Scientific Papers Series Management , Economic Engineering in Agriculture and Rural Development
Vol. 14, Issue 1, 2014
PRINT ISSN 2284-7995, E-ISSN 2285-3952

RESEARCH ON THE CORRELATION BETWEEN THE AGE AT THE FIRST CALVING AND MILK PRODUCTION CHARACTERS

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Abstract

The paper aimed to present the genetic determinism of milk yield traits and age at first calving using a number of 2,237 half sibs, offspring of 989 Friesian bulls and raised in various farms in Romania. Taking into account the peculiarities of half sibs families, it was used a linear mathematical model for unbiased cross classification. Average 305-days milk yield at the first lactation was 3,034.88 ± 14.67 kg, while the average milk fat percentage registered 3.79 ±0.004 %. Average 305 days fat yield accounted for 115.12±0.59 kg, average age at first calving regietered 839.25±1.43 days (27.5 months). Between milk yield and fat percentage, it was found a correlation of r_G - 0.245, reflecting a weak but positive relation between the two traits. The phenotypic correlation was low and a negative one (r_F = -0.181), showing a weak and reverse link between the two traits. Between milk yield and fat yield, both the genotypic and phenotypic correlations were very high and had positive values, r_G = 0.971 and r_F = 0.964. Between fat percentage and fat yield, it was found a genotypic and phenotypic positive correlation, r_G = 0.465, and, respectively, r_F = 0.240. The correlation between age at first calving and milk yield was extremely weak and negative, r_G = - 0.257 şi r_F = - 0.090. Between age at first calving and fat percentage, the correlation was very small and had a negative value (r_G = - 0.187) and (r_F = - 0.032). Between age at first calving and fat yield, both the genetic and phenotypic correlations were weak and negative (r_G = -0.288 and r_F = - 0.093). The values of the heritability and genotypic correlations pointed out the effect of the aditive action of the genes, but the phenotypic correlations indicated that some traits were also determined by the environment factors. Cow selection based on milk yield has a positive impact on the future milk performance. In the breeding programmes, age at first calving should not be neglected as it could lead to a decline of production if it does not fit to the optimal thresholds of the the Friesian breed.

Key words: *age at first calving, correlations, Friesian cows, Romania, genetic determinism, milk production traits*

INTRODUCTION

Age at first calving is one of the most important reproduction traits with a deep impact on milk production [8, 11, 13, 16, 27, 34, 35, 38, 40]

Age at first calving has to be correlated to the heifer body weight in order to assure a mature development and a higher production later during the productive life time. A minimum 450 kg live weight is required for a first age at calving of 23-26 months. The cost per animal could increase by USD 50-75 if a heifer is over 24 months age at first calving [12].

In order to increase milk production, breeding programmes have to pay attention to objectives regarding age at first calving, calving interval and other reproductive traits close connected to milk production characters.

Because of its importance in the growth of milk production, age of first calving has been and still is studied at a larger scale in many countries and in close relationship with the milk production traits for various dairy breeds such as: Holstein Friesian breed [3, 5, 9, 10, 15, 18, 24, 25, 26, 31, 41, 44, 45], Brown Swiss breed [4], Normand Breed [14], Indian cattle breed [42].

In Romania, research results have put into evidence the production potential of Friesian breed [37], but also of Black and White Spotted breed [12, 13, 22, 29], Brown breed, and Simmental breed [6, 33].

Most of the authors revealed the genetic parameters for milk yield and fat yield, but also for age of first calving and all of them proved that age at first calving has a low heritability and is negatively correlated with milk production.

In this context, the paper goal was to study the age at first calving and milk production traits for the Friesian dairy cows raised in various farms of Romania.

The research brings a new mathematical model set up especially to evaluate the genetic determinism of the milk production and age at first calving traits.

MATERIALS AND METHODS

In order to carry out the research study, the a number of 2,237 half sibs descendants from 989 Friesian bulls were used as biological material. The sample of individuals was divided into 44 classes taking into account the heard-year effect. The calculated genetic parameters were heritability and correlation, as well as their analysis. Their determination imposed the calculation of variance and covariance.

