

# Estimation of heritability and genetic correlations between milk yield and linear type traits in primiparous Holstein-Friesian cows

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**ABSTRACT** - Estimation of genetic variability and genetic correlations between production traits (milk yield, fat yield, fat content, protein yield, and protein content) and selected type traits (angularity, fore udder height, rear udder height, front teat placement, teat length, and udder depth) was done using data sets of 10,860 first-calving Holstein-Friesian cows raised in the territory of the Republic of Serbia. Genetic variance and covariance were obtained using the Restricted Maximum Likelihood (REML) method, VCE v6 software, and the multi-trait mixed model. To enable more precise estimates of values for genetic variances and covariance, a relationship matrix was formed for the individual model (animal model), encompassing 21363 animals. The highest heritability values were obtained for milk yield (0.182), fat yield (0.134), and protein yield (0.170). The lowest heritability estimates were for teat length, front teat placement, rear udder height, and udder depth, all being under 0.110. Genetic correlations between production traits and linear type traits were between -0.131 (fat content and front teat length) and 0.307 (protein yield and fore udder attachment). The largest number of traits shows a positive genetic correlation with the traits of milk yield, which thus indicates possibility of genetic improvements of milk yield in cattle without jeopardizing the type traits or vice versa.

**Keywords:** angularity, genetic parameters, Holstein-Friesian, milk traits, udder traits

## 1. Introduction

The modern approach to dairy cattle selection has led to defining new breeding programmes whose focus of selection is shifted from milk production traits to a much more balanced approach, with the accent placed on functional traits, such as longevity and type traits (Miglior et al., 2005; Němcová et al., 2011; Tapki and Guzey, 2013). The new National Breeding Programme in the Republic of Serbia has set as its goal the breeding of Holstein-Friesian cows with desirable type traits, longevity, good fertility, and robustness, while retaining the existing high milk yield (Janković, 2017; Stanojević et al., 2018). The long generation interval in cattle and low heritability for fertility traits has led to increased interest in linear evaluation of type traits in cows, which can be evaluated at an early age and can indirectly influence the improvement of milk production and longevity traits.

According to the International Committee on Animal Recording (ICAR, 2016), linear evaluation of type traits forms the basis of all modern classification systems and the basis for describing the appearance of dairy cows. The evaluation is based on measuring individual type traits without expressing an

opinion and describes the level of expression of a trait, not its desirability (Janković, 2017). Based on the grade for each trait or linear score, animals are ranked into specific categories, and their desirability is used to select parents for the following generation.

The overall score for type traits is defined by the country where the linear evaluation is implemented, according to the economic significance of specific traits and defined breeding goals. According to ICAR recommendations, type traits are classified into four functional entities: frame, dairy character-angularity, legs and hooves, and udder).

Type traits have low to medium heritability (Samoré et al., 2010; Ptak et al., 2011; Dadpasand et al., 2012; Zink et al., 2014; Bohlouli et al., 2015; Susanto et al., 2018) with the advantage that they are registered in one evaluation, making them reliable and relatively inexpensive and can be included in national cattle breeding selection programmes (Němcová et al., 2011).

Since it is often inefficient and expensive to simultaneously select for numerous traits, a more efficient way to improve the hereditary basis is by including traits with high genetic correlations that are, at the same time, traits of interest for breeders. Numerous researchers have established a positive genetic correlation between traits of milk production and linear type traits in cows (Berry et al., 2005; Vallimont et al., 2010; Tapki and Guzey, 2013; Bohlouli et al., 2015; Wasana et al., 2015; Susanto et al., 2018).

Having in mind the economic importance of the Holstein-Friesian breed in Serbia and the world, in general, the goal of this paper was to assess heritability and genetic correlations between production traits and selected linear type traits, primarily because of the possibility to include them in the National Selection Programme, as well as the importance and role of analysed genetic parameters for assessing breeding value.

## 2. Material and Methods

### 2.1. Data collection

The analysed data included 10,860 primiparous Holstein-Friesian cows that were owned by 1703 breeders throughout the territory of the Autonomous Province of Vojvodina, Republic of Serbia (45.2609° N, 19.8319° E), from 2011 to 2015. Animals were daughters of 505 bull sires and the average number of tested daughters per bull sire was 22. First-calving cows were evaluated by 22 evaluators who completed expert training according to the Instructions for the Evaluation of Linear Type Traits and Body Development in the Holstein-Friesian Breed (WHFF, 2008). The average number of animals per farm was 10, with the first calving at an average age of 27 months. The average age of first-calving cows at the evaluation was 30 months, and traits were measured, on average, 95 days after calving, with variability from 15 to 210 days. All of the primiparous cows enrolled in the breeding programme were raised under the similar housing, nutrition, and health conditions. Primiparous cows were nutritionally managed to obtain an average daily gain of 0.55 to 0.65 kg/d from birth to breeding. The main components of their feeding rations consisted of corn silage, alfalfa hay, wheat bran, and feed additives, and later on the cows were fed total mixed ration. Herd average for milk production for these farms was around 6700 kg of milk per lactation (Table 1).

