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Genetic and Phenotypic Parameters for Milk Production Traits in the First and Second Lactation in Romanian Simmental Dairy Cows

Research Article

E. Nistor[1*], V.A. Bampidis[2], M. Pentea[3], M. Matiuti[3], V. Ciolac[4] and F. Adebambo[5]

[1] Department of Animal Science and Biotechnologies, Banat's University of Agricultural Science and Veterinary Medicine, Timişoara, Romania
[2] Department of Animal Production, School of Agricultural Technology, Alexander Technological Educational Institute, Thessaloniki, Greece
[3] Department of Veterinary Medicine, Banat's University of Agricultural Science and Veterinary Medicine, Timişoara, Romania
[4] Faculty of Agriculture, Banat's University of Agricultural Science and Veterinary Medicine, Timişoara, Romania
[5] Department of Animal Breeding and Genetics, University of Agriculture, P.M.B. 2240, Abeokuta, Nigeria

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*Correspondence E-mail: nisnora@yahoo.com

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ABSTRACT

The aim of the present study was to estimate genetic and phenotypic parameters of milk production traits in the first and second lactations of Romanian Simmental dairy cattle. For the estimation of variance, heritability, genetic and phenotypic correlations among milk yield, fat yield, protein yield, and percentages of fat and protein, 3400 first and second lactation records over a period of five years (2005-2010) were evaluated. Genetic correlations of the yields of milk, fat, protein, and percentages of fat and protein in the first lactation were situated among the lowest value of -0.28 between milk yield and protein percentage and the highest value of 0.31 between milk and milk protein yield. Phenotypic correlations were situated from the lowest value of -0.02 registered among yields of milk, fat and protein and protein percentage, and the highest value of 0.98 for milk yield and fat percentage. Accordingly, if the selection goal is defined as maximizing the useful yield while maintaining fat and protein content, the selection criterion must include fat yield, protein yield, and protein content.

KEY WORDS correlation, fat yield, heritability, milk yield, protein yield.

INTRODUCTION

Genetic improvement of milk yield, milk fat content, and prolificacy in dairy cows, greatly depends on the phenotypic and genetic variability, heritability and correlation between these traits, as well as the production potential within the examined population (Pantelic *et al.* 2008). It is known that dairy cattle have a long generation interval and a low reproductive rate (Mashhadi *et al.* 2008). For a long time, dairy selection has been oriented towards increasing milk or milk fat yield. However, in the last decades, emphasis has shifted to increased milk protein content and more importantly, on higher concentrated milk (Cassandro, 2003). Search for the maximum gain in the milk, fat and protein yield, without reducing milk solids and yields, constitutes the new selection goal (Boichard and Bonaïti, 1987). In milk production therefore, the knowledge of the breeding value of dams and sires, the correlations of major traits and degree of heritability of these traits are of great importance in the selection of progenies (Pantelic *et al.* 2008).The objective of this study was to estimate heritability, genetic and phenotypic correlations among production traits (milk yield, fat yield and protein yield, fat and protein percentags), from the first and second lactation records of Romanian Simmental dairy cows enrolled in the official milk-recording program. These parameters are needed to plan the future breeding programs as well as to predict breeding values.

MATERIALS AND METHODS

Data collection, milk sampling and analysis

The study was conducted in a dairy farm from Timiş County in the West of Romania, from 2005 to 2010. The data records of 3,400 dairy heifers and cows of Romanian Simmental breed selected from the herd were extracted from the archive data of Timiş Centre of Animal Improvement and Reproduction, which collects all data from the dairy farms from the entire county. Heifers and cows were housed and treated in accordance with the applicable recommendations of the European Council. The animals care involved the use of Banat's University of Agricultural Sciences and Veterinary Medicine, Timişoara, Romania protocol for milk, fat and protein yields. Cows were machine milked twice a day for a completed lactation of at least 305 days. Milk sampling was carried out two times (morning and evening), when the amount of milk was measured. Samples were immediately processed after delivery to the laboratory (Central Laboratory for the Milk Control Association, Timişoara, Romania) and were analyzed for fat and protein with IR spectroscopy (MilkoScan™Minor4, Denmark) according to method 972.16 of AOAC (1990).

