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GENETIC PARAMETERS OF LINEAR TRAITS AND THE EFFECT OF COW'S FINAL TYPE ASSESSMENT ON THE LONGEVITY OF UKRAINIAN BLACK-AND-WHITE DAIRY BREED

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Abstract

The purpose of this study was to determine the heritability level of cow's linear traits of Ukrainian Black-and-White dairy breed in herds of Ukraine, to define phenotypic relationships between linear traits and dairy productivity, and to study the impact of final assessment on traits of cow's longevity. The level of heritability coefficients of group traits testified about the efficiency of breeding on the results of cow's selection by dairy type (0,408), body (0,384), udder (0,417) and the final assessment (0,512). Heritability coefficients of descriptive traits varied by variability significantly, from 0.106 (hoof angle) to 0.477 (angularity). Correlation coefficients between group linear traits that characterize dairy type, body and udder, milk yield and milk fat for 305 days of first lactation were: 0.464 and 0.386; 0.452 and 0.463; 0.477 and 0.433, respectively. The correlation between descriptive traits and dairy productivity of cows distinguished by the high variability, from average negative (r = -0.376), between fatness and milk fat yield, to close positive (r = 0.495), between angularity and milk yield. According to longevity, economic use, and lactation, cows estimated "Very Good" were dominated by cows with lower "Good Plus", "Good" and "Insufficient" scores, with highly significant difference, on 527-1,429, 526-1,423, and 451-1,180 days (P <0.001), respectively. Over the lifetime milk yield and milk fat, the preference was 10,050-26,012 and 373.1-941.2 kg, respectively (P <0.001). Statistically significant correlations of angularity, rear width, fore and rear udder attachment, central ligament and body condition score can be used as indirect predictors of selection to increase dairy cow productivity.

Key words: *linear type estimation, correlation, heritability, dairy productivity*

INTRODUCTION

Modern dairy farming in the world has been required a solution to an important milk production problem regarding the duration of cow's use. Over the past 50 years, selection and breeding work with Holstein cattle culminated an unprecedented success - its productivity has increased twice. However, in most countries of the world, the genetic potential of cow productivity was steadily increasing by about 100 kg of milk per year (Shook, G. E., 2006) [33]. However, as a result of intensive breeding for milk production deteriorated reproducible quality and animal health (Van Raden, 2004; Miglior et al., 2005) [36, 23]. Since the growth of milk production - a key to the sustainability of the economy, increasing the genetic potential of dairy farming has been a priority for breeders. Therefore, to ensure the profitability of livestock, along with cows breeding on the basis of dairy productivity, the indicator duration of economic use was included as a breeding trait (Wesseldijk, B., 2004; Miglior et al., 2005) [38, 23]. Since studies have shown that longevity had low heritability, ranging from 0.03 to 0.07 (Zavadilová et al., 2009; Zavadilová and Štípková, 2012; Kern et al., 2014; Imbayarwo-Chikosi et al., 2015; Kern et al., 2015; Polupan, 2015) [38, 40, 14, 11, 13, 28], breeders are searching for traits that could be used as predictors of longevity. It was believed that such may be linear traits of type (Shook, G. E., 2006; Du Toit et al., 2012; Kern et al., 2014; Novotný et al., 2017) [33, 8, 14, 25]. Linear traits were highly inherited and there was a high positive correlation between them and longevity (Khmelnychyi and Vechorka, 2015; Novotný et al., 2017; Ladyka et al., 2018) [17, 25, 20].

According to the method of linear classification, cows of Ukrainian Black-and-White dairy breed (UBWDB) in Cherkasy and Sumy regions of Ukraine were estimated. This breed was created by crossing the Simmental and aboriginal Lebedyn cattle with the Holstein breed. In crossbreed cows, against the background of a significant increase in milk productivity and improvement of conformation traits (Khmelnychyi, 2005; Khmelnychyi, 2013; Gladiy et al., 2016) [18, 16, 9], there was a tendency to reduce the length of productive life (Polupan, 2000; 2014; Klopenko and Stavetska, 2015) [30, 19]. Therefore, the search for predictors of longevity, in terms of the prospect of breeding cows of Ukrainian Black-and-White dairy breed, was an important and topical problem for breeders of the present.