**Table 1 - Indicators of phenotype expression and variability of milk production traits in standard lactation (n = 10860)**

Trait	Abbreviation	Mean	SD	CV (%)	Min	Max
Milk yield (kg)	MY	6672	1740	26.07	1811	14395
Fat content (%)	FC	3.81	0.45	11.81	2.04	5.96
Fat yield (kg)	FY	252.83	67.66	26.76	59.00	612.00
Protein content (%)	PC	3.21	0.21	6.54	2.02	5.09
Protein yield (kg)	PY	213.86	56.94	26.62	51.00	472.00

SD - standard deviation; CV - coefficient of variation.

First-calving cows were evaluated for all 18 type traits according to WHFF (2008). However, since the National Breeding Programme for Holstein-Friesian cows primarily aims to improve traits of dairy character and udder, this research covered the following traits: angularity (ANG), fore udder attachment (FUA), rear udder height (RUH), fore teats placement (FTP), teat length (TL), and udder depth (UD), as well as milk production traits (standard lactation period of 305 days): milk yield (MY), fat content (FC), fat yield (FY), protein content (PC), and protein yield (PY). Milk yield control was done by the AT4 method. Milk traits in standard lactation are calculated by the standard method (ICAR - International Agreement of Recording Practices, 2.1.4.1). Linear evaluation of type traits includes evaluation of all traits at their biological extremes in the range from 1 to 9 (Table 2).

The effect of each of the fixed factors, as well as their mutual interaction, was investigated by the analysis of variance method using the statistical software SAS (Statistical Analysis System, version 9.1.3).

**Table 2 - Indicators of phenotype expression and variability of linear type traits (n = 10860)**

Trait	Abbreviation	Ideal score	Type trait score		Mean	SD	CV (%)	Min	Max
			1	9					
Angularity (points)	ANG	9	Lacks angularity	Very angular	6.47	1.40	21.64	2	9
Fore udder attachment (points)	FUA	9	Weak and loose	Extremely strong	5.74	1.46	25.44	1	9
Front teat placement (points)	FTP	5	Outside of quarter	Inside of quarter	4.96	1.14	22.98	1	9
Teat length (points)	TL	5	Short	Long	5.20	1.12	21.54	1	9
Udder depth (points)	UD	5	Below hock	Shallow	5.99	1.22	20.37	1	9
Rear udder height (points)	RUH	9	Very low	High	6.25	1.33	21.28	1	9

SD - standard deviation; CV - coefficient of variation.

## 2.2. Estimation of heritability and genetic correlation

Data used to estimate the heritability coefficient and genetic correlation for milk production traits and type traits were encoded in the PEST software package (Groeneveld et al., 1990), while estimations for genetic variances and covariances were obtained using the Restricted Maximum Likelihood method (REML), VCE v6 software (Groeneveld et al. 2010), and the multi-trait model (all traits were analysed as linear). To more precisely estimate values of genetic variances and covariances, a kinship matrix was created for the animal model, which included 21363 animals.

Analysis and genetic evaluation of type traits were performed using the following model (equation 1):

$$Y_{ijklmno} = \mu + F_i + GG_j + Y \times S_k + AFC_l + O_m + Y_n + FL_o + \text{animal} + e_{ijklmno}' \quad (1)$$

in which  $Y_{ijklmno}$  = phenotypic expression of the investigated trait;  $\mu$  = general population average;  $F_i$  = fixed effect of farm (1703 farms);  $GG_j$  = fixed effect of genetic group [interaction of bull's year of birth (1980-2011) and country of origin (12), 79 genetic groups in total];  $Y \times S_k$  = fixed effect of interaction between calving year and season (five years, every year divided into four seasons: winter, spring, summer, autumn);  $AFC_l$  = fixed effect of age at first calving (animals' age in months, allocated to five classes: I (19-23), II (24-26), III (27-30), IV (31-33), and V (34-44));  $O_m$  = fixed effect of evaluator (22);  $Y_n$  = fixed effect of year of evaluation (four years, from 2012 to 2015);  $FL_o$  = fixed effect of lactation stage in the moment of evaluation (lactation stage in days, allocated to seven classes: I (0-30), II (31-60), III (61-90), IV (91-120), V (121-150), VI (151-180), and VII (181-210)); animal = random effect of an individual for which the kinship matrix was created; and  $e_{ijklmno}$  = random error.

