and m^{th} season of calving (1-64),
$\mathbf{b}_1$– linear regression coefficient of the effect of age at first fertilisation, and
$\mathbf{e}_{ijklm}$– other undetermined effects.

Results and discussion

The results of the analysis of the effects of systematic environment-related factors on milk performance traits in the first three standard lactations i.e. least squares means (LSM), standard errors of the means (SE_{LSM}), significance of the effects and coefficients of determination (R^2) are presented in Table 1.

Breeding area had a very highly significant effect ($P<0.001$) on milk performance traits in standard lactations due to the effect of nutrition, care and management, housing method and the human factor, which justifies the correction of the productive traits for the effect of this factor. Milk and milk fat production was very highly significantly lower in the Niš area i.e. 3771 kg milk and 150.5 kg milk fat.

Lactation number had a very highly significant effect ($P<0.001$) on milk and milk fat production in standard lactations. The production of milk and milk fat showed a steadily increasing tendency across lactations, the lowest in the first lactation (4121 and 161.7 kg, respectively), and the highest in the third standard lactation (4784 and 189.1 kg, respectively), which is in agreement with almost all researchers who evaluated the breeding value of cows *(Mchau and Syrstad, 1991;*

Tarkowski et al., 1994; Gaydarska et al., 2001; Đurđević, 2001; Pantelić et al., 2005; Petrović D.M. et al., 2005, 2006, 2010). Milk fat content showed no statistically significant differences across lactations (P>0.05), and exhibited a downward trend, as opposed to milk and milk fat content.

The effect of *year of birth*, as evidenced through different climatic circumstances, feed quality and quantity, and improvement in breeding technology, was very highly significant (P<0.001), showing no pronounced tendency to increase or decrease across years. Most authors reported significant and very significant effects of year of birth on milk and milk fat yield as an individual systematic factor, whereas *Perišić (1998)* found a non-significant effect (P>0.05) of year of calving on productive traits in Simmental cows, low fluctuations across years and a weak positive genetic trend.

Season of birth and season of calving had no significant effect (P>0.05) on milk performance traits in the first three standard lactations, whereas the *season of birth x year of birth interaction* and the *season of birth x year of birth x season of calving interaction* significantly affected (P < 0.05) milk and milk fat production, and had a very highly significant effect (P<0.001) on milk fat content in the first three standard lactations. There is disagreement among scientists as to the effect of season on productive traits. Naturally, its effect decreases when mono diets are used for dairy cows.

Age at first fertilisation had no significant effect (P>0.05) on the production of either milk or milk fat, whereas its effect on milk fat content in the first three standard lactations was significant (P>0.05).

Table 1. Least squares means, standard errors of the means and significance of the effects of systematic factors and age at first fertilisation on milk performance traits in cows over standard lactations

Systematic effects		MPSL (kg)		MFCSL (%)		MFPSL (kg)	
Farm	**N**	**LSM**	**SE_{LSM}**	**LSM**	**SE_{LSM}**	**LSM**	**SE_{LSM}**
Kraljevo	201	4809.15	80.47	3.935	0.008	188.58	2.990
Jagodina	195	4852.59	50.47	3.910	0.012	189.86	2.106
Niš	207	3771.22	41.20	3.994	0.020	150.48	1.805
F_{exp}		72.485***		10.18***		59.498***	
Lactation							
I	201	4121.23	66.77	3.934	0.013	161.73	2.564
II	201	4495.15	68.18	3.947	0.016	176.92	2.591
III	201	4784.28	65.25	3.960	0.016	189.10	2.545
F_{exp}		**45.211*** **		**0.22ns**		**47.868*** **	
Year of birth							
I	135	4352.31	76.56	3.939	0.025	171.06	3.071
II	60	4764.31	120.31	3.942	0.026	187.15	4.538
III	90	4703.46	105.08	3.908	0.016	183.88	4.196
IV	318	4392.46	55.53	3.963	0.010	173.60	2.153
F_{exp}		**9.398*** **		**3.03***		**7.451*** **	
Season of birth							
I	126	4374.88	79.22	3.939	0.020	172.24	3.215
II	150	4423.90	86.15	3.973	0.017	175.21	3.284
III	177	4585.23	77.05	3.910	0.017	178.90	2.991
IV	150	4447.53	75.73	3.971	0.015	176.18	2.870
F_{exp}		**1.401ns**		**3.09***		**1.652ns**	
Season of calving							
I	150	4419.00	83.226	3.953	0.018	174.21	3.218
II	148	4507.38	81.034	3.960	0.019	177.89	3.083
III	165	4411.92	75.576	3.938	0.016	173.41	2.937
IV	140	4540.17	81.019	3.937	0.015	178.61	3.168
F_{exp}		**0.531ns**		**1.04ns**		**0.659ns**	
Season of birth x year of birth							
F_{exp}		**2.316***		**3.88*** **		**2.271***	
Season of birth x year of birth x season of calving							
F_{exp}		**1.656***		**2.09** **		**1.700***	
Age at 1st fert.							
F_{exp}		**1.249ns**		**4.44***		**0.362ns**	
R^2		**0.659*** **		**0.419*** **		**0.641*** **	