For this purpose, taking into consideration the peculiarities of half sibs families, it was established and used a linear mathematical model for unbiased cross classification similar to one set up by Graybill (1961) [17].

The mathematical model for sires testing using their daughters in various herds was the following one:

Y_{ijk}-□+a_i+b_i+c_{ijk}, where k=0,1,....n_{ij}; j=1,2,......, B; i=1,2,......A and $\sum_j n_{ij} = n_i$ $\sum_i n_{ij} = nj$ $\sum_{ij} ij = n$.

It was considered that a_i, b_j, c_{ijk} are random variables with the averages equal to zero and variance S_a^2, S_b^2, S_c^2. The analysis suposed the use of estimates, which made it a little difficult. Considering within this unbiased cross classification that: R(□, S, B)=R (S1, □□□B) + R (□, B) (2) and R(□, S,B)=R (B1, □□□B) + R (□, B), the total sum was divided in two ways:

$$\sum {}^2_{ijk} = \frac{Y^2...}{n} + R(S,\mu,B) + R(\mu,B) + \text{ (error)}$$

$$\sum {}^2_{ijk} = \frac{Y^2...}{n} + R(B,\mu,S) + R(\mu,S) + \text{(error)}$$

If we proceed in this way and the average of the squares is considered equal to the expected average of the squares, we could obtain two sets of estimates, each of them being unbiased.

Another method could be to divide the total sum of the squares as follows:

$$\sum Y^2_{ijk} = (\frac{Y^2..}{n}) + \left[\sum_i (\frac{Y^2..}{n_i} - \frac{Y^2..}{n}\right] + \left[\sum_j (\frac{Y^2 j..}{nj} - \frac{Y^2..}{n}\right]$$

+ Remaining

This could be placed in a table of variance analysis (Table 1). Then we can find the estimates, equalize the observed average of the squares with the one of the expected squares and solve the resulting set of three equations for three unknowns S_a^2, S_b^2, S_c^2.

Table 1. Analysis of variance for the model of unbiased bifactorial classification

Source of variation	DL	SS	SA	S^2
Total	N	$\sum_{ijk} Y^2_{ijk}$		
Average	1	$\frac{Y^2...}{n}$		
a classes	A-1	$\sum_i \frac{Y_i^2}{n_i} - \frac{Y^2...}{n}$	Ams	$S_C^2+r_5S_b^2+r_6S_a^2$
b classes	B-1	$\sum_i \frac{Y^2 j}{nj} - \frac{Y^2...}{n}$	Bms	$S_C^2+r_3S_b^2+r_4S_a^2$
Remaining	n-A-B+1	Substract	Rms	$S_C^2+r_1S_b^2+r_2S_a^2$

In order to find the expected average of the squares and r_i, we can proceed in the way presented below:

$$E(Ams)=\frac{1}{A-1}E(\sum_i\frac{Y_i^2}{n_i}-\frac{Y^2..}{n})=\frac{1}{A-1}(n-\sum_i\frac{n_i^2}{n})S_a^2+\frac{1}{A-1}(\sum_{ij}\frac{n_{ij}^2}{n^i}-\sum_j\frac{n^2j}{n})S_b^2+S_c^2$$

The values for r_5 and r_6 were obtained from this formula.

Also, E(Bms) could be written simetrically, replacing i by j and changing S_a^2 by S_b^2 in E(Ams). We will obtain:

$$E(Bms)=\frac{1}{B-1}(\sum_i\frac{n_{ji}^2}{nj}-\sum_i\frac{n_i^2..}{n})S_a^2+=\frac{1}{B-1}(n-\sum_j\frac{n^2j}{n})S_b^2+S_c^2$$

of which r_3 and r_4 could be derived. Then, the sum of squares added to $\sum Y_{ijk}^2$ will result:

$$\sum{}_{ijk}^2=\frac{Y^2..}{n}+(A-1)Ams+(B-1)Bms+(n-A+1)Bms$$

Taking into consideration the expected values of the both sides and simplifying, we will obtain:

$$E(Rms)=\frac{1}{n-A-B+1}\left[E(\sum y_{ijk}^2)-E(\frac{Y^2..}{n})-(A-1)E(Ams)-(B-1)E(Bms)\right]$$