Statistical analysis

Data were statistically analyzed using the "Statistica version 9". All parameters were estimated for milk yield, milk fat and protein yield, as well as milk fat and protein content. To describe the variation of the traits the coefficient of variation (CV) was calculated as follows:

CV%= (SD/Xbar)*100.

In the variance estimation and precision module, an alternative to ANOVA estimation was provided by restricted maximum likelihood estimation (REML). Heritability was estimated using half sib method, according to the following equation:

$h^2 = 4\sigma^2_s / (\sigma^2_s + \sigma^2_w)$ (Baker, 1975); where:

σ^2_s= the between sire component of variance

σ^2_w= the within sire component of variance/within component of variance

The analyses were done using REML method, with a multi trait model utilizing an algorithm developed by Boldman and Van Vleck (1991). For the analysis, considering production traits in first and second lactations, the following model was fitted:

$$\mathbf{y} = \mathbf{Xa} + \mathbf{Zb} + \mathbf{e} \qquad [1]$$

where:

with

$E[y] = \mathbf{Xa}$

and

$$\mathrm{Var}\begin{bmatrix}\mathbf{y}\\ \mathbf{b}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\mathbf{ZGZ'} + \mathbf{R} = \mathbf{V} & \mathbf{ZG} & \mathbf{R}\\ \mathbf{GZ'} & \mathbf{G} & \mathbf{0}\\ \mathbf{R} & \mathbf{0} & \mathbf{R}\end{bmatrix}$$

y= a vector of records of the production traits in the first and second lactations.

a= known vector of significant fixed effects.

b= vector of additive genetic values of individual animals.

e= vector of unknown residual effects and.

X,**Y**= incidence matrices for fixed and random effects, respectively.

When $\mathbf{R} = \mathbf{I}\sigma^2_e$, the corresponding full rank Mixed Model Equation MME after multplying both sides by σ^2_c are.

$$\begin{bmatrix}\mathbf{X^{+\prime}X^{+}} & \mathbf{X^{+\prime}}\\ \mathbf{Z'X^{+}} & \mathbf{Z'Z} + \mathbf{G^{-1}\sigma^2_e}\end{bmatrix}\begin{bmatrix}\mathbf{b'}\\ \mathbf{\check{u}}\end{bmatrix} = \begin{bmatrix}\mathbf{X^{+\prime}y}\\ \mathbf{Z'y}\end{bmatrix}$$

or $\mathbf{C^{+}}s = \mathbf{r} \qquad [2]$

where X^+ is an N x N^+_f full rank submatrix of X with N^+_f the column rank of X. For Model [1] with y normally distributed, Meyer (1989) expresses the logarithmic function as:

$$\log \Lambda = -\tfrac{1}{2}\,[\text{constant} + \log|\mathbf{R}| + \log|\mathbf{G}| + \log|\mathbf{C^{+}}| + \mathbf{y'Py}] \qquad [3]$$

where log |R| is the logarithmic determinant of R and

$$P = \mathbf{V^{-1}} - \mathbf{V^{-1}X^{+}}\,(\mathbf{X^{+\prime}V^{-1}X^{+}})^{-1}\,\mathbf{X^{+\prime}V^{-1}}.$$

Formula [3] can be used to calculate the logarithm for any former parameters, being the basic equation of the derivative-free (DF) algorithm. The phenotypic correlation (r_p) was calculated starting from the phenotypic variances and covariances:

$$r_p = Cov_p / (\sqrt{V_{px*}V_{py}})$$

The phenotypic covariance is the sum of the genetic and environmental covariance, and the phenotypic correlation can be written as:

$r_p= Cov_A + Cov_E / (\sqrt{} V_{px*}V_{py})$

The denominator can be differently expressed by the following: $V_A= h^2V_p$ and $V_E= e^2V_p$, so the phenotypic correlation then becomes

$r_p= h_xh_y (Cov_E/(\sqrt{} V_{px*}V_{py})) + e_xe_y= (Cov_A+Cov_E) / (\sqrt{} V_{Ex*}V_{Ey})$

As a result, $r_p= h_xh_y r_A + e_xe_yr_E$

The formula shows that the phenotypic correlation is a result of the genetic and environmental causes of correlation combine together. The genetic correlation was evaluated starting from the component between fathers:

$r_{Gxr}= Cov_{Gxr} / (S_{rx}{}^2{}_*S_{rr}{}^2)$

RESULTS AND DISCUSSION

Average performances in first and second lactations, in Romanian Simmental dairy cows, are presented together with standard deviations and minimum-maximum values, in Table 1.

