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THE FIRST-CALF COWS OF DAIRY BREEDS ESTIMATION BY UDDER MEASUREMENTS AND THEIR USE IN INDEX BREEDING OF UDDER LINEAR TRAITS

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The purpose of this study was to estimate the udder morphological traits of first-born cows of Holstein and Ukrainian Black-and-White dairy breeds by measurements, their assessment by the udder-mass-metric index and establishing the degree of relationship between linear type traits of the udder. 86 heads of Holstein and 112 heads of Ukrainian Black-and-White dairy breed from the herd of private enterprise "Burynske" in Sumy region were used in the research. The udder mass-metric index included live weight of cows, body and udder measurements, and its volume. The advantage of the first-born cows of Holstein breed over peers of Ukrainian Black-and-White dairy breed in terms of udder measurements was established. In animals of Holstein breed, the udder-mass-metric index was on average 15.0, and in Ukrainian Black-and-White dairy cows – 13.1 conventional units, with a difference of 1.9 conventional units, with reliability at P<0.001 in favor of Holstein cows. A significant relationship has been established between udder-mass-metric index and milk productivity. The degree and reliability of relationship between udder parts measurements of the first-born cows of Holstein and Ukrainian Black-and-White dairy breed differed by significant variability, from -0.422 to 0.713 and from -0.486 to 0.698, respectively. The degree and reliability relationship between the udder parts measurements of the first-born cows of Holstein breed (their values are placed below the diagonal) with a slight difference repeat the indicators of correlation coefficients in the peers of Ukrainian Black-and-White dairy breed. The highest correlation was obtained between the anatomically related udder parts – of the front teats length and diameter with the rear ones, and the distance between them. The general conclusion indicates that cows of Ukrainian Black-and-White dairy and Holstein breeds are generally characterized by excellent morphological indicators of the udder, which define its development, including in terms of adaptability to machine milking. Linear measurements make it possible to more objectively evaluate the udder of cows based on development of its parts, and existence of a positive relationship between them and amount of milk yield provides the basis for the effectiveness of cows' selection based on udder traits in practical breeding, which will help increase the milk productivity of animals.

Key words: *Holstein, Ukrainian Black-and-White dairy, measurements, udder, index, correlation.*

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Studies of the udder of cattle cows by measurements, characterizing its structure and size, never lose their relevance in the aspect of breeding to improve its morphological and functional qualities. Comparison of cows of different breeds according to the assessment of the udder indicated about significant variability in their measurements and shapes of the udder and teats (Bardakcioglu et al., 2004; Deng et al., 2012; Abisoye et al., 2021), the shortcomings of which entail deep economic losses and have a significant impact on their welfare and productivity (Tülkü et al., 2005; Hogeveen et al., 2011; Modh et al., 2017).

Research studies of the udder morphological traits of cows have been proven that most of them are important and reliable conformation indicators of high productiv-

ity and milk quality (Bhuiyan et al., 2004; Juozaitiene et al., 2006; Tapki et al., 2013; Akinsola et al., 2018), manufacturability (Nakov et al., 2014), duration of cow's productive use and life (Sewalem et al., 2004; Miglior et al., 2017; Ladyka et al., 2020). An equally important research area of cow's conformation will be the study of relationship between measurements (linear traits) of the udder (Berry et al., 2004; Campos et al., 2012; Khan et al., 2016) with the aim of using them in index breeding (Philipsson et al., 1994; Petrenko et al., 2005; Miglior et al., 2005).

According to indicators of morphological traits of the udder, the estimation of cows was carried out throughout the process of breeding new Ukrainian dairy breeds and continues to be used at the present stage of their improvement. Therefore, the purpose of this study was to assess the variability of the udder morphological traits in a comparative analysis of two breeds – Holstein and Ukrainian Black-and-White dairy, the effectiveness of using the udder-mass-metric index in the early selection of first-calf cows by productivity and to study the relationship between udder measurements, which can be included in breeding indices and used in the selection process of sires, assessed by type.

Materials and research methods. The material for this research were first-calf cows of Holstein (86 heads) and Ukrainian Black-and-White dairy breeds (112 heads) in the controlled herd of PE "Burynske", Sumy region of Ukraine. Measurement and visual udder evaluation was carried out 1.0-1.5 hours before morning milking, 30-40 days after calving. The udder and teats measures were performed at the points shown in Fig. 1 using a measuring tape, compass, caliper and ruler, expressed in centimeters (cm).