The amounts from the right side are calculated, except $E(\sum Y_{ijk}^2)$, which could be

determined as follows:

$$E(\sum_{ijk}Y_{ijk}^2)E\left[\sum_{ijk}(\mu+a_i+b_j+c_{ijk})^2\right]=n(\mu^2+S_a^2+S_b^2+S_c^2).$$

Then:

$$E(Rms)=\frac{1}{n-A-B+1}\Bigg[n(\mu^2+S_a^2+S_b^2+S_c^2)-n\mu^2-\sum_i\frac{n_i^2}{n}S_a^2-\sum_j\frac{n^2j}{n}S_b^2-S_c^2-(n-\sum_i\frac{n_i^2}{n}S_a^2-$$

$$(n-\sum_i\frac{n_i^2}{n}S_a^2-($$

$$\sum_{ij}\frac{n_{ij}^2}{n^i}-\sum_j\frac{n_{.j}^2}{n}-\sum_j\frac{n^2j}{n})S_b^2-(A-1)S_c^2-\sum_{ij}\frac{n_{ij}^2}{nj}-\sum_i\frac{n_i^2}{n})S_a^2-(n\sum_j\frac{n_j^2}{n})S_b^2-(B-1)S_c^2]=$$

$$=S_c^2-\frac{1}{n-A-B+1}(\sum_{ij}\frac{n_{ij}^2}{n^i}-\sum_j\frac{n_j^2}{n})S_b^2-\frac{1}{n-A-B+1}(\sum_{ij}\frac{n_{ij}^2}{nj}-\sum_i\frac{n_i^2}{n.})S_b^2$$

In this way, we could determine r_1 and r_2 as follows:

$$r_1 = \frac{1}{n-A-B+1}\left(\sum_j \frac{n_j^2}{n} - \sum_{ij}\frac{n_{ij}^2}{n_i}\right)$$

$$r_2 = \frac{1}{n-A-B+1}\left(\sum_j \frac{n_i^2}{n} - \sum_{ij}\frac{n_{ij}^2}{n_i}\right)$$

$$r_3 = \frac{1}{B-1}\left(n - \sum_j \frac{n_j^2}{n}\right)$$

$$r_4 = \frac{1}{B-1}\left(\sum_{ij} \frac{n_{ji}^2}{n_j} - \sum_i \frac{n_i^2}{n_i}\right)$$

$$r_5 = \frac{1}{A-1}\left(\sum_{ij} \frac{n_{ij}^2}{n_i} - \sum_j \frac{n_j^2}{n}\right)$$

$$r_6 = \frac{1}{A-1}\left(n - \sum_i \frac{n_i^2}{n}\right)$$

Heritability was determined using the formula: $h^2 = \frac{V_A}{V_F}$ and

$$S_{h2} = (h^2 + \frac{4}{n_i})\sqrt{\frac{2}{S}}$$

Phenoptypic correlation was determined with the formula: $r_F = \frac{\mathrm{cov}\, F_{XY}}{\sqrt{S^2_{FX_x} . S^2{}_{FY}}}$

Genotypic correlation was calculated with the formula: $r_G = \frac{\mathrm{cov}_{G\,XY}}{\sqrt{S^2_{G_X} S^2_{GY}}}$.

For testing the homogeneousness of the variances regarding the calendar month, it was used Snedecor-Fisher Test[12].

The genetic parameters were determined both for milk production and reproduction traits. In order to increase precision for optimizing these parameters and obtaining pertinent data, close to the expected ones, the computer was asked to select the primary data between the following validation thresholds: 1,700-4,600 for milk quantity (kg), 3.3-4.6 for fat percent (%) şi 700-960 for age at first calving (days).

