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REGRESSION ANALYSIS OF MILK PRODUCTION TRAITS IN SIMMENTAL COWS

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Abstract: The relationship between milk production traits over whole lactations was evaluated across three generations of Simmental cows, i.e. between daughters, dams and grand dams, by a phenotypic regression analysis with whole lactation traits in the daughter generation being used as the dependent variables (x_1), and those in the dam and grand dam generations being used as the independent variables (x_2 and x_3). The results were obtained from a sample of 1170 daughters and as many dams and grand dams. The significance of the partial regression coefficients b_2 and b_3 was separately evaluated by a t-test. An analysis of variance was used to estimate the significance of the simultaneous effect of the production traits of dams and grand dams on the milk production achieved in the daughter generation. The calculated value of the partial regression coefficients for the whole lactation production traits across three generations (grand dams, dams and daughters) and their statistical significances determined by the t and F tests, as well as the regression equations used, suggested that the effect of the grand dam generation on the milk production traits in granddaughters was substantially lower than the effect of dams. The calculated partial regression coefficients (b_2 and b_3) were positive and statistically very significant ($P<0.01$), excepting the regression coefficients b_3 for lactation length and b_2 for milk fat content that were not statistically significant ($P>0.05$). A very significant change ($P<0.01$) was observed in all production traits in the daughter generation as simultaneously affected by the traits in the dam and grand dam generations

Key words: Simmental breed, production traits, generation, regression.

Introduction

The heritability of milk production traits of 25%, continuous breeding for their improvement and the enhancement of raising conditions lead to both yield increases and the relationship between the traits across generations. However, the

relevant literature on the relationship between production traits across generations is rather scarce.

Yield increases across generations as being facilitated by continuous breeding work and improving raising conditions, primarily nutrition and care, have been reported by international authors *(Rycken, 1996, 1997, 1998)*, whereas Serbian authors observe declining trends in milk and milk fat yields across generations in imported breeding heifers as being primarily induced by poorer raising conditions and earlier exposure to breeding as compared to the situation in Western European developed countries (Germany, Switzerland, Austria) from which they were imported *(Bogdanovic et al., 2008; Lazarevic et al., 1984; Nenadovic et al., 1986; Petrovic M.M.,1997, 2008; Petrovic D.M., 2008; Petrovic D.M. et al., 2009; Pantelic et al., 2011)*.

The above suggests that more substantial increases in milk performance in Serbian spotted Simmental dairy cattle can be achieved through breeding work, by using superior sire bulls and via timely exposure to breeding along with continuous improvements in raising conditions as compared to the imported Simmental breeding heifers.

In their study on the milk production potential and performance across generations of Simmental cows in Poland, Tarkovski and *Trautman (1997)* attributed the increase in milk production across generations to the use of Simmental sires imported from Germany, Austria and Switzerland.

Analysing the milk performance of Simmental cows in Switzerland during 1995-1996, 1996-1997 and 1997-1998, *Rycken (1996, 1997, 1998)* indicated that milk performance improvement across generations was a result of improvements in both the genetic potential of the bull sires and the raising conditions used.

Materials and Methods

The relationship between milk production traits over whole lactations was evaluated across three generations of Simmental cows, i.e. between daughters, dams and grand dams, by a phenotypic regression analysis with whole lactation traits in the daughter generation being used as the dependent variables (x_1), and those in the dam and grand dam generations being used as the independent variables (x_2 and x_3). The results were obtained from a sample of 1170 daughters and as many dams and grand dams.

Milk production traits of whole lactations, as assessed by regression analysis, included the following:

- lactation length (WLL), (days),
- milk yield over whole lactations (MYWL), (kg),
- milk fat content over whole lactations (MFCWL), (%),
- milk fat yield over whole lactations (MFYWL), (kg) and

- 4% FCM yield over whole lactations (4%FCMWL), (kg).

