African Journal of Biotechnology Vol. 11(47), pp. 10804-10808, 12 June, 2012
Available online at http://www.academicjournals.org/AJB
DOI:10.5897/AJB11.1634
ISSN 1684–5315

Full Length Research Paper

Correlation analysis of milk production traits across three generations of Simmental cows

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Accepted 4 June, 2012

The relationship between milk production traits over whole lactations was evaluated across three generations of Simmental cows (between daughters, dams and granddams) by a corelation analysis with whole lactation traits in the daughter generation being used as the dependent variables (x_1), and those in the dam and granddam 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 granddams. The correlation of whole lactation milk production traits between daughters, dams and granddams, as calculated by simple, partial and multiple correlation coefficients was very weak or non-existent. All of the calculated simple and partial correlation coefficients were positive and mostly statistically very significant (P<0.01). The calculated coefficients of multiple correlation ($R_{1.23}$) between lactation length, milk fat content, milk yield, milk fat yield and 4% FCM yield with the expression of the traits in the daughters being used as the dependent variable and that in the dams and granddams as the independent variable were statistically very significant (P<0.01), amounting to 0.091, 0.251, 0.180, 0.133 and 0.153, respectively.

Key words: Simmental breed, production traits, generation, coefficient of partial correlation, coefficient of multiple correlation.

INTRODUCTION

The heritability of milk production traits of 25% continuous breeding for improvement and the enhancement of raising conditions lead to both yield increases and correlative relationship among traits across generations. However, the relevant literature on the correlation among production traits across generations is rather scarce. Yield increases across generations have been facilitated by continuous breeding work and improving raising conditions, primarily nutrition and care, as reported by Rychen (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 (Lazarević et al., 1984; Nenadovic et al., 1986; Petrović et al., 1997; Pantelić, 1997, 2008).

The above mentioned facts 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. Knowledge of genetic and phenotypic prameters is of great importance in the evaluation of the additive genetic value of milk traits in cattle population (Pantelić et al., 2011). Genetic

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improvent of milk quantity and of the milk fat greatly depends on the phenotypic and genetic variability, heritability and correlation between wanted traits (Pantelić et al., 2008). In their study on the milk production potential and performance across generations of Simmental cows in Poland, Tarkowski 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 to 1996, 1996 to 1997 and 1997 to 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.

Given the above, the objective of this study was to analyze the strength of phenotypic relationship between milk performance traits across generations based on correlation coefficients in order to evaluate the effect of heifer imports into Serbia or pay greater attention to the production of domestic breeding material and continuous improvement of rearing conditions, primarily housing and nutrition, for rapid cost-effective improvement of milk performance of Simmental cattle in Serbia.

MATERIALS AND METHODS

The correlation among milk production traits over whole lactations was evaluated across three generations of cows (between daughters, dams and granddams), by a phenotypic correlation analysis with whole lactation traits in the daughter generation being used as the dependent variable and whole lactation traits in the dam and granddam generations being used as the independent variable. Milk production traits of whole lactations as assessed by the correlation 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 correlation analysis among the three generations, each comprising 1170 Simmental cows, was used to calculate the simple, partial and multiple coefficients of phenotypic correlation and determination and their significance by the analysis of variance method using the Statistica statistical software for Windows Release 5.0. Simple coefficients of phenotypic correlation (r_{12}, r_{13}, r_{23}) were calculated using the formulas:

$$r_{12} = \frac{\sum_{i-1}^{n} x_{1i}x_{2i}}{\sqrt{x_{1i}^2 x_{2i}^2}}\ ;\quad r_{13} = \frac{\sum_{i-1}^{n} x_{1i}x_{3i}}{\sqrt{x_{1i}^2 x_{3i}^2}}\ ;\quad r_{23} = \frac{\sum_{i-1}^{n} x_{2i}x_{3i}}{\sqrt{x_{2i}^2 x_{3i}^2}}\ .$$