RESULTS AND DISCUSSIONS

Average and variability indicators for milk production and reproduction traits

Average 305-days milk yield at the first lactation was 3,034.88 ± 14.67 kg, reflecting a good milk potential, if we take into consideration that at this moment of the productive life a primiparous cow should achieve 60-70 % of the maximum lactation. The variation coefficient for this milk trait accounted for 22.86 %, close to the normal value, reflecting a relative homogeneousness of the individuals within the sample.

Average milk fat percentage registered 3.79 ±0.004 %, a satisfactory value for Friesian breed, but not for the desired goal in breeding programmes (Table 2).

Table 2. Average milk production traits and age at fisrt calving for the Friesian half daughters (N=2,237)

Character	$\overline{X} \pm s\overline{X}$	GSS	DSS.	V %
Milk yield (kg)	3,034.89±14.670	493.34	693.93	22.86
Fat percentage (%)	3.79±0.004	0.16	0.23	6.06
Fat yield (kg)	115.72±0.590	20.30	27.05	23.49
Age at first calving (days)	839.25±1.430	34.37	67.55	8.04

Source:Own calculations

The fat percentage registered a normal value for the variation coefficient reflecting a homogenous distribution of the variables around the average value.

Average 305 days fat yield accounted for 115.12±0.59 kg, depending directly on milk performance and fat percentage. As a result, its value is smaller for Friesian breed. The variation coefficient was 23.49 %, a high value, depending on the variation of milk yield.

Average age at first calving registered 839.25±1.43 days, that is about 27.5 months, a figure close to the normal limits for Friesian cows raised in Romania. The variation coefficient registered 8.04, accepted as a anormal value.

Genetic and phenpotypic parameters of milk yield and age at first calving

Components of variance for milk yield traits and age at fisrt calving

The analysis of variance allowed to put into evidence the components observed needed to establish the effects of various sources of variation such as: genetic differences created between the hals sisters families, due to their sire founders, variations created by the herd-year effect, and variations created within the half sisters families (Table 3).

Table 3.Genotypic and phenotypic variances for milk yield traits and age at first calving

Character/Variance	Age at first calving	Milk yield	Fat percentage	Fat yield
Among sires (S_T^2)	$\frac{285,479}{6,474}$	$\frac{60848,332}{12,636}$	$\frac{1,121}{18,535}$	$\frac{103,838}{11,183}$
Among herds-years (S_{FA}^2)	$\frac{1670,597}{36,603}$	$\frac{191310,560}{39,728}$	$\frac{2,168}{35,846}$	$\frac{303,164}{41,411}$
Among half sisters (S_D^2)	$\frac{2597,979}{56,923}$	$\frac{229386,327}{47,636}$	$\frac{2,759}{45,619}$	$\frac{325,083}{44,406}$
Phenotypic variance (S_F^2)	$\frac{4564,055}{100,000}$	$\frac{481544,650}{100,000}$	$\frac{6,048}{100,000}$	$\frac{732,085}{100,000}$
Genotypic variance (S_G^2)	1181,916	243393,320	4,484	415,352

Source:Own calculations

The share of the variances by variation source of the phenotypic variance indicated a degree of contribution of the aditive action of genes on the determination of each character and also the degree of influence of environment conditions in the farms and cows. The higher the influence of environment conditions, the lower the impact of genetic determination.

Components of the variance for milk yield showed that the genotypic variance represents 50.54 % of total variance. But, the variance among sires represented only 12.56 % of the phenotypic variance. Despite the expectations, in case of the population considered in this study, milk yield has a high genetic determination.

In case of fat percentage, the genoptypic variance represented 74 % of total variance, showing also that the differences among sires are highly genetically determined.

Components of the variance for fat yield reflected a highly share of genotypic variance in the phenotypic variance.

In case of age at first calving, the genotypic variance represented 25.90 % of the phenotypic variance, as expected, because this trait is deeply influenced by environment conditions.

Heritability of milk yield traits and age at first calving is presented in Table 4.