Genetic evaluation of milk production traits was done using the following model (equation 2):

$$Y_{ijkl} = \mu + F_i + GG_j + Y \times S_k + AFC_l + \text{animal} + e_{ijkl}' \quad (2)$$

in which  $Y_{ijkl}$  = phenotypic expression of the investigated trait;  $e_{ijkl}$  = random error;  $\mu$ ,  $F_i$ ,  $GG_j$ ,  $Y \times S_k$ ,  $AFC_l$ , and  $animal$  = model variables as defined in the previous model (model equation 1).

The heritability ( $h^2$ ) of each trait was computed using equation 3:

$$h^2 = \frac{\sigma_a^2}{\sigma_p^2}, \quad (3)$$

in which  $\sigma_a^2$  = additive genetic variance and  $\sigma_p^2$  = total phenotypic variance.

Genetic correlation ( $r_{gxy}$ ) estimates were calculated as follows (equation 4):

$$r_{gxy} = \frac{Cov_{gxy}}{\sqrt{\sigma_{gx}^2 + \sigma_{gy}^2}}, \quad (4)$$

in which  $Cov_{gxy}$  = genetic covariance between  $x$  and  $y$  traits,  $\sigma_{gx}^2$  = genetic variance of  $x$  trait, and  $\sigma_{gy}^2$  = genetic variance of  $y$  trait.

### 3. Results

The study investigated the effect of several fixed effects on the variability of type traits and milk production traits. For the majority of investigated type traits, a statistically highly significant effect was exerted by farm effect where the animal was evaluated, evaluator, interaction between year and season of evaluation, stage of lactation, and genetic group (Table 3).

Heritability estimates indicate genetic variability of examined traits and their evaluation is important for estimating the breeding value of animals and choosing the method of selection.

For all analysed traits, heritability estimates were low (0.047-0.182). The highest heritability values were estimated for milk production traits: MY (0.182), FY (0.134), and PY (0.170) (Table 4). The estimations for heritability values pertained to the following traits: TL, FTP, FUA, and UD and were under 0.110.

Genetic correlations between investigated linear type traits and milk production traits (Table 5) were ranked in the interval from -0.131 (FC and TL) to 0.307 (PY and FUA). A positive genetic correlation (0.282) was also registered between FUA and MY as the most important trait for milk production, while the lowest correlation for MY was established with UD (-0.032).

The only negative genetic correlation was estimated between TL and FUA (-0.032), while a strong positive correlation was established between ANG and FUA (0.787).

**Table 3** - Values for F-test of investigated fixed effects (P-values)

Effect	Trait										
	MY	FC	FY	PC	PY	ANG	FUA	FTP	TL	UD	RUH
F	0.000**	0.000*	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GG	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
Y×S	0.000**	0.000**	0.000**	0.000**	0.060*	0.000**	0.000**	0.000**	0.017*	0.003**	0.000**
AFC	0.000**	0.001**	0.000**	0.000**	0.002**	0.000**	0.000**	0.000**	0.003**	0.000**	0.027*
O	-	-	-	-	-	0.000**	0.019*	0.004**	0.001**	0.021*	0.000**
Y	-	-	-	-	-	0.000**	0.000**	0.009**	0.005**	0.000**	0.000**
FL	-	-	-	-	-	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

MY - milk yield; FC - fat content; FY - fat yield; PC - protein content; PY - protein yield; ANG - angularity; FUA - fore udder attachment; FTP - front teat placement; TL - teat length; UD - udder depth; RUH - rear udder height; F - fixed effect of farm; GG - fixed effect of genetic group; Y×S - fixed effect of the interaction between calving year and season; AFC - effect of age at first calving; O - fixed effect of evaluator; Y - fixed effect of year of evaluation; FL - fixed effect of lactation phase in the moment evaluation.

\* P<0.05, \*\* P<0.01.

