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Original scientific paper

VARIABILITY AND HERITABILITY OF MILK TRAITS OF HOLSTEIN - FRISIAN BULL DAMS AND THEIR PROGENY

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Lazarević M., D. Stanojević, V. Bogdanović, V. Pantelić, N. Maksimović, M. Marinković, N. Mićić (2018): *Variability and heritability of milk traits of Holstein - frisian bull dams and their progeny*.- Genetika, Vol 50, No.1, 243-251.
The research was performed on Holstein-Friesian and Black and White bull dams reared on five farms of Agricultural Corporation of Belgrade - PKB. The study included 575 lactations of cows selected as bull dams and their progeny calved in the period from 2007 - 2014 and represent progeny of 24 bulls. The following dairy traits were analysed in a standard lactation (305 days): milk yield (kg) - **MY**, milk fat content (%) - **% MF**, milk fat yield (kg) - **MFY**, protein content (%) - **% PC** and protein yield (kg) - **PY**. Holstein-Friesian bull dams and their progeny, in standard lactation, produced on average 9239.84 ± 1607.64 kg of milk, with a milk fat content of 3.44 ± 0.20 and protein content of 3.21 ± 0.12. The impact of bull - sire, year of birth, lactation order, farm, year and calving season was present at different levels of statistical significance on yield traits, while the genetic group had no influence on any of the milk traits. Bull - sire, year of birth, lactation order and calving season did not influence the variability of milk fat and protein content. Heritability of observed milk traits was medium to low. The content of milk fat and protein had the lowest values of heritability, 0.014, and 0.024, respectively. The heritability of milk yield, milk fat yield and protein yield was 0.293, 0.319 and 0.273, respectively.
Key words: Holstein – Frisian breed, bull dams, milk traits, heritability

INTRODUCTION

The focus of dairy cattle breeding worldwide is primarily on improving production traits (NIELSEN *et al*., 2005). Most dairy cattle breeding programmes rely on multitrait selection, where predicted breeding values (EBV) for individual traits in the breeding goal are combined

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according to their economic values. EBV for the traits are frequently obtained from single trait models or in some cases from multitrait models for groups of traits (LASSEN *et al.,* 2012). Over recent years, more and more focus has been put on lowly heritable traits leading to breeding values with low accuracies and thereby instability in breeding values for these traits (MIGLIOR *et al.,* 2005).

Variance components and genetic parameters are needed for genetic improvement programs to predict the breeding values of candidates for genetic selection, to choose among mating plans and to predict selection response (MONTALDO *et al*., 2012). Knowledge of the type and amount of genetic variation and distribution of animals for traits considered for selection in the population can help design optimum breeding programs (WILLHAM and POLLAK, 1985). Additive genetic variation has been instrumental for the genetic improvement of traits of economic importance in dairy cattle populations (WILLHAM and POLLAK, 1985). It is essential to identify elite females that can make positive genetic contributions to the next generation (SCHEFERS and WEIGEL, 2012). The first step is to identify the potential cows, candidates to become a bull dam, work that is done at the association entitled to manage the genetic improvement of the breed. The main criterion for a cow to become a bull dam candidate is the phenotypic difference of its performance for milk traits compared to the farm or breed average (BOGNAR *et al*., 2012).

Bull dams represent a group of elite females that are selected based on EBV or GEBV and usually rank among the top 1% of the population. These cows are mated with elite bulls for the purpose of producing bull calves (SCHEFERS and WEIGEL, 2012).

Potential bull dams can be tested as well, and this gives AI companies and breeders an opportunity to screen thousands of potentially elite cows and heifers on commercial farms for the purpose of identifying few superior individuals that can be reproduced by MOET or IVF (SCHEFERS and WEIGEL, 2012).

For any country, breeding objectives need to be outlined and regularly updated to address the changes in the consumer environment. Breeders have to plan ahead because genetic choices made today will improve profit only in future generations, a review of past selection objectives maybe of use in determining new selection goals (OMBURA *et al*., 2007).