N.S. - P > 0.05; * - P < 0.05; ** - P < 0.01; *** - P < 0.001; MPSL(kg) –milk production in standard lactations; MFCSL(%) –milk fat content in standard lactations; MFPSL(kg) –milk fat production in standard lactations, in kg

The *coefficients of determination* (R^2) of 0.659, 0.641 and 0.419 for milk production, milk fat production and milk fat content, respectively, suggest that

most (about 65%) of the total variance in productive traits across standard lactations was explained by the environmental factors analysed, and the rest of the variance (to reach 100%) by different factors which were not evaluated in this study and which can be dealt with in further research. Considerably lower coefficients of determination were determined by *Petrović D.M. et al. (2009 and 2015)* in their studies on the effect of non-genetic factors on milk and milk fat production in whole and standard lactations in Simmental cows.

Conclusion

Based on the model used for the correction of the effect of fixed and continuous environmental factors (breeding area, lactation number, season of birth, season of calving, their interactions, and age at first fertilisation) on milk performance traits in the first three standard lactations, the following conclusions can be drawn:

- The effects of breeding area (farm), lactation group and year of birth were very highly significant ($P<0.001$).
- Season of birth and season of calving had no significant effect ($P>0.05$) on milk and milk fat production in standard lactations.
- The *season of birth x year of birth* interaction and the *season of birth x year of birth x season of calving* interaction significantly affected ($P<0.05$) milk and milk fat production, whereas their effect on milk fat content was very highly significant ($P<0.001$) and highly significant ($P<0.01$), respectively.
- Age at first fertilisation had a significant ($P<0.05$) effect only on milk fat content in the first three standard lactations.
- Coefficient of determination (R^2) was very highly significant ($P<0.001$) and ranged from 0.419 for milk fat content to 0.659 and 0.641 for the production of milk and milk fat, respectively, in standard lactations.

Uticaj fiksnih i kontinuelnih ambijentalnih faktora na proizvodnju mleka u prve tri standardne laktacije kod krava simentalske rase

Milun D. Petrović, Milan M. Petrović, Vladan Bogdanović, Radica Đedović, Simeon Rakonjac, Vladimir Dosković, Miloš Ž. Petrović

Rezime

Uticaj paragenetskih faktora na proizvodnju mleka i mlečne masti u prve tri standardne laktacije ispitivan je na uzorku od 241 krave simentalske rase.

Na ispoljenost osobina mle;nosti u standardnim laktacijama (proizvodnja mleka i mlečne masti i sadržaj mlečne masti) ispitivan je uticaj farme, broja laktacija, sezone rođenja i telenja, njihovih interakcija i uzrasta pri prvoj oplodnji.

Matematičko-statistička analiza podataka, odnosno sve potrebne veličine, kao što su sredine najmanjih kvadrata, standardne greške, analiza varijanse i koeficijenti determinacije izračunate su u programskoj proceduri Opšti linearni model (GLM procedura). Uticaj farme, grupe laktacija i godine rođenja na proizvodnju mleka i mlečne masti bio je vrlo visoko značajan ($p<0,001$). Interakcija između godine i sezone rođenja, kao i između godine i sezone rođenja i sezone telenja značajno je uticala na ispoljenu varijabilnost u proizvodnji mleka i mlečne masti, dok sezona rođenja i telenja kao i uzrast pri prvoj oplodnji nisu statistički značajno uticali ($P>0,05$) na proizvodnju mleka i mlečne masti. Statistički vrlo visoko značajan uticaj ($P<0,001$) na sadržaj mlečne masi u standardnim laktacijama imalo je odgajivačko područje i interakcija godine i sezone rođenja i sezone telenja. Značajan uticaj na sadržaj mlečne masti imala je godina i sezona rođenja kao i uzrast krava pri prvoj oplodnji, dok je uticaj laktacije po redu i sezone telenja bio nesignifikantan. Koeficijenta determinacije (R^2) bio je vrlo visoko značajan ($p<0,001$) i kretao se od 0,419 kod sdržaja mlečne masti do 0,659 i 0,641 kod proizvodnje mleka i mlečne masti u standardnim laktacijama.

Ključne reči: simentalska rasa, proizvodnja mleka, sadržaj mlečne masti, sezona telenja, uzrast pr prvoj oplodnji.

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