MILK PRODUCTIVITY AND BREEDING-GENETIC PARAMETERS OF ECONOMICALLY VALUABLE TRAITS OF HOLSTEIN COWS OF FRENCH SELECTION

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Abstract

The article presents the results on the study of key economically beneficial traits of pedigree French Holstein cows in the herd of Society of limited liability "Holstein." It was found that the milk yield of cows in the first lactation averaged 8119 kg of milk, and in the second lactation, it was 8226 kg of milk, which is by 107 kg more than in the first lactation. Comparative analysis of the milk productivity of locally generated cows and their mothers revealed that the daughters' yields (cows of local generation) during the first lactation period of 305 days exceeded the mothers' yields by 1367 kg of milk. In the second lactation, the average yield of locally generated cows was 8505 kg of milk, which is by1253 kg more than the average in the first lactation. A positive correlation was established for milk yield during the 305-day lactation period between the first and second lactations (+0.201). The heritability coefficient for lactation yield was determined to be ($h^2 = 0.402$).

Key words: correlation, heritability coefficient, Holstein breed of French selection, lactation, local generation.

INTRODUCTION

The Holstein breed has become a leading breed worldwide primarily due to strict and purposeful breeding efforts. It is recognized as a global leader in milk productivity and a set of qualities that allow for better adaptation to the conditions of highly mechanized farms and progressive livestock management technologies (Nogaeva, 2019). The Holstein breed is widely used in many countries with diverse climatic conditions, both for improving local dairy breeds and for purebred breeding (Stolcman, 1980; Shendakov, 2005; Altergot, 2013; Gridin et al., 2013; Ivanova, 2019).

The significance of the Holstein breed, bred in the USA, Canada, and several European countries, has recently increased significantly, including in the Republic of Moldova. Cow's milk and products made from it constitute a substantial part of the population's diet in these countries (Lebedko et al., 2020).

The breeding work plays a crucial role in increasing milk production, as it determines the genetic progress of breeds and herds (Gridin et al., 2019; Ivanova et al., 2021). All other factors, including technological elements, only contribute to the realization of this process.

For successful breeding work in a herd of cattle, it is important to know the phenotypic variability of animal productivity, heritability, and the correlation coefficient between economically valuable selection traits and other parameters (Litovchenko, 2007; Ignatyeva & Lavrentiev, 2020). Variability is influenced by differences in the genotype of animals and external environmental factors that have varying effects on the development of a trait in different individuals. Therefore, the degree of variability in milk yield and other traits is not the same in different herds and populations of cattle. According to literature data, milk fat and protein content, as well as the live weight of cows, are considered more stable indicators, meaning they are less variable (Tamarova, 2005; Seltsov et al., 2012).

Among the key selection traits for cattle are milk yield and milk fat content.

It is known that animals, despite having approximately equal heritability, exhibit different trait formations under the influence of various environmental conditions. The

phenotypic diversity of animal traits is determined by the complex interaction of genetics and living conditions (Baumgard et al., 2011; Berman, 2011; Gorlov et al., 2016).

The magnitude of these traits is influenced by breeding methods, the achieved level of herd cow productivity, feeding and housing conditions, and other factors. Therefore, population-genetic parameters of identical traits in different herds can vary significantly.

The study of milk productivity was conducted on Holstein cows of French breeding (Holstein crossbreeds) in the herd of SLL "Holstein". It is noteworthy that France ranks second in the European Union in terms of whole milk production, accounting for 22.1% of the total production (Medvedeva & Penkov, 2013). Among the 12 major dairy cattle breeds, five have high demand for export: Holstein crossbreeds, Montbeliarde, Normande, Abondance, and. Among them, Holstein crossbreeds exhibit the highest productivity, with an average yield of 9135 kg of milk, protein content of 3.30% over a lactation period of 305 days (Kuba, 2017).

The aim of the research is to study the variability, correlation, and heritability of milk productivity traits at Holstein cows of French breed in the SLL "Holstein" herd.

MATERIALS AND METHODS

The research focused on the population of Holstein cows of French selection in the breeding herd of the Society of Limited Liability (SLL) "Holstein" located in Roshkan village, Anenii Noi district, in the amount of 308 heads. The breakdown by lactations included the first (n = 142), second (n = 72), third (n = 24), fourth (n = 27), fifth (n = 27), and sixth (n = 14) lactations.

The study of the productivity of Holstein cows of French selection involved the use and analysis of pedigree certificates for heifers, pedigree cards for cows, records of milk productivity, and other documents from primary zootechnical records. Evaluation and analysis of cows based on milk productivity were conducted using commonly accepted methods, considering yield over 305 days of lactation, fat content in milk, milk fat production for the lactation, and assessing the variability of these indicators (Cv).