Nucleus herds also provide a suitable environment in which to test and select potential bull dams, as the cows are kept under the same environmental conditions and, thus, are tested on equal bases (HANSEN AXELSSON *et al*., 2014).

The objectives of this study were to determine variability and heritability of milk traits in nucleus dairy herd of bull dams by using the linear method of evaluation, and to determine their importance in selection of cattle.

MATERIALS AND METHODS

The research was performed on Holstein-Friesian and Black and White cattle, reared on five farms of Agricultural Corporation of Belgrade - PKB. The study included 255 cows, of which 164 cows were selected as bull dams and 91 cows were the progeny of bull dams. In total 575 lactations were observed. All cows calved in the period from 2007 - 2014 and represented progeny of 24 bulls. The study included bulls with a minimum of 5 daughters.

The following dairy traits were analysed in a standard lactation (305 days): milk yield (kg) – **MY**, milk fat content (%) - **% MF**, milk fat yield (kg) – **MFY**, protein content (%) - **% PC** and protein yield (kg) – **PY**.

The phenotypic and genetic variability of milk traits was assessed by the method of least squares *LSMLMW*. To determine the origin of phenotypic variability of milk traits the fixed model was used, which is the same as the mixed model used in evaluation of genetic variation, but in this case the bull - sire was considered as a fixed factor.

The mixed model with random influence of bull – sire, fixed influence of year of birth, genetic group, lactation order, farm, year and season of calving, was used to calculate the genetic variability and variance components of studied traits.

Depending on the share of Holstein genes, all cows were divided into 5 groups: I - below 50% of Holstein genes, II - from 50% to 75% Holstein genes, III - from 75% to 87.5% Holstein genes, IV - from 87.5% to 93.75% Holstein genes and V - over 93.75% Holstein genes. Within each year, four calving seasons were observed: winter (December, January and February), spring (March, April and May), summer (June, July and August) and autumn (September, October and November).

Data were analysed using the statistical software package SAS (SAS Institute Inc. 9.3, 2012).

The mixed model used to calculate the genetic variability of milk traits was:

$$Y_{ijklmnop} = \mu + O_i + B_j + G_k + L_l + F_m + Y_n + S_o + e_{ijklmno}$$

where:

- $Y_{ijklmno}$: studied trait,
- μ: general population mean,
- O_i: random effect of i^{th} sire (i=1,…,24),
- B_j: fixed effect of j^{th} year of birth (j=1,…,8),
- G_k: fixed effect of k^{th} genetic group (k=1,...,5),
- L_l: fixed effect of l^{th} lactation order (l=1,2,3,4),
- F_m: fixed effect of m^{th} farm (m=1,…,5),
- Y_n: fixed effect of n^{th} calving year (n=1,…,8),
- S_o: fixed effect of o^{th} calving season (o=1,2,3,4),
- $e_{ijklmno}$: random error with characteristics N $(0,\sigma^2)$.

The heritability of the investigated traits was calculated by the method of interclass correlation between the half - siblings, where the progeny of one sire have 25% of common genes, based on the formula:

$$h^2 = \frac{4\sigma_a^2}{\sigma_a^2 + \sigma_e^2}$$

where: h^2 – heritability, σ_a^2 – variance between sires (additive genetic variance), σ_e^2 – variance errors.

RESULTS AND DISCUSSION

The Table 1 shows the least squares means, standard deviations and standard error of dairy traits in standard lactation.

Table 1. Least squares means (LSM), standard deviations (SD) and standard error (Se) for milk traits in standard lactation (305 days)

