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Heritability of type traits in first calving Black and White cows

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Abstract

Group of secondary traits such as health, longevity, type and milkability represents some of very important factors for successful milk production. These traits have been given great importance in recent years. In order to realize productive life of dairy cows as long and successful as possible, special attention should be directed to traits of type and body constitution.

Objective of the research was to establish heritability coefficients for 14 type traits of first calving Black and White cows, effect of genetic and paragenetic factors (bull sires, farm, year and season of calving, age at scoring and share of Holstein-Friesian [HF] genes) on type traits, so that these scores could be included in calculation of breeding value of the animal. Also, average values of milk traits have been established: milk yield and yield of 4 % fat corrected milk (FCM), content and quantity of milk fat.

Evaluation was performed on a sample of 2 976 first calving Black and White cows. Evaluated cows were reared on 7 farms of the Agricultural Corporation Belgrade in Serbia.

Analysis of discontinuous and continuous influences was done using the method of least squares. Investigation indicated that the value of linear type evaluation should be included in the total evaluation of the breeding value and in this way complete insight into genetic supremacy, especially of breeding bulls, would be obtained. Use of bull semen of proven supremacy in transmission of genes desirable from the aspect of body constitution, in the process of artificial insemination, would lead faster to production herds with animals which are uniform in type, of good conformation and longevity, which is of special significance in conditions of intensive rearing of dairy cattle.

Keywords: dairy cattle, type traits, linear score, heritability, milk traits

Zusammenfassung

Heritabilität von Körperformmerkmalen bei erstabkalbenden schwarzbunten Kühen

Ein bedeutender Faktor für eine erfolgreiche Milchproduktion ist die Gruppe der funktionellen Merkmale wie Langlebigkeit, Typ und Melkbarkeit. Um die Nutzungsdauer der Milchkühe zu verlängern, muss den Typ- und Konstitutionsmerkmalen eine besondere Aufmerksamkeit entgegengebracht werden.

Ziel dieser Untersuchung war die Feststellung der genetischen und paragenetischen Einflüsse (Bulle, Betrieb, Jahr und Saison der Kalbung, Alter beim Kalben und Anteil von Holstein-Friesian Genen) auf die 14 linear beschriebenen Typmerkmale, um diese Beurteilungen in die Schätzung der Gesamtzuchtwerte der Tiere einzubeziehen. In der Arbeit wurden auch die Heritabilitätskoeffizienten für die Typmerkmale geschätzt und durchschnittliche Milchleistungmerkmale ermittelt: Milchleistung und Milchleistung korrigiert auf 4 % Fett (FCM), Milchfettgehalt und Milchfettmenge. In die Untersuchung wurden erstkalbende Schwarzbuntkühe einbezogen, die auf 7 Rinderfarmen der Landwirtschaftlichen Korporation Belgrad, Serbien gehalten wurden.

Die Analyse von diskontinuierlichen und kontinuierlichen Einflüssen wurde mithilfe der Methode der kleinsten Quadrate durchgeführt. Die Untersuchung zeigte, dass die Werte der Linearbeurteilung der Typmerkmale in den Gesamtzuchtwerten der Tiere enthalten sein sollten, um eine vollständige Information über die genetische Veranlagung bei den Zuchtbullen zu bekommen. Mit der Einbeziehung der im Typ und Exterieur hoch veranlagten Bullen in die künstliche Besamung ist ein positiver Einfluss auf die typ- und exterieurbezogene Ausgeglichenheit der Produktionsherden schnell realisierbar, was wiederum für die Nutzungsdauer der Kühe in der intensiven Rinderzucht von Bedeutung ist.

Schlüsselwörter: Milchrind, Typmerkmale, Linearbeurteilung, Heritabilität, Milchleistungmerkmale

Introduction

Visual assessment and recognizing of dairy characteristics of cows can be a preliminary indicator of milk performance, and partially of longevity and reproductive abilities of cattle. Association of some teat and udder morphological characteristics with mastitis incidence have been studied by GULYAS and IVANCSICS (2001). Authors observed a close correlation between these traits. Such assessment is possible due to long–range monitoring and analysing of type traits, as well as forming of the system of evaluation and validation of those traits *(*PANTELIĆ *et al.* 2007). Comparison of differences of methods for analysing type traits were reported by PUSKI *at al.* (2001) and YAALAK and AKBAS (2009).