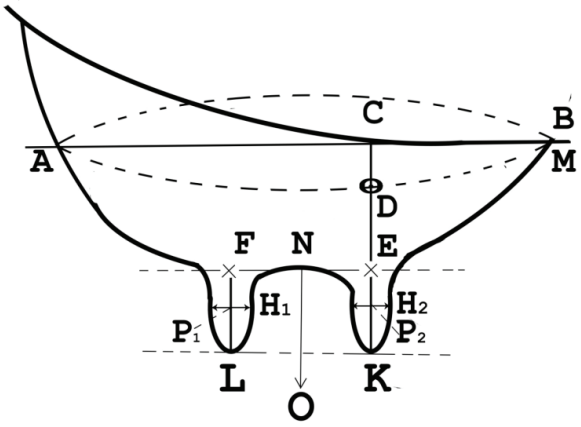

Fig. 1. Udder and teats measurement points

AB – udder girth along a horizontal line at the level of front edge (by tape);

AM – udder length from the back bulge to its front edge (by compass);

CM – front quarter length;

D – maximum udder width above teats of front parts (by compass);

CE – front part depth – vertically from the abdominal wall to the upper teats part (by tape);

EK, FL – front and rear teats length (by ruler);

H_1, H_2 – front and rear teats diameter (by caliper);

P_1P_2 – distance between front and rear teats (by ruler);

NO – distance from the udder bottom to the floor (by tape).

The nominal udder volume (cm^3) was determined as the sum of udder girth multiplied by its front part depth.

Basic statistical data of the udder measurements include the average value (x) and the standard error (S.E.).

By statistical indicators, the average value of measurements (x) and standard error (S.E.) were studied.

$$S.E. = \frac{\sigma}{\sqrt{n}}$$

Where: σ – standard deviation;

n – number of variants.

The coefficient of linear phenotypic correlation was determined by the Pearson formula:

$$r_{xy} = \frac{\sum(x_i - \bar{x}) \times (y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \times \sum(y_i - \bar{y})^2}}$$

Where: x_i – variable value for x;

y_i – variable value for y;

$\bar{x}$ – average value for *x*;

$\bar{y}$ – average value for *y*.

Based on the measurements, was calculated the proposed by I.P. Petrenko et al. (2005) udder-mass-metric index (UMMI) for dairy cows, expressed in conventional units and looked like this:

$$UMMI = \frac{UV \times LW}{WH + OBL + ChG}$$

where: *LW* – live weight, kg;

WH – withers height, cm;

OBL – oblique body length, cm;

ChG – chest girth, cm;

UV – udder volume, dm^3, determined by the formula:

$$UV = {}^{3}\Big/_{P}^{4} \times K\frac{UL}{2} \times \frac{UW}{2} \times UD$$

where: *K* – coefficient (0.6);

UL – udder length, cm;

UW – udder width, cm;

UD – udder depth, cm.

P – Mathematical constant (3.1415), expressing the ratio of circle circumference to its diameter length.

The reliability of obtained data was evaluated by calculating the errors of statistical values (S.E.) and Student's reliability criteria (td) for correlation analysis and Fisher (F) for variance analysis. The probability level was classified

by comparison with standard criteria values. The results were considered statistically significant for the first – P<0.05 (* or [1]), the second – P<0.01 (** or [2]), and the third – P<0.001 (*** or [3]) probability thresholds. Statistical processing of experimental studies was performed by the methods of mathematical statistics using formulas given by (Ladyka, et al., 2023) in Microsoft Excel.

Research results. Table 1 shows the assessment results of the udder morphological traits by measurements in comparison of cows of the two tested breeds. The udder measurements showed the superiority of first-calf heifers of the Holstein breed over the peers of Ukrainian Black-and-White dairy cows in terms of udder girth by 3.2 cm (P <0.001), front lobe depth – 1.4 (P <0.01), distance from the bottom to ground – 0.8, front quarter length – 0.5, udder length – 2.2 (P <0.001), udder width – 2.1 (P <0.001), conventional udder volume – 280 cm^3 (P <0.001).