MATERIALS AND METHODS

The firstborn cows of Ukrainian Black-and-White dairy breed (n = 1,387) were researched in the leading breeding herds of Cherkasy and Sumy regions of Ukraine. Cows were estimated according to the method of linear classification [10]. Two rating systems were used: 100 points and 9 points. The 100-point system took into account four sets of linear traits: dairy type, body, legs and udder. Each conformation complex was estimated independently and had its own weight coefficient in the overall assessment of animal: dairy type (DT) - 15%, body (B) - 20%; legs (L) - 25% and udder (U) - 40%. The final score of type was determined by the formula:

FS = (BW×0.15) + (B×0.20) + (L × 0.25) + (U × 0.40)

On a 9-point scale, 18 such linear descriptive traits were assessed as: height, chest width, body depth, angularity, rump angle, rump width, rear legs side view, rear legs rear view, hoof angle, fore udder attachment, rear udder height, central ligament, udder depth, front and rear teats position, teats length, locomotion and body condition score. Cows were evaluated on 2-4 months of the first lactation, but not earlier than the 15th day after calving. Assessment of linear descriptive traits of udder was performed no earlier than 1 hour before milking. The average degree of manifestation of the trait was estimated at five scores, and biological deviations toward minimal development reduced it to one score and, conversely, if the trait development approached maximum manifestation, the score increased to nine points. The maximum score for firstborn cows was no more than 89 for each set of traits. According to the international scale, assessment was as follows: 85-89 scores - "Very Good", 80-84 scores - "Good Plus", 75-79 scores - "Good" and 70-74 scores - "Satisfactory".

From the indicators of cow's longevity were estimated: life expectancy (number of days from date of birth to date of disposal); duration of cows economic use (number of days from the first calving to date of disposal); lifetime duration of lactations (total duration all day lactations); lifelong milk yield (amount of milk yield for all full lactations, kg); average life fat content in milk (lifelong milk fat × 100 / lifelong milk yield, %); lifelong output of milk fat (sum of milk fat for all lactations, kg); average lifelong milk yield for one day of life, of economic use, and lactation (as a proportion of dividing life yield by the duration of relevant period, kg). Milk productivity indicators - milk yield (kg), fat content (%) and milk fat yield (kg) were evaluated for 305 days of the first lactation.

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 – value for variable X;
y_i – value for variable Y;
$\bar{x}$ – average for X;
$\bar{y}$ – average for Y.

The heritability (h^2) of linear traits was evaluated as calculating the father's influence force indicator (η^2_x) in a one-factor variance complex (Plohinskij, 1964) [27] according to the formula:

$$h^2 = \eta_x^2 = \frac{C_x}{C_y}$$

where:

C_x – factorial variance;

C_y – total variance.

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 ([1]), the second – P<0.01 ([2]), and the third – P<0.001 ([3]) probability thresholds. Statistical processing of experimental studies was performed by the methods of mathematical statistics using formulas given by (Merkur'eva, 1977) [22] in Microsoft Excel.

RESULTS AND DISCUSSIONS

Heritability coefficients of cow's firstborn by estimation of group traits have insignificant variability (Table 1). In general, their level indicated to the effectiveness of breeding on the basis of cow's selection by the assessment of group traits that characterize dairy type, body, udder and especially the final assessment. The variability of heritability coefficients of the 18 descriptive traits was more variable and varied from 0.106 (hooves angle) to 0.477 (angularity).

Table 1. Heritability (h^2) of the linear type traits of firstborn cows and their correlation (r) with traits of milk productivity

Conformation traits		h^2 (heritability)	*r* (milk productivity traits)		
			yield	fat, %	fat, kg
Complexes of traits: dairy type		0.408[3]	0.464[3]	0.241[3]	0.386[3]
body		0.384[3]	0.452[3]	0.225[3]	0.463[3]
limbs		0.293[3]	0.189[3]	0.104[1]	0.117[1]
udder		0.415[3]	0.477[3]	0.214[2]	0.433[3]
final score		0.512[3]	0.498[3]	0.266[3]	0.501[3]
Descriptive traits: height		0.227[3]	0.374[3]	0.189[2]	0.329[3]
chest width		0.149[3]	0.111[1]	0.018	0.125[1]
body depth		0.321[3]	0.383[3]	0.126[1]	0.403[3]
angularity		0.477[3]	0.495[3]	0.214[2]	0.484[3]
rump angle		0.122[1]	0.171[1]	0.058	0.152[1]
rump width		0.249[3]	0.414[3]	0.104[1]	0.374[3]
hock joint angle		0.118[1]	0.077	0.054	0.053
pelvic limbs posture		0.269[3]	0.122[1]	0.017	0.135[1]
hoof angle		0.106[1]	0.104[1]	0.067	0.122[1]
udder attachment	fore	0.375[3]	0.421[3]	0.211[2]	0.384[3]
	rear	0.326[3]	0.382[3]	0.184[2]	0.367[3]
central ligament		0.294[3]	0.361[3]	0.091	0.388[3]
udder depth		0.188[2]	0.018	0.011	0.019
teats position	front	0.142[1]	-0.214[3]	0.062	-0.237[3]
	rear	0.154[1]	-0.186[2]	0.058	-0.244[2]
teats length		0.253[3]	-0.077	-0.024	-0.094
locomotion		0.238[3]	0.281[3]	0.112[1]	0.311[3]
body condition score		0.177[1]	-0.368[3]	0.135[2]	-0.376[3]