The genetic potential of first calf's productivity was determined using the Parental Index of Cows (PIC). The Parental Index was calculated using the Wright path coefficient (Krasota & Dzhaparidze, 1999).

To study the variability and heritability of milk productivity traits in the first lactation, mother-daughter pairs were selected. Each sample consisted of 105 cows and 105 offspring. Parameters studied included yield over 305 days of lactation, fat content in milk, milk fat quantity, and the variability of these indicators (Cv).

The calculation of selection-genetic parameters of productivity and the statistical processing of research materials were conducted using the methodologies proposed by Plokhinsky (1970) and Merkuryeva (1983). The coefficient of correlation (r) was computed on a computer using the CORREL function within the Excel software environment. The heritability of selection traits was determined using the method of doubled correlation ($h^2 = 2r$). The numerical data the research were biometrically processed on a personal computer using Microsoft Excel 2010 software.

RESULTS AND DISCUSSIONS

As a result of studying the main economically valuable traits of Holstein cows of French selection in the SLL "Holstein" herd, it was determined that the average milk yield of the studied population of cows in the first lactation was 8119 kg of milk, as shown in Table 1.

Starting from the third lactation, a decrease in milk yields is observed. In comparison to the first lactation, yields decreased by 329 kg (third lactation), 378 kg (fourth lactation), 440 kg (fifth lactation), and 931 kg (sixth lactation) of milk, with P<0.01, P<0.005 and P<0.001 significance levels, respectively.

As is known, the degree of genetic diversity in a herd is judged by the variability of economically valuable traits. The longer the breeding work was conducted and the more intense was the selection, the smaller would be the magnitude of variability in economically valuable traits. The results of the analysis of selection-genetic parameters of economically valuable traits in the SLL "Holstein" herd, depending on lactation, are presented in Table 2.

Table 1. Characteristics of cows by milk productivity for a range of lactation (X ± Sx)

Lactation	Number of cows, n	Indices			
		Milk yield, kg	Fat content, %	Amount of fat, kg	Body weight, kg
The first	142	8119±52.8	3.83±0.003	312±2.1	639±2.8
The second	72	8226±71.2	3.84±0.004	313±3.8	681±4.7
The third	24	7790±96.9 **	3.84±0.01	299±3.7	687±1.8
The fourth	27	7741±85.6 *	3.83±0.01	296±3.2	695±3.6
The fifth	29	7679±97.3***	3.83±0.01	294±3.5	692±3.4
The sixth	14	7188±95.3***	3.82±0.01	274±3.4	695±3.3
Average	308	8001±36.0	3.83±0.002	307±1.5	663±2.7

Table 2. Coefficient of variation for milk productivity indicators (Cv, %)

Indices	Lactation					
	I	II	III	IV	V	VI
Milk yield	7.8	3.0	1.8	5.8	6.8	5.0
Fat content	0.9	0.9	0.9	0.7	0.7	1.2
Amount of fat	7.9	10.3	6.1	5.6	6.4	4.7
Live weight	2.8	3.0	1.1	1.5	1.7	1.6

It should be noted that the coefficients of variation for all studied productivity traits were below the normative data. However, the lowest indicators were identified for milk fat content. In the research results (Bashchenko et al., 2020; Kruglyak & Biryukova, 2007), it is also noted that the degree of variation in milk fat content is unusually low and amounts to 1.3%.

Low values of coefficients of variation indicate a reduction in genetic diversity and homogeneity in the herd of "Holstein" cows at SLL. Similar data were obtained in research results in 2022 by (Konstandoglo et al., 2023).

To determine the indirect effect of selection on correlated traits, correlation coefficients are used. Differences in this population parameter were identified across lactations, as shown in Table 3. The correlation between milk yield and the percentage of fat in the milk of cows in the first-fifth lactations showed a negative correlation.

Table 3. Genetic correlation between milk productivity indicators in lactation dynamics, $r ± m_r$

Indicators	First lactation	Second lactation	Third lactation	Fourth lactation	Fifth lactation
Milk yield - Fat content, %	-0.397±0.07	-0.617±0.06*	-0.696±0.05***	-0.489±0.08	-0.438±0.01
Milk yield - Amount of fat, kg	0.972±0.02	0.067±0.08	0.990±0.002	0.982±0.04	0.987±0.00

Note: * - P < 005; *** - P < 0.001

A comparative analysis of the correlation results between yield and the percentage of fat revealed a significant difference between the third and first lactations - 0.299 at P < 0.001, and between the second and first lactations - 0.220 at P < 0.05. As evident, the unidirectional selection based on the yield level led to an increase in the negative correlation between these traits, complicating the conduct of successful selection and emphasizing the need for simultaneous selection based on both yield and fat content in the milk.