The regression analysis employed involved the calculation of the $a_{1.23}$ parameters (a) and the partial regression coefficients $b_{12.3}$ (b_2) and $b_{13.2}$ (b_3) using the following general linear multiple regression model involving three variables:

$$\hat{X}_1 = a_{1.23} + b_{12.3}X_2 + b_{13.2}X_3 \quad \text{or} \quad \hat{X}_1 = a + b_2X_2 + b_3X_3$$

The partial regression coefficients $b_{12.3}$ (b_2) and $b_{13.2}$ (b_3) were calculated using the following system of equations:

$$\sum_{i=1}^{n} x_{1i}x_{2i} = b_2\sum_{i=1}^{n} x_{2i}^2 + b_3\sum_{i=1}^{n} x_{2i}x_{3i}$$

$$\sum_{i=1}^{n} x_{1i}x_{3i} = b_2\sum_{i=1}^{n} x_{2i}x_{3i} + b_3\sum_{i=1}^{n} x_{3i}^2$$

Unknown partial regression coefficients (b_2 and b_3) were computed using determinants:

$$b_2 = \frac{D_{b_2}}{D} \quad \text{and} \quad b_3 = \frac{D_{b_3}}{D}$$

The third constant of linear multiple regression a, as the average initial level, was calculated using the formula:

$$a = \overline{X}_1 - b_2\overline{X}_2 - b_3\overline{X}_3$$

The significance of the partial regression coefficients b_2 and b_3 was tested using the following t-test:

Ho: $b_2 = 0$ Ho: $b_3 = 0$

$$t = \frac{|b_2|}{S_{b_2}} \qquad t = \frac{|b_3|}{S_{b_3}}$$

Where:

X_1, X_2, X_3 – value of whole lactation variable traits of daughters, dams and grand dams,

$a_{1.23}$ or a – constant value, representing the average initial level of whole lactation traits,

$b_{12.3}$ or b_2 and $b_{13.2}$ or b_3 – partial regression coefficients,

$\sum_{i=1}^{n} x_{1i}x_{2i}, \sum_{i=1}^{n} x_{2i}^2, \sum_{i=1}^{n} x_{2i}x_{3i}, \sum_{i=1}^{n} x_{1i}x_{3i}, \sum_{i=1}^{n} x_{2i}x_{3i}, \sum_{i=1}^{n} x_{3i}^2$ - corrected sums of squares and intermediates in three generations of cows,

D, D_{b_2}, D_{b_3} - determinants,

S_{b_2}, S_{b_3} - standard errors of the regression coefficients.

The hypothesis that the regression coefficients b_2 and b_3 were equal to unity (Ho: $b_2 = b_3 = 0$) was checked by the analysis of variance method using the Statistica statistical software for Windows Release 5.0. This analysis was used to determine F_{exp} values i.e. the significance of the simultaneous effect of production traits of dams and grand dams on the level of production achieved in daughters.

Results and Discussion

Regression analysis was employed to calculate the parameters $a_{1.23}$ (a) and partial regression coefficients $b_{12.3}$ (b_2) and $b_{13.2}$ (b_3). The significance of the coefficients was evaluated by a t-test (Table 1). An analysis of variance (F test) was used to estimate the significance of the simultaneous effect of the production traits of dams and grand dams on the traits of daughters. The results obtained are given in Tables 2 through 5.

Table 1. Regression analysis of whole lactation traits between three generation of cows (daugher, dam and grand dam)

Traits	Parameter $a_{1.23}$	Partial regression coefficients		Multiple regression equation
		$b_{12.3}(b_2)$	$b_{13.2}(b_3)$	
WLL, days	244.156^{**}	0.135^{**}	0.056^{ns}	$\hat{X}_1 = 244.156 + 0.135X_2 + 0.056X_3$
MYWL, kg	2856.296^{**}	0.193^{**}	0.073^{**}	$\hat{X}_1 = 2856.296 + 0.193X_2 + 0.073X_3$
MFCWL, kg	121.050^{**}	0.146^{**}	0.044^{*}	$\hat{X}_1 = 121.050 + 0.146X_2 + 0.044X_3$
MFYWL, %	2.973^{**}	0.0003^{ns}	0.222^{**}	$\hat{X}_1 = 2.973 + 0.0003X_2 + 0.222X_3$
4%FCMWL, kg	2955.519^{**}	0.168^{**}	0.054^{**}	$\hat{X}_1 = 2955.519 + 0.168X_2 + 0.054X_3$

N.S. - $P > 0.05$; * - $P < 0.05$; ** - $P < 0.01$;

lactation length (WLL), milk yield over whole lactations (MYWL), milk fat content over whole lactations (MFCWL), milk fat yield over whole lactations (MFYWL) and 4% FCM yield over whole lactations (4%FCMWL).