According to important technological udder traits, the first-calf cows of Holstein breed were the best. The front teats length in the first-calf cows of Holstein breed was reliably shorter by 0.5 cm (P <0.001), and rear teats – by 0.3 cm (P <0.01). Between front teats location, the distance was more in first-calf heifers of Holstein breed by 1.1 cm (P <0.01), rear – 0.3, and between front and rear – 1.7 cm (P <0.001). The front and rear teats diameter in Holstein cows decreased by 0.1 cm (P <0.01).

Table 1

Characteristics of the first-calf cows of dairy cattle by the udder morphological traits, cm (x ± S.E.)

The name of the udder measurement		Breed	
		Holstein	Ukrainian Black-and-White dairy
udder girth		144,7 ± 0,52***	141,5 ± 0,48
fore lobe depth		24,8 ± 0,33**	23,4 ± 0,29
bottom-to-ground distance		62,4 ± 0,42	61,6 ± 0,33
fore quarter length		15,3 ± 0,29	14,8 ± 0,25
udder length		44,5 ± 0,26***	42,3 ± 0,23
udder width		35,2 ± 0,28***	33,1 ± 0,24
conventional udder volume, cm^3		3589 ± 49,3***	3309 ± 45,4
teats length	front	5,0 ± 0,10***	5,5 ± 0,08
	rear	4,2 ± 0,08**	4,5 ± 0,06
diameter of teats	front	2,3 ± 0,03**	2,4 ± 0,02
	rear	2,2 ± 0,03**	2,3 ± 0,02
distance between teats	front	17,2 ± 0,29**	16,1 ± 0,25
	rear	8,5 ± 0,19	8,2 ± 0,15
	front and rear	12,6 ± 0,15***	10,9 ± 0,12
form, %	bath-shaped	86	81
	cupped	14	19
teats form, %	cylindrical	92	86
	conical	8	14
stepped udder, %		3	7

Among the estimated Holstein cattle, 86% of first-calf cows had the desired bath-shaped udder and 92% cylindrical teats, that is 5% and 6% more than the Ukrainian Black-and-White dairy breed, respectively. Only 3% of cows were found with a stepped udder among Holstein cows, or 4% less than among Ukrainian Black-and-White dairy cows.

Consequently, a comparative analysis of cows of both breeds testified the best indicators of udder development in cows of the Holstein breed.

About the influence of Holsteins on udder improvement when crossed with other breeds had been reported by other studies (Bardakcioglu et al., 2004; Deng et al., 2012; Stavetska and Klopenko, 2016). At the same time, the results of first-calf cows of the Ukrainian Black-and-White dairy breed assessment by udder measurements testified to its good development in most of the traits, both in shape and in manufacturability. And according to such important traits that characterize the udder size – length and width, they correspond to the target parameters of the desired linear type measurements (42 and 33 cm) for first-calf cows of the Ukrainian Black-and-White dairy breed (Hladii et al., 2018).

A rather important aspect in the genetic improvement of dairy cows is the problem that will relate to the early prediction of milk productivity using of the conformation estimation in general and selection indices developed on their basis, in particular (Petrenko et al., 2005; Miglior et al., 2005).

The selection of cows by breeding indices, providing for inclusion in them of a certain quantitative complex of traits, had a significant advantage over the estimation and selection of animals according to one trait. The selection of cows evaluated by breeding indices allowed not only to more reliably determine the pedigree qualities of animals, but also to obtain offspring, in which a deficiency of one trait can be compensated by the advantage of another or a group of traits (Philipsson et al., 1994, Hazel et al., 1994). In this aspect, the use of selection udder-mass-metric index, pro-

posed by a team of scientists from the Institute of Animal Breeding and Genetics of the UAAS of Ukraine (Petrenko et al., 2005), is not an exception, according to which the conformation parameters of the udder of cows were assessed (Petrenko et al., 2005; Radchenko et al., 2007; Klopenko and Bushtruk, 2017).

Taking into account the importance of the udder-mass-metric index in the selection of dairy cattle, the aim of the research was to determine the dependence of milk productivity of cows on this indicator in a comparative analysis of first-calf cows of the Ukrainian Black-and-White dairy and Holstein breeds.

The distribution of first-calf cows groups of experimental breeds, estimated by the udder-mass-metric index, depending on the index value within the gradations of three conventional units into five classes (Table 2) made it possible to reveal a clear pattern of the correlative influence of its level on the animal milk productivity.