Partial coefficients of phenotypic correlation and determination were calculated using the formulas:

$$r_{12.3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{1-r_{13}^2}\sqrt{1-r_{23}^2}}\ ;\quad r_{13.2} = \frac{r_{13} - r_{12}r_{23}}{\sqrt{1-r_{12}^2}\sqrt{1-r_{23}^2}}\ ;$$

$$d_{12.3} = r_{12.3}^2 \cdot 100\ ;\quad d_{13.2} = r_{13.2}^2 \cdot 100\ ;$$

The multiple phenotypic correlation and determination coefficient was calculated using the formula:

$$R_{1.23} = \sqrt{\frac{r_{12}^2 + r_{13}^2 - 2r_{12}r_{13}r_{23}}{1-r_{23}^2}}\ ,$$

$$d_{1.23} = R_{1.23}^2 \cdot 100$$

A t-test was applied to test the significance of the calculated partial correlation coefficients:

Ho: $r_{12.3} = 0$; Ho: $r_{13.2} = 0$; Ho: $r_{23.1} = 0$.

$$t = \sqrt{\frac{r_{12.3}^2(n-m)}{1-r_{12.3}^2}}\ ;\quad t = \sqrt{\frac{r_{13.2}^2(n-m)}{1-r_{13.2}^2}}\ ;\quad t = \sqrt{\frac{r_{23.1}^2(n-m)}{1-r_{123.1}^2}}\ .$$

The statistical significance of the multiple correlation coefficient was determined by an F-test:

Ho: $R_{1.23} = 0$

$$F = \frac{R_{1.23}^2 : (m-1)}{(1-R_{1.23}^2) : (n-m)}$$

Where, x_{1i} is the value of variable traits of whole lactations in the daughter generation, x_{2i} is the value of variable traits of whole lactations in the dam generation, x_{3i} is the value of variable traits of whole lactations in the granddam generation, r_{12} is the coefficient of simple correlation among the variable traits of whole lactations in daughters and dams, r_{13} is the coefficient of simple correlation among the variable traits of whole lactations in daughters and granddams, r_{23} is the coefficient of simple correlation among the variable traits of whole lactations in dams and granddams, $r_{12.3}$ is the coefficient of partial correlation among the variable traits of whole lactations in daughters and dams with the variable trait of granddams remaining unchanged, $r_{13.2}$ is the coefficient of partial correlation among the variable traits of whole lactations in daughters and granddams with the variable trait of dams remaining unchanged, $R_{1.23}$ is the coefficient of multiple correlation with the whole lactation traits in daughters being used as dependent variables, $d_{12.3}$ is the coefficient of determination for $r_{12.3}$, $d_{13.2}$ is the coefficient of determination for $r_{13.2}$, and $d_{1.23}$ is the coefficient of determination for $R_{1.23}$.

The strength of correlation among milk production traits across three generations as based on the calculated coefficients of simple, partial and multiple correlations, was determined by the Roemer-Orphal scale as shown in Table 1.

RESULTS AND DISCUSSION

Correlation analysis was used to calculate the coefficients of simple (r_{12} and d_{12}, r_{13} and d_{13}, r_{23} and d_{23}), partial ($r_{12.3}$ and $d_{12.3}$, $r_{13.2}$ and $r_{13.2}$) and multiple ($R_{1.23}$ and $d_{1.23}$) phenotypic correlation as well as the coefficient of determination. Their significance was calculated by a t-test and an analysis of variance (F-test). The obtained results are given in Table 2. The calculated simple, partial

Table 1. Roemer-Orphal scale

Coefficient of correlation	Strength of correlation
0.00 - 0.10	No correlation
0.10 - 0.25	Very weak correlation
0.25 - 0.40	Weak correlation
0.40 - 0.50	Moderate correlation
0.50 - 0.75	Strong correlation
0.75 - 0.90	Very strong correlation
0.90 - 1.00	Complete correlation

Table 2. Correlation analysis of the whole lactation traits across the three generations of cows (daughters, dams and granddams).