The calculated coefficient b_2, as shown in Table 1, indicates that a one-day increase in whole lactation length in dams resulted in a 0.135-day increase in lactation length in daughters with the lactation length in grand dams remaining unchanged. The partial regression coefficient b_3 shows that the whole lactation length in daughters increased by 0.0056 days with a one-day increase in lactation length in grand dams, with the lactation length in dams remaining unchanged.

The analysis of the significance of the partial regression coefficients, as determined by the t-test, reveals that the lactation length in daughters was statistically very significantly ($P<0.01$) affected by whole lactation length in dams and non-significantly ($P>0.05$) by whole lactation length in grand dams.

The analysis of variance (Table 2) suggests very significant changes ($P<0.01$) in whole lactation length in daughters as affected simultaneously by lactation length in dams and grand dams ($F_{exp}=14.77797^{**}$).

Table 2. Analysis of variance on the simultaneous effect of whole lactation length in dams and grand dams on the expression of the trait in daughters

Sources of variation	Sums of squares (SS)	Degrees of freedom (df)	Mean squares (MS(SS/df))	F_{exp}
Regression	104012	2	52006.02	14.77797^{**}
Error	12352250	3510	3519.16	
Total	12456262			

N.S. - P > 0.05; * - P < 0.05; ** - P < 0.01; *** - P < 0.001;

The increase of 0.193 and 0.168 kg in milk yield and 4% FCM yield, respectively, in daughters was associated with each kilogram of the yield increase in dams, with the yield in grand dams remaining unchanged (Table 1). The milk yield in daughters was substantially less affected by the milk performance of grand dams. The one-kilogram increase in milk and 4% FCM yields in grand dams induced an increase of 0.073 and 0.054 kg in the respective yields in daughters, with the milk performance of dams remaining unchanged.

The significance of the partial regression coefficients in milk yield and 4% FCM yield, as determined by the t-test, was very high ($P<0.01$).

Very significant changes ($P<0.01$) in both milk yield and 4%FCM yield in daughters were also induced by the simultaneous effect of milk and 4% FCM yields in dams and grand dams ($F_{exp}=58.81113^{**}$ and $F_{exp}=41.96612^{**}$), as suggested by the analysis of variance presented in tables 3 and 4.

Table 3. Analysis of variance on the simultaneous effect of whole lactation milk production traits in dams and grand dams on the milk performance of daughters

Sources of variation	Sums of squares (SS)	Degrees of freedom (df)	Mean squares (MS(SS/df))	F_{exp}
Regression	1.409118E+08	2	70455892	58.81113**
Error	4.204989E+09	3510	1198003	
Total	4.345901E+09			

N.S. - P > 0.05; * - P < 0.05; ** - P < 0.01; *** - P < 0.001;

Table 4. Analysis of variance on the simultaneous effect of the 4% FCM yield over whole lactations in dams and grand dams on the corresponding yield in daughters

Sources of variation	Sums of squares (SS)	Degrees of freedom (df)	Mean squares (MS(SS/df))	F_{exp}
Regression	9.273446E+07	2	46367231	41.96612**
Error	3.878104E+09	3510	1104873	
Total	3.970839E+09			

N.S. - P > 0.05; * - P < 0.05; ** - P < 0.01; *** - P < 0.001;

The milk fat yield in daughters was very significantly (P<0.01) and significantly (P<0.05) affected by the yield in dams and grand dams. Namely, the milk fat yield in daughters showed a 0.146 kg increase as a result of a 1 kg increase in dams, with the yield of grand dams remaining unchanged (b_2=0.146). The 1 kg increase in milk fat yield in grand dams induced a 0.044 kg increase in daughters with the yield in dams remaining unchanged (b_3=0.044).

The analysis of variance given in Table 5 suggests very significant changes (P<0.01) in the milk fat yield of daughters as simultaneously affected by the milk fat yield of both dams and grand dams (F_{exp}=31,50756**).