Disadvantages in type traits lead to lower production, diminished health condition and early culling of cows from the herd. Inclusion of linear type scoring as well as health and fertility traits (DISTL 2001) and disease traits (HINRICHS *at al.* 2006) into evaluation of breeding value of cows contributes to its reliability which reflects positively on total result of selection and success of production. SWALVE and HÖVER (2003) reported that differential use of sires by breeders besides production is highly influenced by type proofs although in this respect clear differences exist between regions. Traits of body composition can be considerably improved through application of certain selection measures depending on the heritability level, but in order for them to be exhibited it is necessary to provide adequate rearing conditions, housing, care and nutrition of animals.

Objective of the research was to determine heritability coefficients for following 14 type traits: stature, strength and capacity, dairy form, rump width, rump angle, rear leg set, fore udder, rear udder height, rear udder width, udder depth, suspensory ligament, udder balance, teat placement and teat length.

In addition, objective of the study was also to determine the effect of genetic and paragenetic factors (bull sires, farm, year and season of calving, age at scoring and share of Holstein-Friesian genes) on type traits of first calving cows of Black and White breed, so that these scores could be included in calculation of breeding value of the animal. Paragenetic factors include the effect of farm, year and season of calving and age at scoring. Also aim of the research was to obtain, in production conditions, relevant data on phenotypic expression and variability of major production indices: milk yield and yield of 4 % FCM, content and quantity of milk fat.

Material and methods

Study of the effect of genetic and paragenetic factors on variability and heritability of linear type trait scores of first calving cows of Black and White breed was performed on a sample consisting of 2 976 animals. Cows were reared on seven farms belonging to Agricultural Corporation Belgrade in Republic of Serbia. Scored first calving cows were daughters of 24 bull sires.

In linear scoring of type 14 traits are evaluated, of which 6 are traits of body composition and 8 are udder traits. Score range from 1 to 9 is used. Average expression of a trait is scored 5. For 4 traits: position of rump and rear legs, udder balance and teat length, this is the best score. For remaining traits it is desirable to have the highest score value (STOJIĆ *et al.* 2002).

Type traits were scored at the beginning of first lactation, between 30th and 150th day of lactation. Animals were evaluated by one person, educated and trained for this operation. Period of evaluation lasted 60 days. Percentage of HF genes in studied population of first calving cows of Black and White breed varied in range from 25 to 83 %.

Rearing facilities on the farm were of semi-closed and closed type. Cows in lactation were housed in tie system on beds of medium length. Nutrition of cows was divided into »summer« and »winter« diets. Winter diet consisted of conserved feeds, hay and silage, with addition of adequate quantities of concentrate feeds, whereas summer diet consisted of introduced green mass in combination with concentrate mixture.

Individual discontinuous (bull-sires, farm, year, season), as well as continuous (share of HF genes, service period, age at calving and scoring) influences were analysed using the method of Least Squares.

Fixed model for investigation of different effects on the variability of linear type trait score:

$$Y_{ijklm} = \mu + O_i + F_j + G_k + S_l + b_1(x_1 - \bar{X}_1) + b_2(x_2 - \bar{X}_2) + e_{ijklm} \quad (1)$$

Mixed model for investigation of variability of linear type trait score:

$$Y_{ijklm} = \mu + O_i + F_j + G_k + S_l + b_1(x_1 - \bar{X}_1) + b_2(x_2 - \bar{X}_2) + e_{ijklm} \quad (2)$$

Mixed model for investigation of the heritability of linear type trait score:

$$Y_{ijk} = \mu + O_i + S_l + b_1(x_1 - \bar{X}_1) + b_2(x_2 - \bar{X}_2) + e_{ijklm} \quad (3)$$

where Y_{ijklm} is the expression of trait in *m* cow, daughter of *i* bull-sire, on *j* farm, which calved in *k* year and *l* season, μ is the general average in equal number of repetitions per treatments, O_i is the effect of *i* bull-sire, F_j is the fixed effect of *j* farm, G_k is the fixed effect of *k* year of calving, S_l is the fixed effect of *l* season of calving, b_1 is the linear regression effect of age at scoring, days, b_2 is the linear regression effect of share of HF genes in % and e_{ijklm} is the random error.

For milk traits main variation-statistical parameters were calculated:

Arithmetic mean ($\overline{X}$)

Standard deviation (SD)

Variation coefficient (CV)

Standard average error ($S\overline{X}$)

Milk yield was corrected to 4 % FCM using Gaines-Davidson formula:

$$4\,\%\,FCM = 0{,}4\,M + 15\,F \qquad (4)$$

where *M* is the milk yield in kg, *F* is the yield of milk fat in kg.