With each subsequent increase in the value of UMMI by three conventional units, the average milk yield of cows in each of the groups gradually grew both in the Holstein and Ukrainian Black-and-White dairy breed.

The difference between adjacent classes in first-calf Holstein cows varied within a fairly wide range, from 222 kg (between classes 7.1-9.0 and 9.1-12.0) to 503 kg (between classes 15.1-18, 0 and 18.1 and more) with a reliable difference in the last comparison (P <0.05). Between the extreme classes, the variance in milk yield for 305 days of first lactation was significant and amounted to 1283 kg (P <0.001).

A similar and supposed pattern was observed according to research data on the correlative variability of milk yield depending on the level of udder-mass-metric index in first-calf cows of the Ukrainian Black-and-White dairy breed. In this comparison, the reliable difference in milk yield between groups I and II was 416 kg (P <0.01) and between IV and V 568 kg (P <0.001). Among the extreme classes, the distinction in milk yield for 305 days of first lactation was significant and amounted to 1400 kg (reliable at P <0.001).

If there was no reliable difference in the mass fraction of fat in milk with the existing intergroup variability in first-calf cows of the Holstein breed (3.79-3.85%), then in the yield of milk fat a significant difference was found in comparisons between groups III and IV (15.2 kg, P <0.01) and IV and V (18.6 kg; P <0.01). In first-calf cows of the Ukrainian Black-and-White dairy breed, a reliable difference in this trait was found between groups I and II (16.9 kg; P <0.05) and IV and V (27.1 kg; P <0.001).

In animals of the Holstein breed, the udder-mass-metric index averaged 15.0, and in the Ukrainian Black-and-White dairy breed – 13.1 conv. un., with an interbreed difference of 1.9 conv. un., with reliability at P <0.001 in favor of Holstein cows. This indicated about the best harmonious combination of body structure and udder in Holstein cows in terms of the conformation development in the dairy type direction.

Consequently, reliable correlative relationship determined between the udder-mass-metric index and indicators of milk productivity evidenced about the possibility of its effective use in mass selection of cows by the conformation type.

Since one of the most important body part of the body structure in dairy cattle is its udder, in our opinion, it will be quite important to know that in addition to the degree of correlation variability between udder measurements and milk yield, there is also a level of relationship between measurements, which can be taken into account when selecting sires estimated by their daughters' conformation type.

Udder girth is an integrated indicator of its size, that was confirmed by positive reliable correlations of the first-calf cows of the Ukrainian Black-and-White dairy breed with the fore quarter depth (r = 0.466), the fore quarter length (r = 0.325) and, especially, with the length (r = 0.632) and width (r = 0.584) of the udder, Table 3 (figures above the diagonal). A slightly smaller, but also positive, correlation was found between the distance of the front (r = 0.268) and rear (r = 0.253) teats. A negative correlation (r = -0.284) was determined between the udder girth and from the bottom to the ground distance, that was explained by its insignificant lowering at a higher mass in accordance with the girth. The fore quarter depth of the udder was reliably

Table 2

Milk productivity of first-calf cows of dairy cattle depending on the level of the udder-mass-metric index (x ± S.E.)

Gradation of UMMI value	Group	Number of animals	Milk yield, kg	Fat content, %	Milk fat, kg
Holstein breed					
7,1 – 9,0	I	7	5827 ± 120,2	3,85 ± 0,091	224,3 ± 6,32
9,1 – 12,0	II	11	6049 ± 165,8	3,79 ± 0,063	229,3 ± 5,69
12,1 – 15,0	III	30	6296 ± 107,3	3,80 ± 0,042	239,2 ± 3,86
15,1 – 18,0	IV	26	6607 ± 135,8	3,85 ± 0,033	254,4 ± 4,11
18,1 і >	V	12	7110 ± 184,1	3,84 ± 0,071	273,0 ± 5,32
On average		86	6434 ± 80,5	3,80 ± 0,022	244,4 ± 2,15
Ukrainian Black-and-White dairy breed					
7,1 – 9,0	I	18	5675 ± 116,3	3,87 ± 0,032	220,0 ± 6,14
9,1 – 12,0	II	20	6091 ± 72,4	3,89 ± 0,043	236,9 ± 5,91
12,1 – 15,0	III	50	6218 ± 68,7	3,89 ± 0,035	241,9 ± 2,64
15,1 – 18,0	IV	11	6507 ± 144,5	3,77 ± 0,042	245,3 ± 5,17
18,1 і >	V	13	7075 ± 92,2	3,85 ± 0,037	272,4 ± 5,22
On average		112	6191 ± 58,6	3,82 ± 0,024	236,5 ± 1,75