Trait	Simple correlation and determination coefficients			Partial correlation and determination coefficients		Multiple correlation and determination coefficients
	r_{12} d_{12}(%)	r_{13} d_{13}(%)	r_{23} d_{23}(%)	$r_{12.3}$ $d_{12.3}$ (%)	$r_{13.2}$ $d_{13.2}$ (%)	$R_{1.23}$ $d_{1.23}$ (%)
WLL (days)	0.085	0.053	0.257	0.074**	0.032^{ns}	0.091**
	0.72	0.28	6.60	0.55	0.10	0.83
MYWL (kg)	0.169	0.095	0.207	0.153**	0.062**	0.180**
	2.86	0.90	4.28	2.34	0.38	3.24
MFYWL (kg)	0.127	0.058	0.148	0.120**	0.040*	0.133**
	1.61	0.34	2.19	1.44	0.16	1.77
MFCWL (%)	0.016	0.251	0.020	0.011^{ns}	0.250**	0.251**
	0.03	6.30	0.04	0.01	6.25	6.29
4%FCMWL (kg)	0.145	0.071	0.172	0.136**	0.047**	0.153**
	2.10	0.50	2.96	1.85	0.22	2.34

n.s., P > 0.05; *P < 0.05; ** P < 0.01. WLL, Lactation length; MYWL, milk yield over whole lactations; MFCWL, milk fat content over whole lactations; MFYWL, milk fat yield over whole lactations; 4% FCMWL, 4% FCM yield over whole lactations.

and multiple correlation and determination coefficients show no correlation or very weak and weak correlation between the phenotypically expressed whole lactation milk production traits of daughters, dams and granddams.

The simple correlation coefficient of whole lactation length across the three generations of cows reveals no correlation between daughters and dams (r_{12}=0.085) and between daughters and granddams (r_{12}=0.053), and weak correlation between dams and granddams (r_{12}=0.257), with the correlative dependence being 6.60% (d_{23}=6.60%). The calculated partial coefficients of correlation of whole lactation length between daughters and dams, with the lactation length of granddams remaining unchanged ($r_{12.3}$), and between daughters and granddams with the lactation length of dams remaining unchanged ($r_{13.2}$), show no correlation of full lactation length among the generations ($r_{12.3}$=0.074 and $r_{13.2}$=0.032). The calculated multiple correlation coefficient ($R_{1.23}$=0.091) also revealed no correlation between lactation length of daughters and those of the independent variables (lactation length in dams and granddams) when simultaneously observed. The F-test used to test the multiple correlation coefficient showed that no correlation with respect to lactation length would be observed in the future in 99% of the cases (F_{exp}=14.778**).

The correlation between milk yield and 4% FCM yield across three generations of cows as measured by simple correlation coefficients shows weak correlation between adjoining generations, that is the daughter-dam and dam-granddam generations, and no correlation between daughter and granddam generations in terms of either milk yield or 4% FCM yield over whole lactations. The calculated value of partial correlation coefficients shows very weak correlation [$r_{12.3}$= 0.153 (MYWL) and $r_{12.3}$=0.136 (4%FCMWL)] between daughters and dams when milk yield and 4%FCM yield remained unchanged in granddams; the correlative dependence being 2.34 and 1.85% ($d_{12.3}$=2.34 (MYWL) and $d_{12.3}$=1.85 (4%FCMWL)), respectively. Moreover, no correlation was observed between daughters and granddams when milk yield and 4%FCM in dams remained unchanged [$r_{13.2}$=0.062 (MYWL) and $r_{13.2}$=0.047 (4%FCMWL)]. The significance of the partial correlation coefficients as measured by a t-test was high (P<0.01). Furthermore, the calculated value of the multiple correlation coefficient suggests very weak correlation between milk and 4% FCM yields in daughters and those in dams and granddams when simultaneously observed [$R_{1.23}$=0.180 (MYWL) and $R_{1.23}$=0.153 (4%FCMWL)], that is, the changes in milk yield and 4%FCM yield in daughters were correlated with the changes in dams and granddamsa and the calculated correlative dependence being 3.24 and 2.34% [$d_{1.23}$=3.24 (MYWL) and $d_{1.23}$=2.34 (4%FCMWL)], respectively. A very high significance of the multiple correlation coefficient in milk yield and 4%FCM yield as analysed by the F-test was observed (F_{exp}=58.811** and F_{exp}=41.966**, respectively).