**Table 4** - Estimated values of heritability ( $h^2$ ), heritability error (SE), and variances (additive variance -  $\sigma_a^2$ , error variance -  $\sigma_e^2$ , and phenotypic variance -  $\sigma_p^2$ ) for investigated traits in first-calving cows

Trait	$\sigma_a^2$	$\sigma_e^2$	$\sigma_p^2$	$h^2 \pm SE$
ANG	0.162±0.032	1.394±0.039	1.583	0.102±0.020
FUA	0.186±0.029	1.495±0.026	1.703	0.109±0.017
FTP	0.078±0.014	1.109±0.016	1.203	0.065±0.012
TL	0.061±0.012	1.018±0.020	1.106	0.055±0.011
UD	0.132±0.0022	1.358±0.0028	1.582	0.083±0.014
RUH	0.098±0.014	1.162±0.021	1.264	0.084±0.011
MY	385247±63654	1563784±59631.6	2121812	0.182±0.030
FC	0.009±0.0023	0.175±0.0032	0.192	0.047±0.012
FY	480±82.34	2920±86.74	3580	0.134±0.023
PC	0.004±0.00046	0.038±0.002	0.046	0.087±0.010
PY	392426±64731.8	1699874±59647.8	2311850	0.170±0.028

ANG - angularity; FUA - fore udder attachment; FTP - front teat placement; TL - teat length; UD - udder depth; RUH - rear udder height; MY - milk yield; FC - fat content; FY - fat yield; PC - protein content; PY - protein yield.

#### 4. Discussion

A number of researchers (Pantelić et al., 2012; Marinov et al., 2015; Khan and Khan, 2015; Janković, 2017) also found that fixed effects of farm size, lactation stage, year and season of assessment, as well as evaluator were statistically significant at  $P < 0.01$  and  $P < 0.001$ , as they affect udder traits and angularity.

The heritability estimate obtained for ANG in the population of first-calving Holstein-Friesian cows was 0.102, and it was lower than the value of 0.23 obtained by Toghiani (2011) and Campos et al. (2012). A lower heritability estimate of 0.07 for ANG was also obtained by Rabbani-Khourasgani et al. (2014) and Van der Laak et al. (2016), who found a coefficient of 0.09. Higher values for the heritability coefficient, in relation to the value obtained for ANG in primiparous cows in this paper, were reported as follows: 0.11 by Dadpasand et al. (2012), 0.17 by Cassandro et al. (2015), 0.18 by Bohlouli et al. (2015), 0.30 by Zavadilová et al. (2014), 0.32 by Tapki and Guzey (2013), and 0.38 by Němcová et al. (2011).

Obtained heritability estimates for udder traits had low values, between 0.055 TL and 0.109 for FUA. The heritability coefficient value for fore udder attachment was lower than the value of 0.19 obtained by Campos et al. (2012), as well as the value of 0.18 obtained by Van der Laak et al. (2016), and 0.20 obtained by Toghiani (2011). Similar heritability estimates with following values were obtained: 0.10 by Cassandro et al. (2015), 0.15 by Dadpasand et al. (2012), and 0.16 by Liu et al. (2014). Higher values for heritability estimates with the following values were obtained: 0.21 by Zavadilová and Štípková (2012), 0.22 by Zink et al. (2014), 0.24 by Zavadilová et al. (2014), and 0.25 by Bohlouli et al. (2015).

The heritability coefficient value for FTP obtained in this investigation was 0.065 and was lower than the values of 0.12 obtained by Cassandro et al. (2015) and 0.13 obtained by Dadpasand et al. (2012). Other researchers obtained even higher heritability coefficient values: 0.22 by Bohlouli et al. (2015), 0.23 by Mikhchi et al. (2013), 0.35 by Van der Laak et al. (2016), 0.39 by Němcová et al. (2011), and 0.44 by Tapki and Guzey (2013). The heritability coefficient value of 0.109 for FUA in the population of first-calving Holstein-Friesian cows in Autonomous Province of Vojvodina was close to that of 0.17 for the Holstein-Friesian population in South Korea.

For UD, the heritability coefficient value of 0.083 obtained in this research was closest to the value of 0.09 obtained by Duru et al. (2012) and 0.11 obtained by Liu et al. (2014) and Cassandro et al. (2015), while other researchers obtained higher values: 0.15 by Susanto et al. (2018), 0.23 by Bohlouli et al. (2015), 0.25 by Campos et al. (2015), 0.32 by Němcová et al. (2011), 0.36 by Van der Laak et al. (2016), and 0.41 by Tapki and Guzey (2013).