Table 3

Relationship degree (r) between measurements of udder parts of first-calf cows of Ukrainian Black-and-White dairy and Holstein breeds

Measurement name	UG	FQD	BGD	FQL	UL	UW	FTL	RTL	FTD	RTD	DFT	DRT
Udder girth (UG)	-	0,466[3]	-0,284[3]	0,325[3]	0,632[3]	0,584[3]	0,122	0,081	0,136	0,173[1]	0,268[2]	0,253[2]
Fore quarter depth (FQL)	0,474[3]	–	-0,486[3]	0,095	0,511[3]	0,483[3]	0,098	0,102	0,095	0,051	0,236[2]	0,092
Bottom-to-ground distance (BGD)	-0,213[2]	-0,422[3]	–	-0,181[2]	-0,213[2]	-0,227[2]	-0,023	0,051	-0,121	-0,092	-0,033	-0,042
Fore quarter length (FQL)	0,366[3]	0,111	-0,197[2]	–	0,277[3]	0,121	-0,101	-0,144[1]	0,096	0,141[1]	-0,066	-0,072
Udder length (UL)	0,654[3]	0,244[2]	-0,067	0,397[3]	–	0,466[3]	0,074	0,089	0,041	0,056	0,132	-0,036
Udder width (UW)	0,522[3]	0,445[3]	-0,106	0,345[3]	0,586[3]	–	0,081	0,079	-0,011	-0,023	0,311[3]	0,188[2]
Front teats length (FTL)	0,071	-0,086	0,031	0,083	0,079	-0,055	–	0,698[3]	0,311[3]	0,191[1]	0,211[2]	0,177[1]
Rear teats length (RTL)	0,166[2]	-0,071	0,024	0,113[1]	0,083	-0,039	0,713	–	0,282[3]	0,213[2]	0,085	0,091
Front teats diameter (FTD)	0,277[3]	0,189[2]	-0,194[2]	0,185[1]	0,232[3]	0,116	0,388[3]	0,326[3]	–	0,661[3]	0,034	0,057
Rear teats diameter (RTD)	0,269[3]	0,144[1]	-0,231[2]	0,163[1]	0,237[3]	0,219[2]	0,255[2]	0,302[3]	0,578[3]	–	-0,036	-0,041
Distance between front teats (DFT)	0,445[3]	0,423[3]	-0,227[2]	0,152[2]	0,391[3]	0,279[3]	0,114	-0,019	-0,028	0,026	–	0,569[3]
Distance between rear teats (DRT)	0,246[1]	0,204[1]	-0,206[1]	0,144[1]	0,224[1]	0,182[2]	0,086	-0,099	0,033	0,026	0,269[3]	–

N o t e: UBWD – above the diagonal; Holstein – below the diagonal.

positively correlated with the length (r = 0.511), width (r = 0.483) and negatively with the distance from the udder bottom to the ground (r = -0.486), which was also natural, since the greater the depth measurement, the shorter distance to the ground.

The measurement of the distance from the udder bottom to the ground was negatively associated with almost all traits, especially the fore quarter length (r = -0.181), length (r = -0.213) and width (r = -0.227) of the udder. The fore quarter length of the udder was positively related to the length (r = 0.277; P <0.001) and width (r = 0.121; not reliable) of the udder. Udder length with width had a fairly close and highly reliable positive relationship (r = 0.466; P <0.001). The anatomically related udder parts of the first-calf cows of Ukrainian Black-and-White dairy breed correlated with high levels of coefficients and reliability – the front teats length with the rear teats (r = 0.698), the front teats diameter with the rear (r = 0.661) and the distance between the front and rear (r = 0.569) teats.