First lactation

In the herd there are individuals with very small but also with high yields. This high variability is due to the bull sires performances, but also due to a reaction to environmental factors.

Variability coefficient values confirm the high heterogeneity of the flock. Obtained results in the first lactation for phenotypic correlations are given in Table 2. The high value of phenotypic correlations registered between milk and milk fat yields, between milk and protein yields, and between fat and protein yields, indicates the presence of a high correlation between these traits. Correlations between the other components of milk production were low, with the specification that the phenotypic correlation between milk protein yield and milk fat content was the lowest. In the first lactation, the highest genetic correlation in Romanian Simmental was registered between milk fat and protein yields. In addition, a high correlation was found between milk yield and milk fat percentage. The other genetic correlations among milk traits were of medium value (between protein yield and milk fat percentage) or very low (between fat yield and protein percentage or between fat yield and milk fat percentage).

Second lactation

Milk, fat and protein yields have been increased in the second lactation, but it maintained in the herd a high variability. Fat and protein percentage were almost of similar values as in the first lactation. In the second lactation, phenotypic correlations among milk yields were high and positive. Phenotypic correlation between protein percentage and milk yield was low and negative.

Genetic correlations for milk traits, in the second lactation were low and some of them were even negative. Milk protein percentage was negatively correlated with, milk yield, milk fat yield and milk protein yield. Milk fat percentage was similarly lowly correlated with, milk yield, milk fat yield, and milk protein yield. A positive and low correlation was registered between milk and milk fat yields, while between milk and milk protein yields a very close value for the genetic correlation was also reported.

Heritability

Heritability estimates, in the present study for milk, fat and protein yields, and fat and protein percentages for the first and second lactation are shown in Table 2. Most heritability estimates for Simmental in the literature are higher than the threshold model estimates reported here. Except for the heritability of milk protein percentage, in the second lactation, heritabilities found for the milk traits, were higher than in the first lactation. The highest heritability was registered for milk fat percentage.

First lactation

Milk yield determined in this study, for the first lactation of Romanian Simmental dairy cows, was lower than that reported for the first lactation, by Freking and Marshall (1992), in Simmental-Hereford hybrids (5808.1 kg). It was also lower than the milk yield found by Vliegher *et al.* (2005) in Belgium White Blue (6191.5 kg), Jersey (6039 kg), Red Holstein (6771 kg) or in Black Holstein (7803 kg) and also found by Trivunovic *et al.* (2008) in Serbian Simmental (6646 kg). In contrast, Gorjanc *et al.* (2001) reported a lower milk yield in the first lactation for Brown Swiss (4106 kg) and Slovenian Simmental (3725 kg) and Rekik *et al.* (2009) in Tunisian Holstein (3871 kg). The average milk fat and protein yields in Romanian Simmental dairy cows in the first lactation were lower compared to those obtained by Macciotta *et al.* (2002) in the first lactation in Italian Simmental cows (224.2 kg and 195.9 kg, respectively) or by Trivunovic *et al.* (2008) in Simmental cows (254.3 kg and 215.3 kg, respectively). Gorjanc *et al.* (2001) also found a lower milk fat yield for Brown Swiss (160.7 kg) and Slovenian Simmental (146.6 kg), as well as lower milk protein yield (143.3 kg and 127.1 kg, respectively). For milk fat yield, Gerber *et al.* (2008) found in Bavarian Simmental breed reared on extensive and intensive farms, in the first lactation, a value of 178.1 and 267.9 kg and 146.1 kg and 227.5 kg for milk protein yield.