Source: Own calculations.

Given the economic and functional importance of each descriptive linear trait, it should be noted that the higher heritability of most of them correlated with indicators of milk productivity. These include height, body depth, angularity, rump width, fore udder attachment, rear udder attachment height, central ligament and body condition score.

The level of heritability coefficients of group and most descriptive traits, that correlate with traits of dairy productivity of cows estimated Ukrainian Black-and-White dairy breed, coincided with similar research results of other authors.

This was reported in the study of heritability of linear traits of Canadian Holstein (Bilal et al., 2016) [3], Brown Swiss and Holstein in Switzerland (De Haas et al., 2007) [7], Czech Simmentals (Novotný et al., 2017) [25], Jersey of Brazil (Sabedot et al., 2018) [31], Brown Swiss of Slovenia (Špehar et al., 2012) [34].

Correlative variability in dairy cattle breeding was as important as heritability. The close positive relationship existing between two estimated traits made it possible to more efficiently conduct breeding of cows through indirect selection according to one of the correlating traits.

The correlation coefficients between linear traits of the UBWDB firstborn cow type and their dairy productivity traits are shown in Table 1. Close relationships were obtained between group traits and milk productivity with high reliability according to the Student criterion. High correlation coefficients received between group of linear traits that characterize the dairy type, body and udder, and milk yield for the first 305 days of lactation. The correlation coefficients between these linear traits and milk fat were almost at the same level.

Between the group of traits that characterize the condition of limbs and traits of milk productivity, the phenotypic correlations appeared slightly weaker.

The highest phenotypic correlation coefficients were found between the final score and the traits of milk productivity, especially milk yield and milk fat yield.

The correlation coefficients between the descriptive traits and the milk productivity of the firstborn UBWDB cows differed significantly by variability, from moderate negative (r = -0.376), between fatness and milk fat yield, to close positive (r = 0.495), between angularity and milk yield.

According to the descriptive traits of UBWDB cows, that characterize the body development of cows, closely and positively influenced on the amount of milk yield and milk fat yield, height, body depth, angularity, and rump width. The relationship between chest width and rump width with yield and milk fat was positive but slightly weak. In other studies, phenotypic correlations between descriptive traits that characterize the body and milk productivity were different by quantity and direction depending on the breed (Pahlevan and Moghimi Esfandabadi, 2010; Tapki and Ziya Guzey, 2013; Bilal et al., 2016) [26, 35, 3].

The level of positive correlation between angularity and milk yield and milk fat in this study indicated about corresponding potential possibility of dairy productivity of UBWDB cows with high score for angularity. Similar genetic (0.58) and phenotypic (0.40) correlations between angularity and milk yield were confirmed by studies of Bilal et al. (2016) [3]. According to the linear classification of Czech Holstein cows, Zink et al. (2014) [42] found a moderate genetic correlation of milk yield (0.32), milk fat (0.42) and milk protein (0.34) with angularity. According to linear estimation of cow's type of Holstein breed of Turkey, phenotypic and genetic correlation of angularity with milk yield was 0.29 and 0.42, milk fat - 0.26 and 0.40, and milk protein - 0.25 and 0.45, respectively (Tapki and Ziya Guzey, 2013) [35]. This level of relationship indicated the need to include angularity in the group of linear selection traits that would enhance the productivity potential of dairy cows.