Trait	Category	Number of lactation	LSM	SD	Se
MY	Bull dam progeny	198	8555.020	1557.549	110.690
	Bull dam	377	9599.507	1515.852	78.070
	Overall mean	**575**	**9239.840**	**1607.645**	**67.043**
%MF	Bull dam progeny	198	3.441	0.214	0.015
	Bull dam	377	3.446	0.201	0.010
	Overall mean	**575**	**3.444**	**0.205**	**0.009**
MFY	Bull dam progeny	198	293.537	52.350	3.720
	Bull dam	377	329.602	48.229	2.484
	Overall mean	**575**	**317.183**	**52.521**	**2.190**
%PC	Bull dam progeny	198	3.210	0.137	0.010
	Bull dam	377	3.214	0.114	0.006
	Overall mean	**575**	**3.213**	**0.122**	**0.005**
PY	Bull dam progeny	198	274.117	48.706	3.461
	Bull dam	377	308.142	47.650	2.454
	Overall mean	**575**	**296.426**	**50.629**	**2.111**

The Holstein-Friesian bull dams and their progeny, in standard lactation produced on average 9239.84 ± 1607.64 kg of milk, with the milk fat content of 3.44 ± 0.20 and the protein content of 3.21 ± 0.12. The average milk production of bull dams was 9599.51 kg, with milk fat yield of 329.60 kg and protein yield of 308.14 kg . Bull dam progeny produced on average 8555.02 kg of milk in standard lactation with 293.54 kg of milk fat and 274.12 kg of protein yield. Milk production of bull dam progeny was 1044 kg lower than bull dams' milk production. BOGNAR *et al*. (2012) have conducted a study on 55 Romanian Black and White cows selected as bull dams and 225 candidate bull dams. Candidate bull dams produced 8719.4 kg of milk with 3.933% and 343.9 kg of milk fat. The average production of the bull dams was 9686.9 kg milk, 3.945% fat content and milk fat yield of 383.35 kg. Lower milk yield in standard lactation of first calving Holstein - Friesian heifers is stated by STANOJEVIĆ *et al.* (2012).

EMAN *et al.*, (2016) state the average milk yield for first calving heifers in Egypt, in the lactation of 305 days, of 8801 kg, with 268 kg of milk fat and 219 kg of protein. ATIL (2006) reports the milk yield of 4030 ± 1112 kg in the standard lactation, achieved by Holstein - Friesian breed in Turkey. KAWAHARA *et al*., (2006) reports average production of Holstein-Friesian cows in Japan - milk, fat, and protein yields, and fat and protein contents were 7,899 kg, 301 kg, 253 kg, 3.83%, and 3.18%, respectively.

SAHIN *et al.*, (2012) reports first lactation mean values for 305-day milk yield, actual lactation milk yield, and lactation length were 6222±35.8 kg, 6651±42.6 kg, and 327±1.3 days. Second and third 305-day lactation yields were proportionately 8% and 11% greater, respectively.

BESKOROVAJNI (2014) has determined the average milk yield of cows of Holstein - Friesian breed in the first standard lactation of 6478.82 kg, with 3.55% milk fat. WELLER and EZRA (2004), in the Israeli Holstein population, have found high levels of milk yield in standard lactation of 10.281 kg of milk with 3.23% milk fat and protein content of 3.04%.

The influence of genetic and nongenetic factors on the variability of milk traits of bull dams and their progeny in standard lactation is presented in the Table 2.

Table 2. F – values for genetic and non genetic factors affecting milk traits in standard lactation (305 days)

Trait	F - value							R^2
	Sire	Year of birth	Genetic group	Lactation order	Farm	Calving year	Calving season	
	df_1=23	df_1=7	df_1=4	df_1=3	df_1=4	df_1=7	df_1=3	
	df_2=522							
MY	2.33	2.17	0.85	15.88	2.54	1.34	7.40	0.31548
MY p - value	0.0005	0.0354	0.4966	<0.0001	0.039	0.2277	<0.0001	
%MF	1.15	1.92	1.21	6.31	7.68	8.17	1.36	0.45977
%MF p - value	0.2911	0.0647	0.3038	<0.0001	<0.0001	<0.0001	0.2549	
MFY	2.38	2.68	0.38	13.97	6.23	2.24	6.36	0.31514
MFY p - value	0.0004	0.0099	0.8215	<0.0001	<0.0001	0.03	0.0003	
%PC	0.60	0.42	0.39	1.11	18.66	10.11	2.18	0.30119
%PC p - value	0.9268	0.8873	0.8162	0.3518	<0.0001	<0.0001	0.0897	
PY	2.23	2.29	0.62	15.18	3.87	2.32	6.92	0.31933
PY p - value	0.001	0.0264	0.6461	<0.0001	0.0042	0.0245	0.0001	