Table 1 Milk yield, milk composition, and trait variability of Romanian Simmental dairy cows[1]

	$\bar{x}$	$\bar{x}$ S	SD	X_{min}	X_{max}	CV%
First lactation period						
Yield (kg/period)						
Milk	4311.03	22.21	1295.07	1428.1	10334.2	30.04
Fat	170.32	0.866	50.54	56.7	403.3	26.97
Protein	137.09	0.740	43.19	43.08	331.3	31.5
Milk content (%)						
Fat	3.918	0.003	0.173	3.7	4.3	4.42
Protein	3.198	0.002	0.128	3.0	3.4	4.01
Second lactation period						
Yield (kg/period)						
Milk	4977.18	23.81	1388.15	1390.2	13023.8	27.89
Fat	195.97	0.95	55.22	52.38	595.14	28.17
Protein	160.43	0.80	47.13	42.95	437.35	29.37
Milk content (%)						
Fat	3.90	0.003	0.19	3.6	4.3	4.89
Protein	3.19	0.002	0.13	3.0	3.4	4.04

[1] n= 3,400.

Table 2 Heritability[1], genetic[2] and phenotypic[3] correlations among milk traits in Romanian Simmental dairy cows[4] for the first and second lactation periods

	h^2	Milk yield	Milk fat yield	Milk protein yield	Milk fat percentage	Milk protein percentage
First lactation period						
Milk yield	0.144	-	0.306	0.307	0.760	0.250
Milk fat yield	0.287	0.982	-	0.970	0.023	0.082
Milk protein yield	0.280	0.964	0.963	-	0.556	0.077
Milk fat percentage	0.560	0.030	0.060	0.003	-	0.045
Milk protein percentage	0.643	0.023	0.024	0.022	0.190	-
Second lactation period						
Milk yield	0.183	-	0.3105	0.3107	0.057	-0.285
Milk fat yield	0.369	0.977	-	0.097	0.165	-0.080
Milk protein yield	0.381	0.974	0.976	-	0.243	-0.083
Milk fat percentage	0.708	0.040	0.004	0.006	-	0.064
Milk protein percentage	0.377	-0.025	-0.023	-0.022	0.0197	-

[1] h^2= heritability.
[2] above diagonal.
[3] below diagonal.
[4] n= 3,400.

Moreover, in our study, milk fat and protein percentages in the first lactation was close to the values obtained by Gorjanc *et al.* (20-01) in Brown Swiss (fat 3.89%, protein 3.22%) and Slovenian Simmental (fat 3.92%, protein 3.26%) and by Calus et al. (2005) in Australian Friesian (fat 3.87%). Obtained results of phenotypic correlations between: milk yield and milk fat yields; milk yield and protein yields and between fat and protein yields, indicates the presence of strong and complete correlations between these traits in the first lactation. Boichard and Bonaiti (1987) reported a much lower phenotypic correlations between protein and fat yields in French Friesian (0.56), in Normande (0.51) and in Montbel- iarde (0.48). Correlations between the other components of milk production were low. Phenotypic correlation between milk protein yield and milk fat percent age was the lowest, which might have resulted from a high phenotypic variability in Romanian Simmental breed. The highest genetic correlation in Romanian Simmental in the first lactation was found between milk fat and protein yields. In addition, a high correlation was found between milk yield and milk fat percentage. The other genetic correlations among milk traits were of medium value (between protein yield and fat percentage) or very low (between fat yield and protein percentage or between fat yield and fat percentage). The genetic correlation between milk and milk fat yields was very low, compared with that reported by Pantelic *et al.* (2008) in Serbian Simmental of 0.989. In contrast, genetic correlation between milk yield and milk fat percentage found in Romanian Simmental was much higher, than the genetic correlation (-0.125) found between these two traits by Pantelic *et al.* (2008). Boichard and Bonaiti (1987) found in French Friesian a more pronounced genetic relationship between milk and protein yields (0.87 to 0.92). In the same vein, Boichard and Bonati (1987) reported an antagonistic genetic correlation between milk yield and fat percentage (-0.43) and between milk yield and protein percentage (-0.54) compared with the positive genetic correlations obtained in Romanian Simmental for the same couple of milk traits.