These studies have found that high-performance UBWDB firstborn cows were differed by rump width. This was evidenced by the level of correlation of rump width with milk yield and milk fat. In studies by other authors, variability of relationship of rump width with milk productivity depended on the breed being estimated. In this connection, De Haas et al. (2007) [7] reported that rump width correlated positively with milk yield in Holstein (0.26) and Red-and-White (0.18) breeds, but was negative (-0.15) in Brown Swiss. Low level of genetic and phenotypic correlation of rump width with milk yield was revealed by Alphonsus et al. (2010) [1] in Friesian × Bunay cows, 0.088 and 0.109, respectively. Low similar genetic and phenotypic relationships of Holstein cows in Brazil have been reported by Campos et al. (2015) [5] (0.05 and 0.10), Turkish Holstein by Tapki and Ziya Guzey (2013) [35] (0.02 and -0.03), cows Sahival by Khan M.A. and Khan M.S. (2016) [15] (0.04 and 0.05). Such significant correlative variability between rump width and dairy productivity was explained by the origin and direction of breed selection.

Descriptive traits that characterize the limbs condition - hock joint angle, pelvic limbs posture and hoof angle, weakly correlated with indicators of milk productivity of dairy cows firstborn UBWDB. About non-effectiveness by selection on these grounds due to low or negative correlation between them and milk yield was reported by Khan M.A. and Khan M.S. (2016) [15] (from -0.20 to 0.07), Bohlouli et al. (2015) [4] (from -0.08 to 0.06), Tapki and Ziya Guzey (2013) [35] (from -0.05 to 0.05).

Out of the estimated seven morphological traits of UBWDB firstborn cows' udders, only three were positively associated with milk yield and milk fat. These are the fore udder parts attachment, height rear udder attachment and central ligament. These linear traits perform a supportive function, preventing the udder with age to fall below the hock. The phenotypic correlations of UBWDB firstborn cows, obtained between descriptive traits of udder (fore and rear udder attachment and central ligament) and dairy productivity indicated that selection for them will increase milk production.

These results were consistent with studies of Berry et al. (2004) [2] according to which these traits correlate with yield with corresponding coefficients of 0.32; 0.48 and 0.36. However, they are significantly different from results obtained by Tapki and Ziya Guzey (2013) [35], therefore genetic and phenotypic correlations between fore udder parts attachment and milk yield, fat and protein content, milk fat and protein were negative within -0.30 to -0.18. Positive but low correlations were between the rear udder attachment and central ligament with above-mentioned traits of milk productivity with the corresponding variability coefficients 0.08-0.15 and 0.07-0.18. Similar results were obtained in studies of Campos et al. (2015) [5] (0.11-0.19 and 0.07-0.15).

Between udder depth and milk productivity traits the phenotypic correlations of cows firstborn UBWDB were quite low. Similar genotypic and phenotypic correlations of udder depth with milk yield were identified by Bohlouli et al. (2015) [4] (0.12 and 0.04). In most studies (Alphonsus et al., 2010; Tapki and Ziya Guzey, 2013; Madrid and Echeverri, 2014; Campos et al., 2015; Khan M.A. and Khan M.S., 2016) [1, 35, 21, 5, 15]. such correlations are negative with coefficient variability of -0.470 to -0.129. The low or negative correlations between udder depth and milk productivity were explained by the fact that cows at the time of linear classification had high daily milk yield, by which the udder was lowered to the bottom, so the score decreased.

The position and teats length of UBWDB cows' firstborn was negatively correlated with milk yield and milk fat. These findings are consistent with similar studies by Khan M.A. and Khan M.S. (2016) [15], Bohlouli et al. (2015) [4], Campos et al. (2015) [5]. The direction and strength of this correlation depended on the filling of udder with milk at the time of cow's assessment, the greater its filling, the lower score and the higher negative correlation.

Good estimates of UBWDB firstborn cows for traits of hock joint angle, pelvic limb posture, and angle hoofs in the sum provided a positive correlation between locomotion and milk productivity. About association from moderate to low between movement and traits of milk productivity has been reported by Tapki and Ziya Guzey (2013) [35] (from 0.16

to 0.29) and Zink et al. (2014) [42](-0.04 to 0.10).

Linear score by fatness cows firstborn UBWDB negatively associated with milk yield and milk fat and positively with fat content. Monitoring such studies also pointed about negative correlations between body condition score and traits of milk productivity. For example, in studies of Alphonsus et al. (2010) [1] genetic and phenotypic correlations between fatness and milk yield were -0.465 and -0.370, respectively. According Tapki and Ziya Guzey (2013) [35] genetic and phenotypic correlations between body condition score and traits of milk productivity (yield, milk fat and protein) were negative with variability from -0.29 to -0.34 and from -0.19 to -0.21. Similar negative genetic correlations between body condition score and milk yield (-0.34), milk fat (-0.45) and milk protein (-0.39) were obtained by Zink et al. (2014) [42]. After calving in the first lactation period, dairy cows' productivity was increasing much faster than dry matter consumption, even in a complete diet, so a negative energy balance arising. To cover the energy deficit, the animal used its own body reserves, accompanied by appropriate body condition loss. As a rule, during this period, a linear classification of cows was carried out, therefore, the score in highly productive animals for fatness decreased.