The heritability coefficient value for RUH of 0.084 in first-calving Holstein-Friesian cows obtained in this research was identical to the value obtained by Rabbani-Khourasgani et al. (2014) and close to the

**Table 5** - Estimation of value of genetic correlations and standard errors between investigated traits in first-calving cows

Trait	MY	FC	FY	PC	PY	ANG	FUA	FTP	TL	UD	RUH
	-	-0.262±0.043	0.983±0.029	-0.161±0.033	0.978±0.034	0.218±0.045	0.282±0.060	0.091±0.005	0.177±0.049	-0.032±0.007	0.023±0.003
		-	-0.013±0.001	0.638±0.062	-0.139±0.006	0.176±0.050	0.052±0.010	0.523±0.004	-0.131±0.036	0.128±0.040	0.124±0.036
			-	-0.031±0.009	0.976±0.028	0.243±0.047	0.230±0.077	0.223±0.006	0.178±0.033	0.041±0.003	0.063±0.005
				-	0.037±0.009	0.052±0.008	0.193±0.064	0.152±0.006	0.078±0.006	-0.092±0.006	0.179±0.039
					-	0.221±0.063	0.307±0.085	0.103±0.007	0.221±0.034	-0.083±0.001	0.072±0.003
						-	0.787±0.074	0.652±0.004	0.021±0.002	0.247±0.051	0.312±0.040
							-	0.548±0.005	-0.032±0.035	0.432±0.059	0.434±0.037
								-	0.223±0.054	0.079±0.003	0.148±0.049
									-	0.038±0.049	0.088±0.003
										-	0.413±0.035

MY - milk yield; FC - fat content; FY - fat yield; PC - protein content; PY - protein yield; ANG - angularity; FUA - fore udder attachment; FTP - front teat placement; TL - teat length; UD - udder depth; RUH - rear udder height.

value of 0.10 obtained by Toghiani (2011) and Cassandro et al. (2015). Higher values for this coefficient were obtained: 0.20 by Zavadilová and Štípková (2012), 0.25 by Bohlouli et al. (2015), and 0.49 by Němcová et al. (2011). The heritability value for FUA of 0.109 obtained in this research was lower than the value of 0.19 obtained by Janković (2017) and 0.23 estimated by Tapki and Guzey (2013).

Low heritability values were obtained for milk production traits as well. In literature, heritability for milk production traits was in the range from low to medium high ( $h^2 = 0.05-0.42$ ), which correlates with results obtained in this paper. In an improved Black Pied cattle population, Djedović et al. (2013) established heritability values for MY, FC, and FY of 0.15, 0.06, and 0.10, respectively. Higher heritability values for milk production traits than those presented in this paper were determined by Costa et al. (2000) during the research of heredity in Holstein populations in the USA and Brazil. Mentioned researchers obtained heritability values for MY and FY of 0.25 and 0.22 for Brazilian Holstein, i.e. 0.34 and 0.35 for those same traits in the US cow population. The difference between heritability values obtained in different dairy cattle populations results from a wide diversity of climate and ambient conditions primarily relevant to animal nutrition and housing. In cases of such pronounced differences, the applied model may result in a higher residual variance and, therefore, in lower heritability values (Bohlouli et al., 2015).

Genetic correlations between investigated linear type traits and milk production traits (Table 5) were ranked in the interval from  $-0.131$  (FC and TL) to  $0.307$  (PY and FUA). A positive genetic correlation ( $0.282$ ) was also registered between FUA and MY as the most important trait for milk production, while the lowest correlation for MY was established with UD ( $-0.032$ ).

The only negative, very weak genetic correlation was estimated between TL and FUA ( $-0.032$ ), while a strong positive correlation was established between ANG and FUA ( $0.787$ ).

Similarly to the results obtained in this paper, other numerous studies also reported both positive and negative correlations between production traits and linear type traits in dairy cows. Researching the correlation of type traits and milk production yield in first-calving cows, Short and Lawlor (1992), obtained moderate genetic correlations ranging from  $-0.48$  for UD to  $0.54$  for dairy character. Brotherstone (1994) established genetic correlations between MY and ANG ( $0.43$ ), as well as between production and UD ( $-0.44$ ). Similarly to this investigation, Berry et al. (2005) obtained positive genetic correlations between production traits and all linear type traits, except UD. Vallimont et al. (2010) recorded stronger genetic correlations between production traits and type traits ( $0.52$  to  $0.63$ ). In the investigation of correlation between type traits and milk production in Holstein-Friesian bull dams, Pantelić et al. (2012) obtained very weak genetic correlations in relation to milk production ranging from  $-0.12$  for rear legs-side view to  $0.23$  for median suspensory ligament. Genetic correlations closest to those in this paper were reported by Janković et al. (2016), ranging from  $-0.36$  for udder depth to  $0.28$  for body depth, while Kruszyński et al. (2013) obtained genetic correlation values ranging from very low, indicating no correlation ( $-0.09$  for teat position), to low for UD ( $0.30$ ). Analysing genetic parameters for udder traits alone, Liu et al. (2014) obtained genetic correlation values between udder traits and milk production ranging from  $-0.20$  for UD to  $0.82$  for RUH. In their research of correlations between type traits and milk yield, Bohlouli et al. (2015) established positive correlations for all type traits that varied from  $0.02$  for FTP to  $0.26$  for ANG. In addition, Khan and Khan (2016) obtained genetic correlation values ranging from  $-0.23$  for UD to  $0.40$  for RUH.