Estimates of heritability, genetic and phenotypic correlations for the first lactation, as given in Table 2, were lower than that found by Hashemi *et al*. (2009) in Iranian Holstein (0.26), but higher in Romanian Simmental for fat yield, and fat percentage, compared with the results obtained for Iranian Holstein (0.24 and 0.36), respectively. The low heritability found in dairy cows for the present study, may be explained by the low mean performance of Romanian Simmental. Heritability estimates of milk yield and composition may increase as the production level of herd increases (Hashemi *et al.* 2009). Boichard and Bonaiti (1987) found for milk yield in the first lactation, higher heritabilities close to 0.30 for Normande and Montbeliarde, and 0.37 in Holstein. Toit *et al.* (1998) also reported in South African Jersey in the first lactation, a higher heritability of 0.35 for milk yield. For fat and protein percentages, they found closer value of heritabilities of 0.57 and 0.58, respectively. Rothschild and Henderson (1979) similarly reported a heritability of 0.41 in American Holstein, for milk yield in the first lactation.

Second lactation

In the second lactation, the average milk yield is within the range of average milk yield of 4459-6907 kg registered by Perisic *et al.* (2009) between the years 2004 and 2006, for Simmental cows in some European countries (Hungary, Slovenia, Czech Republic, Slovakia, Austria, Norway, Italy, France, Germany, Poland, Switzerland). Macciotta *et al.* (2002) found for the Italian Simmental in the second lactation a higher average values for milk yield of 6225 kg, fat yield of 243.3 kg, and protein yield of 211.7 kg. The average fat percentage in the second lactation in Romanian Simmental was higher, compared with that observed by Hanus *et al.* (2008) in Czech Holstein breed (3.46%).
Pešek *et al.* (2005), studying the Czech Simmental, found an average fat percentage of 4.59 during their one month study (a very high value compared with the fat percentage found in Romanian Simmental). Protein percentage in the first and second lactation in Romanian Simmental had nearly the same value. Rothschild and Henderson (1979) found in American Holstein for milk yield in the second lactation, a heritability of 0.35. High values for the coefficient of variation in both lactations (over 26%) indicate a very heterogeneous population for milk, fat, and protein yields.

For the second lactation, reports of phenotypic correlations among milk yields for this Romanian Simmentals were very high and positive (between milk and fat yields, between milk and protein yields, between milk fat and protein yields). Chauhan and Hayes (1991) found in Canadian Holstein a lower correlation between milk and fat yields of 0.73 and 0.9 between milk and protein yields. Phenotypic correlation between protein percentage and milk yield in Romanian breed, was low and negative.

Genetic correlations in the Romanian Simmental were small between milk and fat yields, and between milk and protein yields. Chauhan and Hayes (1991) in Canadian Holstein reported a higher genetic correlation, between milk and fat yields, of 0.45. They also found a much higher correlation of 0.79 between milk and protein yields. Between milk yield and milk protein percentage in Romanian Simmental, a negative genetic correlation was registered. Chauhan and Hayes (1991) reported a negative and much lower genetic correlation (-0.54) between milk yield and milk protein percentage in Canadian Holstein.

For milk yield and milk fat percentage in Romanian Simmental a genetic correlation was found much higher than that found in Canadian Holstein (-0.49) by Chauhan and Hayes (1991) or Wilcox *et al*. (1971) in Guersney (-0.35) and in Holstein (-0.3). In their investigation of genetic parameters for milk yield of Holstein-Friesian cows, Campos *et al.* (1994) established a higher genetic correlation between milk and milk fat yields of 0.743.

As reported in Table 2, heritabilities found in Romanian Simmental breed for milk yield, was lower than the estimate registered by Nixon *et al.* (2009) in Canadian Holstein of 0.26, whilst a higher heritability was registered for fat percentage (0.708). For fat yield, heritability had a value closer to 0.38, value reported in the Holstein breed by Hardie *et al.* (1978). The value of heritability for protein yield exceeded the estimated one from paternal half-sib correlations values of 0.13 to 0.20 in literature. A lower heritability of 0.25 for protein yield in Holstein was found by Hardie *et al.* (1978) and Nixon *et al.* (2009) in Canadian Holstein (0.21). Chauhan and Hayes (1991) found in Canadian Holstein a higher heritability for milk yield (0.29), but lower for fat yield (0.31) and for protein yield (0.25). Chauhan and Hayes (1991), found values of heritability lower (0.65) for milk fat percentage, and almost double (0.61) for milk protein percentage. Hallowell *et al.* (1998) reported in Holstein breed a much higher heritability for milk (0.57) but much lower for fat percentage (0.37). Estimated heritabilities in Iranian Holstein, found by Mashhadi *et al.* (2008) were higher for milk yield (0.35), but lower than that reported in Romanian Simmental for: fat yield, protein yield, fat percentage and for protein percentage. In addition, Strabel and Misztal (1999) in Polish Black and