The result of linear classification of dairy cattle was its final assessment, characterizing the breeding value of animal in overall harmony of the body structure development. The number of estimated firstborn cows was divided into four groups according to the final score by the international classification scale (Table 2).

Among the estimated livestock, the largest percentage of animals were rated "Good Plus". The results of cows ranking testified the dependence of longevity traits on the final score of type. With its decline, traits of duration of use and lifelong milk productivity of cows decreased accordingly. In terms of life expectancy, economic use, and lactation, cows with a “Very Good” rating were dominated by low-scoring cows with a highly significant difference, at 527-1,429, 526-1,423, and 451-1,180 days, respectively (P <0.001).

Table 2. Traits of longevity depending on the size of final score of linear classification (x ± S.E.)

Traits of productive longevity		Final assessment, scores			
		85-89 “Very Good”	80-84 “Good Plus”	75-79 “Good”	70-74 “Insufficient”
Number of estimated cows	heads	115	1112	134	26
	%	8.3	80.2	9.7	1.8
Life expectancy of cows, days		3,223 ± 88.6	2,696 ± 21.4	2,044 ± 92.7	1,794 ± 144.1
Duration of cows economic use, days		2,389 ± 85.4	1,863 ± 18.8	1,177 ± 81.5	966 ± 151.1
Duration of lactation, days		2,013 ± 91.3	1,562 ± 19.2	1,091 ± 76.4	823 ± 146.4
Lifetime milk yield, kg		38,013 ± 966.1	27,963 ± 126.7	16,224 ± 1,108.3	12,001 ± 618.1
Lifetime milk fat	%	3.74 ± 0.022	3,75 ± 0.004	3.77 ± 0.028	3.79 ± 0.029
	kg	1,421.7 ± 44.35	1,048.6 ± 11.3	611.6 ± 51.1	480.5 ± 48.2
Milk yield per day of life, kg		11.8 ± 0.23	10.4 ± 0.09	7.9 ± 0.29	6.7 ± 0.45
Milk yield per day of economic use, kg		15.9 ± 0.28	15.0 ± 0.07	13.8 ± 0.33	12.4 ± 0.51
Yield of milk per day of lactation, kg		18.9 ± 0.29	17.9 ± 0.06	14.9 ± 0.35	14.6 ± 0.48

Source: Own calculations.

About effectiveness of the final assessment in the breeding and selection process of animals was evidenced by the indicators of lifelong milk productivity of animal group according to the linear classification “Very Good”. The most informative indicator of the effectiveness of longevity was a lifelong milk yield, according to which a group of cows with 85-89 scores outperformed other groups with lower estimates per 10,050-26,012 kg of milk (P <0.001). With insignificant variability of fat content, from the same group of cows has been received at 373.1-941.2 kg milk fat more than from others (P <0.001).

Analyzing the traits that clearly complement the indicators of lifelong productivity - yield for one day of life, economic use and lactation, we can note a similar pattern, which was that higher rates of these traits also depended on the level of final assessment. Cows with a final score of “Very Good” were better by the listed traits with a significant difference in their favor respectively on 1.4–5.1, 0.9–3.5, and 1.0–4.3 kg of milk (P <0.001) compared to the rest of groups.

In general, about relationship between descriptive linear traits and functional life has been reported by many researchers (Caraviello et al., 2004; Zavadilová et al., 2009; Jovanovac and Raguž, 2011; J. du Toit et al., 2012; Morek-Kopec and Zarnecki, 2012; Kern et al., 2015 and others) [6, 41, 12, 8, 24, 13].

Whereas there are fewer reports with different correlation coefficients on the connection between the final score and life expectancy. About relationship between final assessment and duration of productive life (r = 0.22) was reported by Sawa et al. (2013) [32] and real longevity (r = 0.13) by Vanderick et al. (2006) [37].