Results

Body development and type are very important indicators of production abilities of cows, their potential to consume sufficient quantities of food, produce technologically suitable/adequate milk, reduce consumption of energy in production and remain in production as long as possible giving numerous offspring (PANTELIĆ *et al.* 2009).

Linear type trait score enables more precise evaluation as a result of better definition of certain traits, as well as estimation of the heritability level and correlation between type traits and other economically important traits.

In Table 1 least square means and their errors are presented, as well as the effect of bull-sires, farm, year and season of calving, age at scoring and share of HF genes on linear type trait scores of first calving Black and White cows.

Average scores for body development obtained in this research by method of Least Squares varied in the range from 5.29 (rear leg set) to 7.06 (dairy form). Score for rump angle was very close to desired score (5) – 5.37. Udder scores were in range from 4.91 (teat length) to 6.92 (rear udder width). Udder balance was evaluated with average score 5.05, and suspensory ligament – 6.35.

The effect of bull-sires on all evaluated traits of type was statistically highly significant ($P<0.01$), except for udder depth, whereas the effect of the farm was highly significant on all traits except udder balance where established statistical significance was at the level of $P<0.05$. Year of calving had no effect on rear leg set and expression of suspensory ligament ($P>0.05$), significant effect on teat length ($P<0.05$), and highly significant effect on remaining traits ($P<0.01$). Season of calving influenced highly significantly ($P<0.01$) scores for stature, strength and capacity, dairy form, rump width, fore udder attachment, rear udder width and udder balance; significant effect ($P<0.05$) was established on rump angle and rear udder height, and on remaining traits no statistically significant effect was registered ($P>0.05$). Age at scoring/evaluation had statistically high significant effect ($P<0.01$) on expression of traits of stature, strength and capacity, dairy form, rump width, fore udder attachment and

teat placement, and on other investigated type traits it had no statistically significant effect ($P>0.05$). Contrary to stated continuous and discontinuous factors, share of HF genes had no statistically significant ($P>0.05$) effect on any of the evaluated type traits. In addition to investigated genetic and paragenetic factors, other functional traits, such as mass at birth, mass at calving, reproduction parameters and health condition of animals, influence life productivity of cows.

Table 1
Least square means (μ) and mean errors of linear type scores of first calving cows and F-test of investigated effects.
LS Mittelwerte (μ) und Standardfehler (SE) der linear geschätzten Typmerkmale der erstkalbenden Kühe und F-test der untersuchten Einflüsse

Traits			F- test of investigated effects					
	μ	SE	Sires	Farm	Year	Season	Age	HF, %
			$df_1=23$ $df_2=2\,940$	$df_1=6$ $df_2=2\,940$	$df_1=1$ $df_2=2\,940$	$df_1=3$ $df_2=2\,940$	$df_1=1$ $df_2=2\,940$	$df_1=1$ $df_2=2\,940$
Stature	6.37	0.07	4.591**	22.868**	59.798**	20.438**	69.060**	1.295
Strength and capacity	6.74	0.06	3.131**	43.766**	38.267**	5.844**	45.384**	0.396
Dairy form	7.06	0.05	2.868**	104.91**	24.679**	6.804**	10.460**	0.318
Rump width	6.49	0.07	4.158**	51.767**	59.559**	11.157**	27.632**	0.146
Rump angle	5.37	0.05	3.123**	36.834**	8.990**	3.259*	0.320	1.627
Rear leg set	5.29	0.04	2.399**	6.806**	0.462	1.865	0.663	0.020
Fore udder	6.60	0.05	2.572**	55.586**	19.602**	11.184**	16.699**	1.325
Rear udder height	6.53	0.07	4.185**	159.00**	19.485**	3.356*	0.681	0.002
Rear udder width	6.92	0.05	2.840**	87.803**	31.077**	5.963**	1.983	1.536
Udder depth	6.57	0.03	1.480	49.487**	19.981**	1.613	1.674	0.000
Suspensory ligament	6.35	0.06	2.257**	41.032**	0.089	0.480	3.358	0.004
Udder balance	5.05	0.03	1.915**	2.251*	14.766**	5.332**	0.015	1.734
Teat placement	5.36	0.05	3.065**	14.132**	8.135**	0.472	6.846**	2.825
Teat length	4.91	0.06	4.929**	5.497**	4.835*	0.816	3.658	0.002

df degrees of freedom, *$P<0.5$, **$P<0.01$, Values without asterisk are non-significant

Heritability, as the value expressing and measuring average additive gene effect, is one of the major characteristics of quantitative traits from the aspect of creation of genetically highly valuable populations of cattle. Heritability level represents relation between variations generated by the action of genotype and total variance which includes all effects.