In the SLL "Holstein" herd, the milk productivity of locally bred cows and their mothers was studied for the first 305 days of lactation, Table 4.

Table 4. Comparative characteristics of locally bred Holstein cows and their mothers based on milk productivity for the first lactation

Indices	Number of cows, N	Milk yield for 305 days, kg		Fat content, %		Amount of fat, kg	
		X ± Sx	Cv, %	X ± Sx	Cv, %	X ± Sx	Cv, %
Daughters	105	7716±63.5***	8.4	3.84±0.005	1.2	297±2.3***	8.0
Mothers	105	6349±41.9	6.8	3.97±0.005	1.3	252±1.6	6.4

Note: ** - P < 0.01; *** - P < 0.001

Through a comparative analysis of the milk productivity of locally bred cows and their mothers, it was found that the yields of daughters (locally bred cows) exceeded the yields of their mothers by 1367 kg of milk. In terms of milk fat quantity, daughters also had an advantage of 45 kg.

Accordingly, the coefficients of variation for yield and milk fat quantity in locally bred cows were slightly higher than the analyzed traits in mothers. However, it is worth noting that the range of variability is not wide for the analyzed population of cows, leading to a reduction in their genetic diversity and an increase in the level of homozygosity.

It is important to highlight that 54 locally bred cows completed their second lactation. The results of the study of productivity for the first two lactations of locally bred cows, as well as correlation and heritability indicators, are presented in Table 5.

Table 5. Milk productivity of locally bred cows, correlation between lactations (r), and heritability (h^2), $X \pm Sx$

| Lactation | Number of cows, n | Milk yield | | Fat content, % | Cv,% | Amount of fat, | Cv, % |
		kg	Cv, %			kg	
First	54	7252±78.1	7,5	3.85±0.01	1.1	296±12.1	8.4
Second	54	8505±50.0***	4,3	3.84±0.003	0.6	323±4.3	9.8
Correlation (I-II), r		0.201±0.13		-0.152±0.14		0.037±0.14	
Heritability, h^2		0.402		0.304		0.074	

The comparative analysis productivity in locally bred cows showed that during the second lactation, the average milk yield was 8505 kg, which is by1253 kg higher than the average for the first lactation. The variability of milk yield and fat content for the second lactation is slightly lower than for the first lactation. However, for this trait, it is a relatively low indicator, as it is known that in most herds, the coefficient of variability for milk yield is at least 20-25%, and for fat content, it is at least 5-7% (Seltsov et al., 2012).

A positive correlation for milk yield over 305 days of lactation was found between the first and second lactations (0.201), with a weak relationship.

The heritability coefficient for milk yield over lactation was ($h^2 = 0.402$). This allows us to conclude that heritability for milk yield was predominantly influenced by genetic factors.

SLL "Holstein" continues to import breeding animals, and in 2022 - 32 heifers were imported. The study of milk productivity indicators for first-calf heifers at the end of lactation showed that the milk yield averaged 8734 ± 57.6 kg, fat content was 3.82 ± 0.003%, and the amount of milk fat averaged 335 ± 2.5 kg.

The study of milk production indicators at imported pregnant heifer ancestors (Table 6) demonstrated that the average milk production of mothers was 8378 kg, fat content was 3.93%, and the total fat was 331 kg.

Table 6. Milk productivity index at ancestors, French-origin Holstein breed ($X \pm Sx$)

Indices	Mother	Cv, %	Mother's Mother	Cv, %	Father's Mother	Cv, %
Herd size, n	26		26		25	
Milk, kg	8378±354.2	21.6	8946±361.1	20.6	10851±432.1	19.9
Fat content, %	3.93±0.09	11.3	4.02±0.08	10.2	4.08±0.07	8.5
Fat quantity, kg	331±14.1	21.7	357±12.5	17.9	438±17.7	19.8

The average milk production of maternal grandmothers was 8946 kg, with a fat percentage of 4.02, and the total fat amount was 357 kg. The analysis revealed that the milk yield of maternal grandfathers in the highest lactation was 10851 kg.

The coefficients of variability (Cv) for milk yield in the analyzed groups of mothers ranged from 19.9% (mothers of fathers) to 21.6% (mothers). Regarding fat content and the quantity of milk fat, it is noteworthy that the values of these traits in the sample on average also corresponded to literature data.

To assess the potential capabilities of animals for all indicators of female ancestors, there were calculated the Breeding Index of Cows (BIC) and the realization of the genetic potential of first-calf heifers (Table 7).