Based on the results of these studies, the following general conclusion can be drawn. In the process of dairy cattle intensification, with introduction of advanced technologies and methods of breeding, there was a need to obtain animals with a strong conformation type that can provide them with long-lasting highly productive longevity. The selection of cows with score of "Very Good" and "Good Plus" at the age of the first lactation will contribute to this, which will provide them with high productivity in adulthood throughout life.

CONCLUSIONS

The high level of heritability coefficients of group traits characterizing dairy type, body, udder, and final assessment will ensure the effectiveness of UBWDB cow breeding in the direction of increasing milk productivity.

Close phenotypic correlations with dairy performance of such descriptive traits as: height, body depth, angularity, rump width, front udder parts attachment, height of rear parts attachment, central ligament, and body condition score indicate the need for their use in breeding programs. They can be used as indirect predictors of selection to increase dairy productivity of cows.

The selection of firstborn cows with a final score of “Very Good” and “Good Plus” will help increase the lifelong productivity of adult cows over the long term.

REFERENCES

[1]Alphonsus, C., Akpa, G.N., Oni, O.O., Rekwot, P.I., Barje, P.P., Yashim, S.M., 2010, Relationship of Linear Conformation Traits with Bodyweight, Body Condition Score and Milk yield in Friesian × Bunaji Cows. Journal of Applied Animal Research, 38 (1), 97–100. DOI: https://doi.org/10.1080/09712119.2010.9707164

[2]Berry, D.P., Buckley, R., Dillon, P., Evans, R.D., Veerkamp, R.R., 2004, Genetic relationships among linear type traits, milk yield, body weight, fertility and somatic cell count in primiparous dairy cows. Irish Journal of Agricultural and Food Research, 43:161–176.
DOI: http://hdl.handle.net/11019/432

[3]Bilal, G., Cue, R.I., Hayes, J.F., 2016, Genetic and phenotypic associations of type traits and body condition score with dry matter intake, milk yield, and number of breedings in first lactation. Canadian Journal Animal Science, 96, 434–447.
DOI: dx.doi.org/10.1139/cjas-2015-0127

[4]Bohlouli, M., Alijani, S., Varposhti, M.R., 2015, Genetic relationships among linear type traits and milk production traits of Holstein dairy cattle. Ann. Animal Science, 15 (4), 903–917.
DOI: 10.1515/aoas-2015-0053

[5]Campos, R.V., Cobuci, J.A., Kern, E.L., Costa, C.N., McManus, C.M., 2015, Genetic Parameters for linear type traits and milk, fat, and protein production in Holstein cows in Brazil. Asian-Australasian Journal of Animal Sciences, 28 (4), 476-484.
DOI: http://dx.doi.org/10.5713/ajas.14.0288

[6]Caraviello, D. Z., Weigel, K. A., Gianola D., 2004, Analysis of the Relationship between type traits and functional survival in US Holstein cattle using a Weibull proportional Hazards model. Journal Dairy Science, 87 (8), 2677–2686.
DOI: 10.3168 / jds.S0022-0302 (04) 73394-9

[7]De Haas, Y,. Janss, L.L.G., Kadarmideen, H.N., 2007, Genetic and phenotypic parameters for conformation and yield traits in three Swiss dairy cattle

breeds. Journal of Animal Breeding and Genetics, 2007 Feb; 124 (1), 12-9.
DOI: 10.1111/j.1439-0388.2007.00630.x

[8]Du Toit, J., Van Wyk, J.B., Maiwashe, A., 2012, Relationships between functional herd life and conformation traits in the South African Jersey breed. South African Journal of Animal Science, 42(1), 47-54. DOI: http://dx.doi.org/10.4314/sajas.v42i1.6

[9]Gladiy, M.V., Polupan, Yu.P., Bazyshina, I.V., Pochukalin, A.E. et al., 2016, Henezys i perspektyvy chervonoi molochnoi khudoby in Ukraine [The genesis and prospects of Red dairy cattle in Ukraine]. Rozvedennia i henetyka tvaryn. Vinnytsia, 51, 41-60.

[10]ICAR Recording Guidelines approved by the General Assembly held in Berlin, Germany, on May 2014. Copyright: 2014, ICAR. 618 p.

[11]Imbayarwo-Chikosi, V.E., Dzama, K., Halimani, T.E., Van Wyk, J.B., Maiwashe, A., Banga, C.B., 2015, Genetic prediction models and heritability estimates for functional longevity in dairy cattle. South African Journal of Animal Science, 45 (2), 106-121.