Heritability coefficients of linear type scores are presented in Table 2. Heritability coefficients for body composition traits were in range from 0.066 (rear leg set) to 0.310 (rump angle) and the value of the heritability coefficient for expression of dairy form was 0.293. For remaining three traits similar values of the heritability level were established (stature 0.155, strength and capacity 0.187 and rump angle 0.178).

The lowest heritability values in group of udder traits were established for following traits: udder balance (0.045) and suspensory ligament (0.097). Slightly higher heritability values were determined for traits teat placement and udder depth (0.103 and 0.167, respectively). Medium values of heritability coefficients were established for fore udder attachment (0.244), rear udder width (0.293) and teat length (0.262). The highest heritability value was

established for rear udder height – 0.441. Values of heritability errors varied in the range from 0.022 to 0.116.

Table 2
Heritability (h^2) and errors of heritability (Sh^2) of linear type scores of first calving cows
Heritabilität (h^2) und Heritabilitätsfehler (Sh^2) der linear geschätzten Typmerkmale der erstkalbenden Kühe

Traits	h^2	Sh^2
Stature	0.155	0.050
Strength and capacity	0.187	0.058
Dairy form	0.293	0.083
Rump width	0.310	0.087
Rump angle	0.178	0.056
Rear leg set	0.066	0.028
Fore udder	0.244	0.072
Rear udder height	0.441	0.116
Rear udder width	0.293	0.083
Udder depth	0.167	0.053
Suspensory ligament	0.097	0.036
Udder balance	0.045	0.022
Teat placement	0.103	0.037
Teat length	0.262	0.076

Increase of production and improvement of milk quality and fertility are main prerequisites of modern cattle production. Investigated first calving cows of Black and White breed have realized following production results presented in Table 3: average duration of lactation 343.24 days, milk yield 5 543.73 kg, milk fat content 3.68 %, milk fat yield 203.82 kg and yield of 4 % FCM 5 274.74 kg. Production of milk of first calving cows of Black and White breed was calculated per lactation.

Table 3
Mean values of milk traits of first calving Black and White cows in first lactation
Mittelwerte der Milchleistungsmerkmale der erstkalbenden Schwarzbuntkühe in der ersten Laktation

Traits	$\bar{x}$	SD	CV	$S\bar{x}$
Duration of lactation, days	343.24	66.45	19.36	1.22
Milk yield, kg	5 543.73	930.17	16.78	17.05
Fat, %	3.68	0.16	4.35	0.00
Fat, kg	203.82	35.19	17.26	0.64
4% FCM, kg	5 274.74	892.76	16.93	16.37

$\bar{x}$ arithmetic mean, SD standard deviation, CV variation coefficient, $S\bar{x}$ standard average error

Studied first calving cows of Black and White breed have not realized satisfactory production in accordance to their genetic potential because of unfavourable climatic conditions and lack of optimum conditions for maximal expression of production capacities of heads of cattle. Climatic conditions have important impact on process of food preparation and reflect on the quality and nutritional value of food, which has direct impact on production traits of cows. With adequate nutrition and housing, and implementation of selection and zoo-technical measures, level of milk production on farms of the Agricultural Corporation Belgrade would increase.

Discussion

Comparison of linear type scores with similar research papers by other authors faces certain obstacles consisting of different scoring system, different traits which are included in evaluation, as well as different breeds. Linear type scores were object of research by SMITH *et al.* (1998), VAN DORP *et al.* (1998), SMOTHERS *et al.* (1998), MONARDES *et al.* (1990), KLEI *et al.* (1998). KOENEN and GROEN (1998), reported in their research linear type scores – average values for type traits of 5.23 for body depth, 4.76 for udder depth and 4.87 for rump width. Average values of type scores for bull dams of Holstein-Friesian breed were established by PANTELIĆ *et al.* (2010): stature 7.11, strength and capacity 7.34, dairy form 7.23, rump width 6.31, rump angle 5.29, rear leg set 5.10, fore udder 6.69, rear udder height 6.95, rear udder width 7.31, udder depth 6.70, suspensory ligament 6.85, udder balance 5.17, teat placement 5.96 and teat length 5.23. Reported results are higher in relation to type scores of first calving cows obtained in this study, which confirms the statement that bull dams are elite animals in population.