The degree and reliability of the relationship between the parts of udder measurements of first-calf cows of the Holstein breed (their values are below the diagonal in Table 3) with a slight difference repeat the indicators of correlation coefficients of the peers of Ukrainian Black-and-White dairy breed. So, the udder girth of Holstein cows positively was correlated with the depth measurements (r = 0.474) and the fore quarter length (r = 0.366), length (r = 0.654) and width (0.522) of the udder, distance between the front (r = 0.445) and rear (r = 0.246) teats and negatively with the distance from the udder bottom to the ground (r = -0.213). Udder depth measurement of cows was negatively and closely related to the distance from the bottom to the ground (r = -0.422), weakly with the fore quarter length (r = -0.111) and much closer and positively with the length (r = 0.244) and width (r = 0.445) udder. By measurement of the udder bottom distance from the ground, correlations with other measurements were weak and negative. The length of the fore-udder quarter was positively and reliably associated with length (r = 0.397) and width (r = 0.345). High correlation coefficients in first-calf cows of the Holstein breed were obtained according to anatomically related traits – length of rear teats with front ones (r = 0.713), front teats diameter with the length of front ones (r = 0.388) and rear ones (r = 0.326), rear teats diameter with front teats diameter (r = 0.578).

The close correlations between anatomically related udder measurements in cows of both breeds obtained in studies were consistent with similar data obtained (Patel et al, 2016; Mingoas et al, 2017; Simčič et al, 2021; Sinha et al, 2021).

Conclusions. Summing up the results of studies on the assessment of the udder, we can make a general conclusion that the cows of the Ukrainian black-and-white dairy and Holstein breeds were generally characterized by good morphological indicators characterizing its development, including in the aspect of adaptability to machine milking.

The udder-mass-metric index characterizing the optimal ratio of the main measurements of cows, their live weight with the udder development has a rather significant relationship with the level of milk productivity. It can be used in practical breeding for preliminary selection of first-calf cows in order to increase milk production and consolidate towards the desired conformation type.

Linear measurements make it possible to more objectively evaluate the udder of cows according to his parts development, and the existence of a positive relationship between them will give reason to indirect selection, which will contribute to the effectiveness of cow's selection based on the udder traits in practical breeding.

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Оцінка корів-первісток молочних порід за промірами вимені та їх використання в індексній селекції

Метою даного дослідження було оцінити морфологічні ознаки вимені корів-первісток голштинської та української чорно-рябої молочної порід шляхом оцінки за промірами, оцінити їх за вим'я-масо-метричним індексом і встановити ступінь зв'язку між лінійними промірами вимені. У дослідженнях було використано 86 голів голштинської та 112 голів української чорно-рябої молочної породи стада приватного підприємства «Буринське» Сумської області. Вим'я-масо-метричний індекс включав живу масу корів, проміри тіла, проміри вимені та його об'єм. Встановлено перевагу корів-первісток голштинської породи над однолітками української чорно-рябої молочної породи за промірами вимені. У тварин голштинської породи вим'я-масо-метричний індекс становив у середньому 15,0, а в української чорно-рябої молочної – 13,1 ум. од., з різницею 1,9 ум. одиниць, з достовірністю при P<0,001 на користь голштинських корів. Встановлено значний зв'язок між вим'я-масо-метричним індексом і молочною продуктивністю. Ступінь і достовірність зв'язку між промірами часток вимені корів-первісток голштинської та української чорно-рябої молочної породи відрізнялися значною варіабельністю від -0,422 до 0,713 та від -0,486 до 0,698 відповідно. Ступінь та достовірність зв'язку між промірами статей вимені корів-первісток голштинської породи (їхні значення розміщені нижче діагоналі) з незначною відмінністю повторюють показники коефіцієнтів кореляцій ровесниць української чорно-рябої молочної породи. Найбільшу кореляцію виявлено між анатомічно спорідненими частинами вимені – довжиною та діаметром передніх дійок із задніми та відстанню між ними.

Узагальнюючий висновок свідчить, що корови української чорно-рябої молочної та голштинської порід характеризуються в цілому відмінними морфологічними показниками вимені, які характеризують його розвиток, у тому числі в аспекті пристосованості до машинного доїння. Лінійні проміри дозволяють об'єктивніше оцінювати вим'я корів за розвитком його статей, а існування додатного зв'язку між ними і величиною надою дає підставу для ефективності селекції корів за ознаками вимені в практичній селекції, що сприятиме збільшенню молочної продуктивності тварин.

Ключові слова: *голштинська, українська чорно-ряба молочна, проміри, вим'я, індекс, кореляція.*