The correlation of milk fat yield between the three generations of cows as measured by the simple correlation coefficients showed as in the case of the correlation of milk and 4% FCM yields, very weak correlation between the adjoining generations of daughters and dams, and dams and granddams (r_{12}= 0.127 and r_{23}= 0.148), and no correlation in milk fat yield between daughters and dams (r_{13}=0.058). The correlation of milk fat yield between adjoining generations was also confirmed by the partial correlation coefficients. The correlation in milk fat yield between daughters and dams, with the yield in granddams remaining unchanged, was very weak ($r_{12.3}$=0.120), with the dependence being 1.44% ($d_{12.3}$=1.44), as opposed to no correlation observed between daughters and granddams, when the milk fat yield of dams remained unchanged ($r_{13.2}$=0.040). The significance of the partial correlation coefficients as measured by the t-test was very high (P<0.01). The multiple correlation coefficient shows very weak and highly significant (P<0.01) positive correlation of milk fat yield between daughters and dams and granddams as independent variables, when observed simultaneously ($R_{1.23}$=0.133). The milk fat content showed weak correlation between non-adjoining generations (daughter and granddam generations; r_{12}= 0.251 and d_{12}= 6.30%), whereas no correlation was observed between adjoining generations, as determined through simple correlation coefficients (r_{12} = 0.016 and r_{23} = 0.020). The weak and very significant (P<0.01) correlation of the milk fat content between the daughter and granddam generations, when the content remained unchanged in dams, was also expressed by the partial correlation and determination coefficient, being 0.250 and 6.25% ($r_{13.2}$=0.250 and $d_{13.2}$=6.25), respectively, whereas the milk fat content of daughters and dams when the content in granddams remained unchanged, showed no statistically significant (P>0.05) correlation ($r_{12.3}$=0.011 and $d_{12.3}$=0.01%). The multiple correlation coefficient showed weak, positive correlation between the milk fat content of daughters as the dependent variable and the content in the simultaneously observed dams and granddams as the independent variable ($R_{1.23}$=0.251). The observed changes in the milk fat content of daughters were correlated with the changes in dams and granddams, with the coefficient of determination being 6.29% ($d_{1.23}$=6.29). The calculated multiple correlation coefficient was very significant (F_{exp}=117.784**).

Overall, the correlation of whole lactation milk production traits between daughters, dams and granddams, as calculated by simple, partial and multiple correlation coefficients, was very weak or non-existent. All of the calculated simple and partial correlation coefficients were positive and mostly statistically very significant (P<0.01). Also, the calculated coefficients of multiple correlation ($R_{1.23}$) between lactation length, milk fat content, milk yield, milk fat yield and 4% FCM yield with the expression of the traits in the daughters being used as the dependent variable and that in the dams and granddams as the independent variable, were statistically very significant (P<0.01), amounting to 0.091, 0.251, 0.180, 0.133 and 0.153, respectively.

Conclusion

The results of the correlation analysis, including the calculated simple, partial and multiple correlation and determination coefficients, suggest very weak phenotypic correlation among milk production traits and no correlation among non-adjoining generations, such as in the case of the yield of milk, milk fat and 4% FCM between daughters and granddams, resulting in the quite low effect of imported breeding heifers in increasing the milk production of Simmental cows in Serbia. Therefore, much greater attention should be focused on producing local breeding materials by using genetically superior sires and through continuous improvement of raising conditions, primarily housing and nutrition, in order to enhance the milk performance of Simmental dairy cattle in Serbia in the fastest and most cost-effective way possible.

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