There is objective possibility that in further selection measures and application of corrective mating these traits can be improved. However, adequate rearing conditions must not be neglected housing, care and nutrition of high quality are of great importance in order for full genetic potential of cows to be expressed. SWALVE and HÖVER (2003) were reported that differential use of sires by breeders besides production is highly influenced by type proofs although in this respect clear differences exist between regions.

Considering the fact that linear type trait score is based on assumption that traits being evaluated have normal distribution within the population, i.e. that there is a limited number of animals with extreme low or extreme high characteristics, it is possible to treat these traits as quantitative properties. Hence, it is possible to apply certain methodological procedures for the purpose of determining the transmission level of these traits on the progeny.

Linear evaluation is used in selection of breeding animals, and for this purpose it should be always attempted to have parent couples which mutually compensate lacks in the exterior. But, in most breeding programmes the main problem in the genetic improvement of functional traits (health, fertility, feet and leg traits and longevity) is their poor recording and also most often a recording that is only distantly related to the physiological background (SWALVE 2003).

Values of heritability of type scores in researches carried out by many authors showed high variability which depending on the breed, housing system and evaluation. Minimum value of heritability coefficient for placement of rear teats and fore udder attachment of 0.09 is stated by MONARDES *et al.* (1990). WEIGEL *et al.* (1998) established heritability values for 14 type traits in range from 0.15 (pastern angle) to 0.42 (stature). Similar values of heritability of type traits from 0.11 to 0.43 are reported by SMITH *et al.* (1998), VISSHER and GODDARD (1995), VAN DORP *et al.* (1998), as well as association Semex Deutschland (2001). GENGLER *et al.* (1997) presented data for heritability coefficient of type traits of Jersey breed in range from 0.13 for pastern angle to 0.40 stature.

Maximum heritability values for type traits are stated by PRYCE *et al.* (2000) in range from 0.16 for pastern angle to 0.59 for stature. Similar results are reported by Canadian Association of Holstein Cattle – CDN (2001) from 0.13 (pastern angle) to 0.53 (stature). TEMPELMAN and

BURNSIDE (1990) established heritability values of type traits in cows of Canadian Holstein breed in range from 0.1 for legs and hoofs to 0.29 for capacity.

One of potential causes for such different values of heritability coefficients are rearing conditions, housing and nutrition of cows on farms, i.e. applied management, through the effect on total variation of expressed traits. Different values of heritability of milk traits for Friesian cows in Egypt and Germany were investigated by TAWFIK *at al.* (2000). Heritability was less under subtropical condition (TEKERLI and KOCAK 2009). Additive genetic variance over test days was showing higher values in the middle of lactation but, phenotypic and permanent environmental variances were increased after second part of the lactation (TAKMA and AKBAS 2007). The removal of additive maternal genetic effects and covariance between direct and maternal genetic effects from the model increased estimates for heritability. Also, there is the effect of the persons performing the evaluation on total variation of the trait expression, i.e. their subjective assessment, in spite of harmonization of the score criteria.

By implementation of intensive selection, genetic variability is reduced, and therefore also the heritability is reduced. Study of the heritability coefficient is extremely important in evaluation of breeding value of domestic/farm animals, and it has significant impact on correct/proper selection of breeding method.

Investigations point out that values of linear type scores should be included in evaluation of total breeding value of animals, and in this way more complete insight into genetic superiority, especially of breeding bulls, will be obtained. Use of semen deriving from bulls which are superior in transferring of genes for desired traits of body stature in wide population will result faster in obtaining of herds of uniform type animals, of good conformation, health condition and longevity, which could be achieved by implementation in practice of the system of corrective mating.

Deficiencies in type traits lead to lower level of production, poorer health condition and premature culling of cows from the herd. Inclusion of linear type score in evaluation of breeding value of cows contributes to the reliability of the valuation of the breeding value and this reflects positively on total results of selection and success of production.

Taking into account the exterior and proper selection of the progeny we greatly reduce the possibility for transfer of negative traits which can be carried by parent couples as recessive, and can be spread very fast in the population due to mass implementation of artificial insemination.

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