Genetic correlations obtained in this study between linear type traits and milk production traits indicate the existence of positive genetic correlations between studied traits, except between MY and UD ( $-0.032$ ). This, as well as all mentioned studies, indicate that by selection for type traits and by appropriate improvement of body conformation of the dairy cow, it is possible to simultaneously influence an increase in MY and milk content.

In this study, low heritability values obtained for milk production traits, especially for protein and fat content, as well as genetic correlation values, are mainly lower compared with cited authors. These differences could be a result of different models applied for their estimation and different systems of linear type trait evaluation, but also of differences in population size, size and structure of the

studied sample, number and level of training of the classifiers, as well as previous inadequate selection, especially of bull sires, and not of actual heritability in the observed population. Therefore, to assess heritability, it is necessary to use an adequate model and a larger number of individuals, which will reduce the share of variability caused by external factors in total variability and increase the variability caused by genotype of individuals, which generally leads to more accurate assessment of heritability.

## 5. Conclusions

Obtained results show that higher milk, fat, and protein yields are obtained by cows with more pronounced angularity, i.e. dairy character, as well as those with good front and rear udder attachments. The general goal in dairy cattle production is to keep cows in production as long as possible, with regular calving and high milk yield, which is important for the economic aspects of milk production. Obtained results also indicate the possibility of improving milk production and type traits by independent selection, primarily through bull-sires within national selection and breeding programmes. To achieve a maximum effect of selection, milk production traits and type traits should be included with optimal ratio within the national selection programme, in accordance with set goals.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

Conceptualization: H. Ismael and S. Trivunović. Data curation: D. Janković. Formal analysis: D. Stanojević. Methodology: H. Ismael and R. Djedović. Project administration: V. Bogdanović. Resources: D. Janković and S. Trivunović. Software: D. Stanojević. Supervision: S. Trivunović. Validation: D. Janković. Writing-original draft: H. Ismael and R. Djedović. Writing-review & editing: V. Bogdanović and R. Djedović.

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## References

- Berry, D. P.; Harris, B. L.; Winkelman, A. M. and Montgomerie, W. 2005. Phenotypic associations between traits other than production and longevity in New Zealand dairy cattle. *Journal of Dairy Science* 88:2962-2974. [https://doi.org/10.3168/jds.S0022-0302\(05\)72976-3](https://doi.org/10.3168/jds.S0022-0302(05)72976-3)
- Bohlouli, M.; Alijani, S. and Varposhti, M. R. 2015. Genetic relationships among linear type traits and milk production traits of Holstein dairy cattle. *Annals of Animal Science* 15:903-917.
- Brotherstone, S. 1994. Genetic and phenotypic correlations between linear type traits and production traits in Holstein-Friesian dairy cattle. *Animal Production* 59:183-187.
- Campos, R. V.; Cobuci, J. A.; Costa, C. N. and Braccini Neto, J. 2012. Genetic parameters for type traits in Holstein cows in Brazil. *Revista Brasileira de Zootecnia* 41:2150-2161. <https://doi.org/10.1590/S1516-35982012001000003>
- Campos, R. V.; Cobuci, J. A.; Kern, E. L.; Costa, C. N. and 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* 28:476-484. <https://doi.org/10.5713/ajas.14.0288>
- Cassandro, M.; Battagin, M.; Penasa, M. and De Marchi, M. 2015. Short communication: Genetic relationships of milk coagulation properties with body condition score and linear type traits in Holstein-Friesian cows. *Journal of Dairy Science* 98:685-691. <https://doi.org/10.3168/jds.2014-8153>
- Costa, C. N.; Blake, R. W.; Pollak, E. J.; Oltenacu, P. A.; Quaas, R. L. and Searle, S. R. 2000. Genetic analysis of Holstein cattle populations in Brazil and the United States. *Journal of Dairy Science* 83:2963-2974. [https://doi.org/10.3168/jds.S0022-0302\(00\)75196-4](https://doi.org/10.3168/jds.S0022-0302(00)75196-4)