df_1, df_2 – degree of freedom, R^2 – coefficient of determination

The impact of bull, year of birth, lactation order, farm, year and season of calving on the variability of milk traits was present at different level of statistical significance, while the genetic group showed no influence on the variability of the milk traits. STANOJEVIĆ *et al*., (2016) report that an increase in the share of Holstein-Friesian genes does not have such a drastic impact on milk yield, as opposed to the length of productive life.

The impact of bull – sire was demonstrated (p<0.001) on variability of all yield traits but did not show statistically significant effect on variability of milk fat and protein content. Bull - sire, year of birth and calving season did not influence the variability of milk fat and protein content. The impact of farm on the variability of all studied traits at different levels of statistical importance was present. The effect of lactation order showed very high statistical importance (p<0.001) on studied milk traits, except on protein content.

PETROVIĆ *et al.* (2015) have reported that effect of farm, lactation group and calving season on standard lactation milk performance was found to be highly significant (P<0.01), except of the effect of calving season on milk fat percent in standard lactations which showed statistical significance (P<0.05). The interactions between year and season of birth, farm and calving season, and farm and lactation group had a highly significant effect (P<0.01) on all milk performance traits studied. The resulting coefficients of determination (R^2) ranged from 0.20 for milk fat yield to 0.37 for milk fat percent.

Statistically significant effects ($p<0.01$) of the farm, bull, year and month of calving are reported by ATIL (2006).

Varying of milk traits, influenced by season and year of calving, ocurr due to the difference in temperature and humidity, as well as the quality and quantity of available food. Different housing conditions, nutrition and care, designated as the farm management, contribute to the differences in the manifestation of milk traits.

STANOJEVIĆ *et al.*, (2012) in their study of the impact of bull, farm and calving season on the phenotypic manifestation and variability of milk yield, milk fat yield and protein yield in standard lactation, have established high statistical significance ($p<0.01$) of said factors. By examining the impacts of the bull, farm, year, season and lactation order on variability of milk yield, fat content, milk fat yield and 4% fat corrected milk, BESKOROVAJNI (2014) has found a significant impact of those factors on the variability of traits in the whole and standard lactation.
The calculated coefficients of determination, indicating the level of variation of the performance traits over standard lactations that can be explained by the model, ranged from 0.301 for protein content to 0.459 for milk fat content, showing that the variability of the traits was affected not only by genetic factors but also by a large number of other non-genetic factors that were not included in the model.

The Table 3 shows the values of the coefficient of heritability and variance components of studied milk traits.

Table 3. Heritability (h^2) and variance components of milk traits in standard lactation (305 days)

Trait	σ^2_a	σ^2_e	h^2
MY	153409.3	1942881.1	0.293
%MF	0.00008953	0.0251	0.014
MFY	179.92535	2075.1	0.319
%PC	0.00006791	0.01129	0.024
PY	140.24178	1915.8	0.273

h^2 – heritability, σ^2_a – additive genetic variance, σ^2_e – variance error

Heritability of observed milk traits was medium to low. The heritability of milk yield in the standard lactation was 0.293. The content of milk fat and protein had the lowest values of heritability, 0.014, and 0.024, respectively. The heritability values of the milk fat and protein yield were 0.319 and 0.273, respectively. Obtained results are consistent with the results of GHIASI *et al.*, (2013) and EL-AWADY AND OUDAH (2011), while slightly higher values (0.47 and 0.48) are reported by ATIL (2006).

EMAN *et al*., (2016) used three models in estimating genetic parameters, variance and covariance components for some productive traits in first three lactations in Holstein-Friesian cattle based on inclusion and/or exclusion of direct maternal effect. Depending on the applied model, the heritability of milk fat yield ranged from 0.198 to 0.361, and herita
bility of protein yield from 0.181 to 0.295.