Table 5. Analysis of variance on the simultaneous effect of milk fat yield over whole lactations in dams and grand dams on the milk fat yield in daughters

Sources of variation	Sums of squares (SS)	Degrees of freedom (df)	Mean squares (MS(SS/df))	F_{exp}
Regression	106358	2	53178.91	31.50756**
Error	5924228	3510	1687.81	
Total	6030586			

N.S. - P > 0.05; * - P < 0.05; ** - P < 0.01; *** - P < 0.001;

The milk fat content in daughters increased 0.0003% with each percent of increase in dams, with the content in grand dams remaining unchanged. The effect was not statistically significant (P>0.05). Conversely, the effect of the milk fat content in grand dams on that in daughters, with the content in dams remaining unchanged, was

highly significant (P<0.01). Moreover, the 1% increase in the milk fat content in grand dams resulted in a 0.222% increase in daughters.

Table 6. Analysis of variance on the simultaneous effect of milk fact content over whole lactations in dams and grand dams on the content in daughters

Sources of variation	Sums of squares (SS)	Degrees of freedom (df)	Mean squares (MS(SS/df))	F_{exp}
Regression	5.41486	2	2.707431	117.7837^{**}
Error	80.68248	3510	0.022986	
Total	86.09735			

N.S. - P > 0.05; * - P < 0.05; ** - P < 0.01; *** - P < 0.001;

A statistically very significant (P<0.01) change ($F_{exp}=117.7837^{**}$) was observed in the milk fat content in daughters as induced by the simultaneous effect of the milk fat content in dams and grand dams, as suggested by the analysis of variance results given in Table 6.

Conclusion

The calculated value of the partial regression coefficients for the whole lactation production traits across three generations (grand dams, dams and daughters) and their statistical significances determined by the t and F tests, as well as the regression equations used, suggest the following:

- the effect of the grand dam generation on the milk production traits in granddaughters was substantially lower than the effect of dams;
- the calculated partial regression coefficients (b_2 and b_3) were positive and statistically very significant (P<0.01), excepting the regression coefficients b_3 for lactation length and b_2 for milk fat content that were not statistically significant (P>0.05).
- a very significant change (P<0.01) was observed in all production traits in the daughter generation as simultaneously affected by the traits in the dam and grand dam generations

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Korelaciona analiza povezanosti proizvodnih osobina kroz tri generacije krava simentalske rase

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Rezime

Povezanost osobina mlečnosti u punim laktacijama analizirana je između tri generacije krava simentalske rase, odnosno između kćerki, majki i baba, fenotipskom regresionom analizom u uslovima kada su osobine punih laktacija u generaciji kćerki posmatrane kao zavisno (x_1), a osobine punih laktacija u generaciji majki i baba kao nezavisno promenljive (x_2 *i* x_3). Rezultati su dobijeni na uzorku od po 1170 kćerki, majki i baba.

Pojedinačno ispitivanje značajnosti delimičnih regresionih koeficijenata b_2 i b_3 izvršeno je t-testom, a analizom značajnosti istovremenog uticaja proizvodnih osobina majki i baba na ostvarenu proizvodnju kod kćerki izvršena je metodom analize varijanse.

Na osnovu izračunate vrednosti delimičnih regresionih koeficijenata za proizvodne osobine celih laktacija kroz tri generacije (babe, majke i kćerke) i njihove statističke značajnosti određene t i F testom, kao i jednačina regresije konstatovano je da je uticaj generacije baba na proizvodnju unuka znatno manji u odnosu na uticaj kojeg imaju majke. Svi izračunati delimični koeficijenti regresije (b_2 *i* b_3) bili su pozitivni i statistički vrlo značajni ($P<0.01$), izuzimajući koeficijent regresije b_3 kod trajanja laktacije i b_2 kod sadržaja mlečne masti koji nisu bili statistički značajni ($P>0.05$). Značajnost promena svih posmatranih proizvodnih osobina u generaciji kćerki pri istovremenom uticaju tih osobina iz generacije majki i baba bila je vrlo visoka ($P<0.01$).

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