- Dadpasand, M.; Zamiri, M. J.; Atashi, H. and Akhlaghi, A. 2012. Genetic relationship of conformation traits with average somatic cell score at 150 and 305 days in milk in Holstein cows of Iran. *Journal of Dairy Science* 95:7340-7345. <https://doi.org/10.3168/jds.2011-5002>
- Djedović, R.; Bogdanović, V.; Stanojević, D.; Beskorovajni, R.; Trivunović, S.; Petrović, M. and Samolovac, L. 2013. The assessment of the selection effects on milk traits in Black-White cattle. p.18-21. In: *Proceedings of the 23rd International Symposium New Technologies in Contemporary Animal Production*. Faculty of Agriculture, Novi Sad, Serbia.
- Duru, S.; Kumlu, S. and Tuncel, E. 2012. Estimation of variance components and genetic parameters for type traits and milk yield in Holstein cattle. *Turkish Journal of Veterinary and Animal Sciences* 36:585-591. <https://doi.org/10.3906/vet-1012-660>
- Groeneveld, E.; Kovac, M. and Mielenz, N. 2010. *VCE6 User's guide and reference manual*. Institute of Farm Animal Genetics, FLI, Mariensee.
- Groeneveld, E.; Kovač, M. and Wang, T. 1990. PEST, a general purpose BLUP package for multivariate prediction and estimation. p.488-491. In: *Proceedings of the 4th World Congress on Genetics Applied to Livestock Production*, Edinburgh, Scotland.
- ICAR - International Committee for Animal Recording. 2016. *International agreement of recording practices*. ICAR Recording Guidelines, section 5 - ICAR guidelines on conformation recording methods in dairy cattle, beef cattle and dairy goats. p.197-249.
- Janković, D.; Djedović, R.; Trivunović, S.; Ivanović, D.; Štrbac, Lj.; Kučević, D.; Stanojević, D. and Radinović, M. 2016. Variability and effects of farms, classifiers and lactation stage on linear type traits scores of primiparous Holstein-Friesian cows. p.150-158. In: *Proceedings of the International Symposium on Animal Science*. Faculty of Agriculture, Belgrade, Serbia.
- Janković, D. 2017. *Breeding values estimation of Holstein Friesian bulls for type traits*. PhD thesis. University of Belgrade, Faculty of Agriculture, Belgrade-Zemun, Serbia.
- Kern, E. L.; Cobuci, J. A.; Costa, C. N. and Pimentel, C. M. M. 2014. Factor analysis of linear type traits and their relation with longevity in Brazilian Holstein cattle. *Asian-Australasian Journal of Animal Sciences* 27:784-790. <https://doi.org/10.5713/ajas.2013.13817>
- Khan, M. A. and Khan, M. S. 2015. Non-genetic factors affecting linear type traits in Sahiwal cows. *The Journal of Animal & Plant Sciences* 25:29-36.
- Khan, M. A. and Khan, M. S. 2016. Genetic and phenotypic correlations between linear type traits and milk yield in Sahiwal cows. *Pakistan Journal of Agricultural Sciences* 53:483-489. <https://doi.org/10.21162/PAKJAS/16.3369>
- Kruszyński, W.; Pawlina, E. and Szewczuk, M. 2013. Genetic analysis of values, trends and relations between conformation and milk traits in Polish Holstein-Friesian cows. *Archiv Tierzucht* 56:536-546. <https://doi.org/10.7482/0003-9438-56-052>
- Liu, S.; Tan, H.; Yang, L. and Yi, J. 2014. Genetic parameter estimates for selected type traits and milk production traits of Holstein cattle in southern China. *Turkish Journal of Veterinary and Animal Sciences* 38:552-556. <https://doi.org/10.3906/vet-1107-37>
- Marinov, I.; Penev, T. and Gergovska, Z. 2015. Factors affecting linear type traits in black-and-white cows. *International Journal of Current Microbiology and Applied Sciences* 4:374-383.
- Miglior, F.; Muir, B. L. and Van Doormaal, B. J. 2005. Selection indices in Holstein cattle of various countries. *Journal of Dairy Science* 88:1255-1263. [https://doi.org/10.3168/jds.S0022-0302\(05\)72792-2](https://doi.org/10.3168/jds.S0022-0302(05)72792-2)
- Mikhchi, A.; Mashhadi, M. H. and Jafarabadi, G. A. 2013. Estimation of genetic parameters for udder type traits in the first lactation of Iranian dairy Holstein cattle. *Research Opinions in Animal and Veterinary Sciences* 3:457-461.
- Němcová, E.; Štípková, M. and Zavadilová, L. 2011. Genetic parameters for linear type traits in Czech Holstein cattle. *Czech Journal of Animal Science* 56:157-162. <https://doi.org/10.17221/1435-CJAS>
- Pantelić, V.; Nikšić, D.; Ostojić-Andrić, D.; Novaković, Ž.; Ružić-Muslić, D.; Maksimović, N. and Lazarević, M. 2012. Phenotypic and genetic correlations of milk and type traits of Holstein-Friesian bull dams. *Biotechnology in Animal Husbandry* 28:1-10. <https://doi.org/10.2298/BAH1201001P>
- Ptak, E.; Jagusiak, W.; Żarnecki, A. and Otwinowska-Mindur, A. 2011. Heritabilities and genetic correlations of lactational and daily somatic cell score with conformation traits in Polish Holstein cattle. *Czech Journal of Animal Science* 56:205-212. <https://doi.org/10.17221/1432-CJAS>
- Rabbani-Khoursangani, M.; Ansari-Mahyari, S. and Edriss, M. A. 2014. Genetic analyses of conformation traits and their relationships with reproductive traits in Holstein cows. In: *Proceedings of the 10th World Congress of Genetics Applied to Livestock Production*.
- Samoré, A. B.; Rizzi, R.; Rossoni, A. and Bagnato, A. 2010. Genetic parameters for functional longevity, type traits, somatic cell scores, milk flow and production in the Italian Brown Swiss. *Italian Journal of Animal Science* 9:e28.
- Short, T. H. and Lawlor, T. J. 1992. Genetic parameters of conformation traits, milk yield, and herd life in Holsteins. *Journal of Dairy Science* 75:1987-1998. [https://doi.org/10.3168/jds.S0022-0302\(92\)77958-2](https://doi.org/10.3168/jds.S0022-0302(92)77958-2)