Table 4. Heritability and its error for milk yield traits and age at first calving

Character	$h^2 \pm S_h^2$	
Milk yield	0.505	0.069
Fat percentage	0.741	0.101
Fat yield	0.567	0.077
Age at first calving	0.258	0.037

Source:own calculations

As one can see from the table above, ***milk yield*** had a heritability of 0.505, a higher figure than the normal ones (0.25-0.30), but close to the ones reported by other authors [22, 42].

Fat percentage has also registered a high heritability, (h^2=0,741), similar to the values calculated by other authors in Romania and other countries [1, 21, 38].

Fat yield recorded h^2=0,567, proving a high genetic determination, as mentioned by other authors in some studies. [1, 22, 28, 29].

Age at first calving registered a heritability of 0.258, a little bit higher, but similar to the one found by some authors [27].

All these high values could be explained by the import of sires and frozen semen from sires which are relatives and used in Romania for artificial insemination for the same cow population with a deep impact on the growth of the genetic variability.

In the USA, it was reported a heritability of 0.44 for milk yield in a cow population relatively closed from a reproductive point of view, and well genetically preserved [8]

Phenotypic and genotypic correlations between milk yield traits and age at first calving.

The analysis of variance was made for six couples consisting of the traits mentioned above, as presented in Table 5.

Table 5.Components of covariance for various pairs of milk yield traits and age at firts calving

Covariance/ Pairs of traits	Among sires Cov_T	Among herds-years $Cov_{F.A.}$	Among half sisters	Phenotypic covariance Cov_F	Genotypic covariance Cov_G
Milk yield x Fat %	5.115	5.694	-13.708	-2.979	20.460
Milk yield x Fat yield	2,442.730	7,370.197	8,290.327	18,103.255	9,770.922
Fat % x Fat yield	0.400	0.850	0.296	1.547	1.600
Age at first calving x Milk yield	-1,089.897	-1,862.311	-1,268.209	-4,220.400	-43,509.511
Age at first calving x Fat %	-0.271	-2.683	-0.225	-0.523	-1.086
Age at first calving x Fat yield	-50.500	-65.561	-55.055	-171.197	-202.321

Source:Own calculations

The change of a trait attracted the variation of another trait in a special direction or another. Thus, the components of the variance reflected that the increase of milk yield will decline the fat percentage, but it will grow up the fat yield.

The change of fat percentage does not affect fat yield too much.

But, the change of age at first calving could cause substantial changes regarding milk yield, fat percentage and fat yield.

Genotipic and phenotypic correlations reflected the links between various pairs of traits (Table 6).

Between milk yield and fat percentage, it was found a correlation of r_G - 0.245, reflecting a weak but positive relationship between the two traits.

But the phenotypic correlation was a negative one (r_F = -0.181), showing a weak and reverse link between the two traits.

All the authors found such a negative correlation between these two characters.

Between milk yield and fat yield, both the genotypic and phenotypic correlation were very high and had positive values, reflecting a strong relationship and of the same sense between the change of the two characters (r_G = 0.971 and r_F = 0.964).

These values are similar to the ones obtained by other authors in Romania [1, 28, 39].

Between fat percentage and fat yield, it was found a genotypic and phenotypic positive correlation, r_G = 0.465, and, respectively, r_F = 0.240, reflecting a weak link between these two characters.

Compared to the results obtained by other Romanian authors, these correlations are a little bit higher. [1, 28, 39]

The correlation between age at first calving and milk yield was extremely weak and negative, r_G = - 0.257 and r_F = - 0.090. Therefore, a higher age at first calving could determine a diminished milk yield at the first lactation.

Between age at first calving and fat percentage, the correlation was very small and haa a negative value, reflecting a minor importance of these traits (r_G = - 0.187) and (r_F = - 0.032).

Between age at first calving and fat yield, both the genetic and phenotyoic correlations were weak and negative (r_G = -0.288 and r_F = - 0.093).