STANOJEVIĆ *et al*. (2012) suggest different heritability values obtained in the population of improved Black and White breed. The heritability of milk traits (milk yield, milk fat content, protein content in milk, milk fat yield and protein yield) had following values: 0.115, 0.049, 0.017, 0.119 and 0.111, respectively.

KAWAHARA *et al.* (2006), have estimated fractions of additive genetic variances to phenotypic variances (heritabilities across a herd in the narrow sense) were 0.306, 0.287, 0.255, for milk, fat and protein yields, respectively. HOEKSTRA *et al.* (1994) have estimated in the Dutch Black and White dairy cow population the heritability for milk production traits of 0.48, 0.36, and 0.33 for 305 days milk, fat, and protein yields, respectively. ĐEDOVIĆ *et al.* (2013) have established, in the population of improved Black-White cattle, heritability values for milk yield, milk fat content and milk fat yield of 0.15, 0.06 and 0.10 respectively. TOGHIANI *et al.* (2012) have obtained lower heritability estimates of 0.26, 0.149, and 0.238 for yields of milk, fat, and protein, respectively but higher heritability estimates for fat and protein percent (0.228). VISSCHER and THOMPSON (1992), with British cows, also report higher heritability estimates for yields of milk and fat of 0.39 and 0.36, respectively.

CONCLUSION

From the present results, the phenotypic manifestation and variability of milk traits of Holstein - Frisian bull dams and their progeny are under influence of bull - sire, year of birth, lactation order, farm, year and calving season. Different housing conditions, nutrition and care contributed to the differences in the expression of milk traits. The heritability of observed milk traits was medium to low.

The focus in dairy cattle breeding program was on improving milk production traits. Traits that are unfavourable correlated with milk production, such as longevity, fertility, duration of service period, calving ease, udder development shoved undesirable genetic trends and had to be given special consideration In the further research, reproductive and functional traits should be included in selection creteria which would lead to more genetic improvement and contribute the economic efficience of milk production.

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VARIJABILNOST I HERITABILITET OSOBINA MLEČNOSTI BIKOVSKIH MAJKI HOLŠTAJN FRIZIJSKE RASE I NJIHOVOG POTOMSTVA

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Izvod

Istraživanje je sprovedeno na grlima holštajn – frizijske i crno – bele rase koja su odabrana za bikovske majke i potomstvo bikovskih majki. Grla su gajena na pet farmi Poljoprivredne korporacije Beograd u periodu od 2006 do 2014 i predstavljaju potomke 24 bika. Istaživanjem je obuhvaćeno 575 laktacija. Analizirane su sledeće osobine mlečnosti u standardnoj laktaciji (305 dana): prinos mleka (kg) – **MY**, sadržaj mlečne masti (%) – **%MF**, prinos mlečne masti (kg) – **MFY**, sadržaj proteina (%) – **%PC** i prinos proteina (kg) – **PY**. U standardnoj laktaciji bikovske majke holštajn – frizijske rase i njihovo potomstvo proizvele su prosečno 9239,84 ± 1607,64 kg mleka sa sadržajem mlečne masti 3.44 ± 0.20 i sadržajem proteina 3.21 ± 0.12. Uticaj bika, godine rođenja, laktacije po redu, farme, godine i sezone teljenja, prisutan je na različitom nivou statističke značajnosti u varijabilnosti prinosa mleka, mlečne masti i proteina dok genetska grupa nije uticala na varijabilnost osobina mlečnosti. Uticaj bika, godine rođenja, laktacije po redu i sezone teljenja nije značajan u varijabilnosti sadržaja mlečne masti i proteina. Heritabilitet posmatranih osobina mlečnosti je bio srednji do nizak. Najniže vrednosti heritabiliteta su dobijene za sadržaj mlečne mast i proteina, 0,014 i 0,024, odgovarajuće. Heritabilitet prinosa mleka, mlečne masti i proteina je 0,293, 0,319 i 0,273, odgovarajuće.

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