- Stanojević, D.; Djedović, R.; Bogdanović, V.; Raguž, N.; Kučević, D.; Popovac, M.; Stojić, P. and Samolovac, Lj. 2018. Genetic trend of functional productive life in the population of black and white cattle in Serbia. *Genetika* 50:855-862. <https://doi.org/10.2298/GENSR1803855S>
- Susanto, A.; Suyadi; Nurgiartiningsih, V. M. A. and Hakim, L. 2018. (Co)variance components and genetics parameter estimation for linear traits in Holstein cattle in Indonesia: traits related to foot/leg and udder. *Archives Animal Breeding* 61:491-496. <https://doi.org/10.5194/aab-61-491-2018>
- Tapki, I. and Guzey, Y. Z. 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.
- Toghiani, S. 2011. Genetic parameters and correlations among linear type traits in the first lactation of Holstein Dairy cows. *African Journal of Biotechnology* 10:1507-1510.
- Vallimont, J. E.; Dechow, C. D.; Daubert, J. M.; Dekleva, M. W.; Blum, J. W.; Barlieb, C. M.; Liu, W.; Varga, G. A.; Heinrichs, A. J. and Baumrucker, C. R. 2010. Genetic parameters of feed intake, production, body weight, body condition score, and selected type traits of Holstein cows in commercial tie-stall barns. *Journal of Dairy Science* 93:4892-4901. <https://doi.org/10.3168/jds.2010-3189>
- Van der Laak, M.; Van Pelt, M. L.; de Jong, G. and Mulder, H. A. 2016. Genotype by environment interaction for production, somatic cell score, workability, and conformation traits in Dutch Holstein Friesian cows between farms with or without grazing. *Journal of Dairy Science* 99:4496-4503. <https://doi.org/10.3168/jds.2015-10555>
- Wasana, N.; Cho, G.; Park, S.; Kim, S.; Choi, J.; Park, B.; Park, C. and Do, C. 2015. Genetic relationship of productive life, production and type traits of Korean Holsteins at early lactations. *Asian-Australasian Journal of Animal Sciences* 28:1259-1265. <https://doi.org/10.5713/ajas.15.0034>
- WHFF - World Holstein Friesian Federation. 2008. Documentation. Type harmonisation. Available at: <[http://www.whff.info/documentation/documents/typetraits/TypeHarmonisation\\_2009update.pdf](http://www.whff.info/documentation/documents/typetraits/TypeHarmonisation_2009update.pdf)>. Accessed on: Apr. 11, 2020.
- Zavdilová, L. and Štípková, M. 2012. Genetic correlations between longevity and conformation traits in the Czech Holstein population. *Czech Journal of Animal Science* 57:125-136. <https://doi.org/10.17221/5566-CJAS>
- Zavdilová, L.; Příbyl, J.; Vostrý, L. and Bauer, J. 2014. Single-step genomic evaluation for linear type traits of Holstein cows in Czech Republic. *Animal Science Papers and Reports* 32:201-208.
- Zink, V.; Zavdilová, L.; Lassen, J.; Štípková, M.; Vacek, J. and 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* 59:539-547. <https://doi.org/10.17221/7793-CJAS>