[12]Jovanovac, S., Raguž, N., 2011, Analysis of the relationships between type traits and longevity in Croatian Simmental cattle using survival analysis. Agriculturae Conspectus Scientificus. 76 (3), 249–253.

[13]Kern, E.L., Cobuci, J.A., Costa, C.N., McManus, C.M., Braccini, N.J., 2015, Genetic association between longevity and linear type traits of Holstein cows. Scientia Agricola, 72 (3), 203-209.
DOI: http://dx.doi.org/10.1590/0103-9016-2014-0007

[14]Kern, E.L., Cobuci, J.A., Costa, C.N., McManus, C.M., Campos, G.S., Almeida, T. P., Campos, R.V., 2014, Genetic association between herd survival and linear type traits in Holstein cows under tropical conditions. Italian Journal Animal Science.13, 3419.
DOI: 10.4081/ijas.2014.3419

[15]Khan, M.A., Khan, M.S., 2016, Genetic and phenotypic correlations between linear type traits and milk yield in Sahiwal cows. Pakistan Journal of Agricultural Sciences, 53 (2), 483-489.
DOI: http://www.pakjas.com.pk

[16]Khmel'nychyi, L.M., 2013, Praktychnyy dosvid, stan ta perspektyva vykorystannya metodyky liniynoyi klasyfikatsiyi koriv molochnoyi khudoby v Ukrayini [Practical experience, status and prospects of using the method of linear classification dairy cattle cows in Ukraine]. Visnyk Sums'koho natsional'noho ahrarnoho universytetu. Seriya “Tvarynnytstvo”, 7 (23), 11–19.

[17]Khmelnychyi, L.M., Vechorka, V.V., 2015, Tryvalist' zhyttya koriv ukrayins'koyi chorno-ryaboyi molochnoyi porody v zalezhnosti vid rivnya liniynoyi otsinky morfolohichnykh oznak vymeni [Longevity of cows of Ukrainian Black-and-White Dairy breed depending on the level of linear estimation udder morphological traits]. Naukovo-teoretychnyy zbirnyk Zhytomyrs'koho natsional'noho ahroekolohichnoho universytetu, 2 (52), 57–62.

[18]Khmelnychyi, L.M., 2005, Porivnialna kharakterystyka koriv-pervistok ukrainskoi chorno-riaboi molochnoi ta holshtynskoi porid za eksteriernym typom [Comparative characteristic cows-heifers of Ukrainian Black-and-White Dairy and Holstein breeds by conformation type]. Rozvedennia i henetyka tvaryn. K.: Ahrarna nauka, 39, 216–222.

[19]Klopenko, N.I., Stavetska, R.V., 2015, Henetychna determinatsiia hospodarskoho vykorystannia koriv molochnoho napriamu produktyvnosti za vbyrnoho skhreshchuvannia [Genetic determination of cow economic use by dairy productivity direction for absorbing crossbreeding]. Tekhnolohiia vyrobnytstva i pererobky produktsii tvarynnytstva: Zb. nauk. prats Bilotserk. nats. ahrar. un-t. Bila Tserkva, 1, 23–28.

[20]Ladyka, V., Khmelnychyi, L., Khmelnychyi, S., 2018, Dependence of the longevity of cows Ukrainian brown dairy breed from estimation of linear traits of conformation type. LXXXIII Zjazd Naukowy PTZ im. Michała Oczapowskiego, Wyzwania zootechniki w warunkach rolnictwa zrównoważonego. Streszczenia Sekcja Chowu i Hodowli Bydła. Lublin, 21.

[21]Madrid, S., Echeverri, J., 2014, Association between conformation traits and productive performance in Holstein cows in the department of Antioquia, Colombia. Veterinaria y Zootecnía, 8 (1), 35-47.

[22]Merkureva, E.K., 1977, Geneticheskie osnovy selektsii v skotovodstve [Genetic principles of selection in cattle breeding]. Moscow, Kolos, 240 p.

[23]Miglior, F., Muir, B.L., Van Doormaal, B.J., 2005, Selection indices in Holstein cattle of various countries. Journal Dairy Science, 88, 1255-1263.
DOI: 10.3168/jds.S0022-0302(05)72792-2

[24]Morek-Kopec, M., Zarnecki, A., 2012, Relationship between conformation traits and longevity in Polish Holstein Friesian cattle. Livestock Science,149: 53–61. DOI: 10.1016/j.livsci.2012.06.022

[25]Novotný, L., Frelich, J., Beran, J., Zavadilová, L., 2017, Genetic relationship between type traits, number of lactations initiated, and lifetime milk performance in Czech Fleckvieh cattle. Czech Journal Animal Science, 62, 501-510. DOI: https://doi.org/10.17221/60/2017-CJAS

[26]Pahlevan, R., Moghimi Esfandabadi, A., 2010, Study of production, reproduction and type traits in a Holstein population (in Persian). Journal Animal Science, (Iran), 3, 1–12.