Table 7. Realizing of the Genetic Potential of dairy productivity

Parental Index of Cows (PIC)		Own productivity		Realization of genetic potential (RGP), %	
Milk Yield, kg (X ± Sx)	Fat Content, % (X ± Sx)	Milk Yield, kg (X ± Sx)	Fat Content, % (X ± Sx)	Milk Yield	Fat Content
9138±375.4	3.99±0.08	8734±57.6	3.82±0.003	95.6	95.7

The analysis of the obtained data revealed that the parental index for milk yield was at the level of 9138 kg and 3.99% for fat content. The realization of the genetic potential for milk yield was 95.6%, and for fat content in milk, it was 95.7%. To assess the heritability indicators, it was used the method of correlating the traits of daughters with their mothers, as shown in Figure 1.
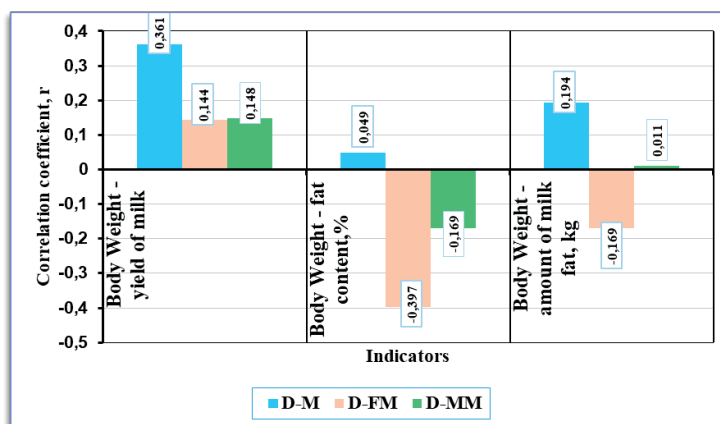

Figure 1. Correlation between Productivity Indicators and Body Weight of Daughters and Maternal Ancestors

The analysis of the milk yield relationship showed that a positive weak connection was established between Daughter-Mother's Mother (D-MM) and Daughter-Father's Mother (D-FM) - 0.148 and 0.144, respectively. A moderate positive correlation was identified between daughters and mothers (D-M) - 0.361.

For fat content in milk, the correlation between daughters and fathers' mothers (D-FM) was negative, with moderate strength (r = -0.397).

The main genetic parameter that numerically indicates the proportion of inherited variability of a trait and, therefore, serves as a selection criterion, is the heritability coefficient (h^2). Based on the obtained data, it can be concluded that milk yield and the quantity of milk fat of first-calf heifers were more influenced by heritability ($h^2 = 0.29$-0.72) and ($h^2 = 0.39$), respectively, Table 8.

Table 8. Heritability (h^2) of Main Productive Traits

No.	Indices	Daughter - Mother (D-M)	Daughter - Mother's Mother (D-MM)	Daughter - Father's Mother (D-FM)
1.	Milk Yield	0.72	0.30	0.29
2.	Fat Content	0.10	0.09	0.79
3.	Amount of fat	0.39	0.02	0.34

Maternal ancestors had the greatest influence on milk yield and the quantity of milk fat - $h^2 = 0.72$ (Mother), $h^2 = 0.30$ ((Mother's Mother), and 0.39 (Mother), respectively.

For the fat content in milk, $h^2 = 0.1$ (M) and $h^2 = 0.09$ (MM) were more influenced by para-typical factors, as the heritability coefficients for this trait were very low or absent (FM).

CONCLUSIONS

Coefficients of variability for all studied productivity traits were below normative values, indicating a reduction in genetic diversity and homogeneity within the herd of SLL "Holstein." Comparative analysis of Holstein cows of local breeding and their mothers based on milk productivity for the first 305 days of lactation revealed that the milk yield of daughters (local breeding cows) for the first lactation exceeded the milk yield of mothers by 1367 kg, and the difference was significant ($P < 0.001$).

A weak positive correlation was found between milk yield for the first and second lactations (0.201), and the correlation for fat content was weakly negative (-0.152).

The heritability coefficient between the first and second lactations for local breeding cows for milk yield was ($h^2 = 0.402$). Heritability for milk yield was mainly influenced by genetic factors.

A weak positive correlation was found between daughters and mother's mother (D-MM) and daughters and father's mother (D-FM) - 0.148 and 0.144, respectively. A moderate positive correlation was observed between daughters and mothers of daughters - mothers (D-M) - 0.361.

The milk yield and quantity of milk fat at first-calf heifers were primarily influenced by heritability ($h^2 = 0.29$-0.72) and ($h^2 = 0.39$), respectively.

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