Table 6. Genotypic and phenotypic correlations between various pairs of milk traits and age at first calving

Genotypic correlations			Traits	Phenotypic correlations		
-0.288	-	-	Fat yield	-	-	-0.093
-0.187	0.465	-	Fat percentage	-	0.240	-0.032
-0.257	0.971	0.245	Milk yield	-0.181	0.964	-0.090
Age at first calving	Fat yield	Fat percentage	Studied traits	Fat percentage	Fat yield	Age at first calving

Source:Own calculations

Comparing the F value obtained for each character with F from tables for P=0.05, P = 0.01 şi P=0.001, one can conclude that the variances are not homogenous, therefore the H_0 hypothese can not be accepted, but the true one, H_1. Therefore, the two factors taken into consideration have a deep influence on the milk production traits and age at first calving (Table 8).

Table 7.Analysis of variance for F Test for milkyield and age at first calving

Sursa de variație	DL	SS	AP	F
Age at first calving				
Global variance among groups	11	2,551,367.739	2,311,942.521	-
Error	4,089	86,387,361.361	21,126.769	-
Total	4,100	88,938,729.100	-	10.978
Milk yield				
Global variance among groups	11	111,521,313.490	10,138,301.226	-
Error	4,089	29,766,975,717.830	7,279,761.8936	-
Total	4,100	3,088,821,831.320	-	13.926
Fat percentage				
Global variance among groups	11		2,482	0.225
Error	4,089	309.648	7,572	-
Total	4,100	312.130	-	2.979
Fat yield				
Global variance among groups	11	176,336.579	16,036.052	-
Error	4,089	4,425,984.551	1,082.412	-
Total	4,100	4,602,381.131	-	14.815

Source: Own calculations

Table 8. Calculated F value compared to the critical interval for various probabilities

Selection character	Calculated F	Critical interval for:		
		P=0.05	P=0.01	P=0.001
		1.80-1.83	2.26-2.28	2.86-2.89
Age at first calving	10.978	No	No	No
Milk yield	13.926	No	No	No
Fat precentage	2.979	No	No	No
Fat yield	14.8185	No	No	No

Source: Own calculations

The results of the Test Bartlett applied on the variances froma a month to another, caused by the systematic factors taken into consideration are given in Table 9.

Comparing the B calculated statistic with the tabled one, one can notice the differences. The conclusion is that the variables are substantially influenced by the month of calving.

Therefore, between age at first calving and milk production traits it was found a strong influence, as the dispersions were not homogenous for any probability rate and any selection trait.

Table 9. Calculated B value compared to the critical interval for various probabilities

Selection character	Calculated B	Critical interval for:		
		P=0.05	P=0.01	P=0.001
		18.30-21.02	23.20-26.21	29.58-32.90
Age at first calving	140,081	No	No	No
Milk yield	12.361	No	No	No
Fat percentage	101.260	No	No	No
Fat yield	11.752	No	No	No

Source: Own calculations

This allow to draw the conclusion that it is compulsory to evaluate the influence of age at first calving on milk production traits and to set up corresponding correction factors in order to increase the accuracy of the data which are later used in the sires breeding value estimation based on their half daughters performances in milk production.

CONCLUSIONS

The genotypic parameters determined in this study are close to the results mentioned by other authors in Romania and other countries, but they are in general a little higher.

The values of the heritability and gentypic correlations pointed out the effect of the aditive action of the genes, but comparing the genotypic correlations with the phenotypic correlations, one can conclude that some traits are determined also by environment factors.

As a conclusion, cow selection based on milk yield has a positive impact on the future milk performance and implicitely on fat yield.

In the breeding programmes, age at first calving should not be neglected as this reproduction character, despite that it has weak influences on production performance, it could lead to a decline of production if it does not fit to the optimal thresholds of the the Friesian breed.

From a practical point of view, farmers have to pay attention to the age at first calving and correlate it with the heifer weight. This means to assure good raising conditions so that the first calving to take place no longer than 24-25 months of heifer age as milk production to reach a corresponding level to the breed potential.

ACKNOWLEDGMENTS

The author thanks the dairy farmers involved in this research for all their support to provide the basic data and interest in the final conclusions for breeding practice.

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