[27]Plokhinskij, N.A., 1964, Nasleduemost' [Heritability]. Novosibirsk, 196.

[28]Polupan, Yu.P., 2015, Henetychna determinatsiia tryvalosti ta efektyvnosti dovichnoho vykorystannia chorno-riaboi molochnoi khudoby [Genetic determination of the duration and effectiveness of life-long use of Black-and-White dairy cattle]. Rozvedennia i henetyka tvaryn, 49, 120–133.

[29]Polupan, Yu. P., 2014, Efektyvnist' dovichnoho vykorystannya koriv riznykh krayin selektsiyi [Effectiveness of cows lifelong use in different countries of breeding]. Visnyk Sums'koho natsional'noho ahrarnoho universytetu. Seriya “Tvarynnytstvo”, 2 (25), 14–20.

[30]Polupan, Yu. P., 2000, Efektyvnist dovichnoho vykorystannia chervonoi molochnoi khudoby [Efficiency of lifetime use of Red Dairy cattle].

Rozvedennya i henetyka tvaryn. K.: Ahrarna nauka, 33, 97–105.
[31]Sabedot, M.A., Romano, G. de S., Pedrosa, V.B., Pinto, L.F.B., 2018, Genetic parameters for type score traits and milk production in Brazilian Jersey herds. Revista Brasileira de Zootecnia, 47:e20170093. DOI: https://doi.org/10.1590/rbz4720170093
[32]Sawa, A., Bogucki, M., Krwhel-Czopek, S., Neja, W., 2013, Relationship between conformation traits and lifetime production efficiency of cows. Life Sciences, 85-084. DOI: https://doi.org/10.1155/2013/124690
[33]Shook, G. E., 2006, Major advances in determining appropriate selection goals. Journal Dairy Science, 89:1349–1361.
[34]Špehar, M., Štepec, M., Potočnik, K., 2012, Variance components estimation for type traits in Slovenian Brown Swiss cattle. Acta argiculturae Slovenica, 100 (2), 107–115.
[35]Tapki I., Ziya Guzey, Y., 2013, Genetic and phenotypic correlations between linear type traits and milk production yields of Turkish Holstein dairy cows. Greener Journal of Agricultural Sciences, 3, 755–761.
[36]Van Raden, P.M., 2004, Selection in Net Merit to improve lifetime profit. Journal Dairy Science, 87, 3125-3131. DOI: 10.3168/jds.S0022-0302(04)73447-5
[37]Vanderick, S., Croquet C., Mayeres P., Soyeurt H., Gengler, N., 2006, Correlations of longevity evaluation with type traits in walloon region. Belo Horizonte, MG, Brasil. 8th World Congress on Genetics Applied to Livestock Production, August 13-18. DOI: https://www.researchgate.net/publication/268327679
[38]Wesseldijk, B., 2004, Secondary traits make up 26% of breeding goal. Holstein International, 11 (6), 8–11.
[39]Zavadilová, L., Štípková, M., 2012, Genetic correlations between longevity and conformation traits in the Czech Holstein population. Czech Journal of Animal Science 57 (3), 125–136.
[40]Zavadilová, L., Němcová, E., Štípková, M., Bouška, J., 2009, Relationships between longevity and conformation traits in Czech Fleckvieh cows. Czech Journal of Animal Science, 54 (9), 387–394.
[41]Zavadilová, L., Štípková, M., Němcová, E., Bouška, J., Matějíčková, J., 2009, Analysis of the phenotypic relationships between type traits and functional survival in Czech Fleckvieh cows. Czech Journal of Animal Science, 54 (12), 521–531. DOI: https://www.agriculturejournals.cz/publicFiles
[42]Zink, V., Zavadilová, L., Lassen, J., Štípková, M., Vacek, M., Štolc, L., 2014, Analyses of genetic relationships between linear type traits, fat-to-protein ratio, milk production traits, and somatic cell count in first-parity Czech Holstein cows. Czech Journal of Animal Science, 59(12), 539-547. DOI:http://www.agriculturejournals.cz/publicFiles/138127.pdf