White breed found a lower heritability for milk yield of 0.14. Dedkova and Wolf (2001) estimate heritabilities of 0.28 to 0.30 for milk yield in Holsteins and 0.21 to 0.26 for Czech Pied cattle in the first three lactations, which are slightly higher than the heritabilities for milk yield found in the present study.

Heritability indicates what percentage of total variation for a trait is the result of genetic differences between animals and it is an important factor in the rate of genetic change (Wilcox *et al.* 1971). The higher the heritability the greater the genetic control on the trait, and the more rapidly selection will result in genetic progress. Generally, fat and protein percentages (first lactation) have high heritabilities. For the Romanian Simmental, milk heritability was low in both lactations, which means that there are small chances of inheritance by the descendants. Only milk fat percentage has a higher heritability (over 0.5) in both lactations, with great chances to be inherited. As it can be seen from Table 2, even in the first lactation protein percentage had a high heritability, this trait was not transmitted in the second lactation, which will make this trait more difficult to improve.

If a dairy producer will try to change milk composition by selection, chances for success would be very good. However, product value is determined by volume rather than percentage. Selection on component percentages generally is not recommended. Most dairy producers are well aware that increases in milk component percentages tend to be associated with reduced milk volume. Genetic correlations between milk component percentages and milk yield substantiate this general rule. The genetic correlation measures the extent to which two traits are controlled by the same genes. Values from 0.4 to 1.0 indicate that two traits will progress strongly in the same direction if selection is for one of the traits alone. This expected decline in protein content suggests definition of a new selection goal, which maximizes fat and protein yield, while maintaining protein content (Albuquerque *et al*. 1996). The possible decrease in protein content, which would have negative technological consequences, cannot be totally neglected, even with selection exclusively based on solid yields. Today, the main selection criterion used is the useful yield. This trait takes an intermediate position between fat and protein yields with which it is highly correlated (0.92 to 0.98). The corresponding useful content is closer to fat than to protein content. Therefore, this selection criterion may lead to a slight decline in protein content that must be compensated by a greater emphasis laid on selection for protein content (Arione *et al*. 2005). Selection on the ratio of protein to fat content is excluded, since it decreases fat content instead of increasing protein content that is less variable. Genetic correlations around zero indicate that two traits operate in a fairly, independent pattern. Some of the negative correlations are large enough to indicate rather strong divergence between tests and yield if selection is for one or the other trait alone. Recall that economic considerations recommend maximizing volume of component rather than percentage content. Since milk volume and component percentage are antagonistic, selection could be based on the economic value of the total product produced by the cow. Several correlations between production and reproduction traits were spotted as having potential relevance in the selection of Romanian Simmental. Generally, results did not confirm previous literature data, correlations obtained in this study being generally lower. Results for milk and fat confirm the well-established choice of selection on fat yield to increase it as much as possible while maintaining or improving fat percentage. As shown by the yield- percentage correlations, selection on useful yield seems relatively satisfactory.

CONCLUSION

Heritabilities indicated that there was a considerable amount of variation in milk yield, similar to that found for fat. Genetic correlation between yields shown to be high, but the negative correlation between milk and protein percentage (second lactation) will not permit a rapid genetic change under divergent selection. To satisfy the human population's demand for milk, butter and other derived products, the desired breeding goal would seem to be the increase in milk yield, while holding the fat percentage constant. Negative genetic association between milk yield and protein percentage, suggest that this trait must be included in selection programs if its level were to be maintained while increasing milk yield.

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