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Heritabilities of and genetic and phenotypic correlations between condition score and production and conformation traits in Black-and-White cows

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The objectives of this study were to estimate the heritability (h^2) of body condition score (BCS), body conformation (type) and production traits of Black-and-White cows maintained by small farmers of Eastern Poland as well as genetic (r_G) and phenotypic (r_P) correlations between the traits mentioned. Considered were 2012 cows with completed 305-day lactation from the years 1997-1999. The h^2 estimate for BCS was 0.37. Out of 26 condition and conformation traits considered, the r_P of 17 and r_G of 13 traits appeared negative. The r_G values ranged from -0.30 (musculature) to 0.45 (udder).

KEY WORDS: body conformation / condition score / cows / heritability / production traits

The evaluation of cows' body conformation in Poland with the use of 9-point linear system has been introduced in the year 1997, while in other countries in 1983. Since then, reports have been published related to body conformation and its significance for cattle performance [Guliński and Litwińczuk 1999, Wójcik 2002]. The relations between conformation and performance or longevity seem extremely important from the practical point of view [Brotherstone 1994, Veerkamp *et al*. 1995, Guliński and Litwińczuk 1999, Wójcik 2002]. A proper body conformation affects significantly the 305-day milk yield and ease of machine milking, as well as reproduction, longevity and cows' resistance to diseases [Funk *et al*. 1991, Brotherstone 1994, Guliński and Litwińczuk 1999, Veerkamp *et al*. 1995, Wójcik 2002].

The available data indicate a wide variation in the heritability or correlation coefficients between the conformation traits and milk performance of cows as affected by the breed, utility type and country [Grabowski and Dymnicki 1974, Funk *et al*. 1991, Ducrocq 1993, Brotherstone 1994, Veerkamp and Brotherstone 1997, Guliński and Litwińczuk 1999, Koenen *et al*. 2001, Veerkamp *et al*. 2001, Wójcik 2002, Dechow *et al*. 2003]. Recently, the cows' breeding goals are focused on the increase of milk yield, under the assumption that profit would increase with increased yield per cow. Production circumstances have given rise to interest in directly reducing cost of production, and breeding objectives are moving from increasing yield to increasing economic efficiency. Individual recording of traits related to costs, such as feed intake, health and fertility is troublesome, time consuming and expensive. As the consequence, attention has to be paid to traits that can be measured more easily under field conditions and are biologically related to cost traits [Gallo *et al*. 2001]. Among those, body condition score and linear type traits system could be of value.

The aim of this study was to estimate the heritability coefficients for body condition, conformation, and selected production traits in Black-and-White dairy cows as well as to identify genetic and phenotypic correlation coefficients for these traits.

Material and methods

The traits were considered of 2012 Black-and-White cows kept in 150 small dairy farms of Eastern Poland in the years 1997-1999. Using the linear evaluation method, 28 conformation traits were scored (from 1 to 9 points) by four trained and experienced classifiers. Body condition scoring (BCS) of dry and lactating cows was carried out by the same team of classifiers, approximately at 3-month intervals, according to the system proposed by Wildman *et al*. [1982] using a scale ranging from 1 („leany") to 5 („fatty") with 0.5 point intervals. Moreover, the data on 305-days milk yield and composition of cows were withdrawn from their files of official milk recording. Analysed traits are listed in Table 1. In the linear model applied for statistical evaluation the following effects were included:

– fixed effect of classifier (1, 2, 3, 4);
– effect of per cent of Holstein-Friesian blood in genotype (≤25, 25.1-50, 50.1-75, >75);
– effect of stage of lactation (dry period, 1-100, 101-200, 201-305 days);
– effect of cow's age (<3.5, 3.5-6, >6 years);
– effect of estimation season (I – April/September, II – October/March);
– random effect of a sire.

The estimation of heritability (h^2) was based on 55 groups of sire's half-siblings of not less than 15 animals. Co(variance) component and related parametres were estimated using REML multiple-trait procedure with unequal design for different traits. For each trait the analysis was performed in matrix notation with the formula:

$$Y = Xb + Zu + e$$

where:

Y – vector of observations;
b – vector of fixed effects;
u – vector of random sire effects;
X – matrices corresponding with vectors b;
Z – matrices corresponding with vectors u.

Table 1. Means and their standard deviations for conditions score and conformation and production traits

No.	Trait	Mean	Standard deviation
1	Body depth	6.74	0.86
2	Chest width	5.52	1.12
3	Rump angle	5.43	1.02
4	Rump width	5.59	1.05
5	Rear leg rear	5.40	0.79
6	Foot angle	5.56	1.14
7	Fore udder placement	6.24	1.19
8	Fore udder attachment	5.70	0.98
9	Rear udder height	5.59	0.91
10	Udder support	6.62	1.17
11	Rear udder height	6.15	1.42
12	Udder width	5.40	1.07
13	Teat placement	4.44	0.92
14	Teat length	4.88	1.04
15	Musculature	6.70	0.88
16	Angularity	6.09	0.90
17	Capacity[1]	10.88	1.33
18	Type & conformation[2]	11.66	0.77
19	Overall feet & legs[3]	15.27	0.78
20	Mammary system[4]	39.70	2.15
21	Overall score[5]	77.43	3.56
22	Stature	3.09	1.87
23	Head	7.11	0.94
24	Loin	6.48	1.09
25	Bone quality	6.71	0.96
26	Udder texture	6.84	1.05
27	Conditions score	3.11	0.42
28	Milk yield	4701	946
29	Fat percent	4.15	0.34
30	Protein percent	2.90	0.32

[1] General type trait, scored as follows: [2] 0-15 pts., [3] 0-15 pts., [4] 0-20 pts., [5] 0-30 pts., [6] 0-100 pts.

From variation components, heritability coefficient (h^2) was estimated according to the formula:

$$h^2 = \frac{4 \times \delta_0^2}{\delta_0^2 + \delta_e^2}$$

where: δ^2_0 – variation component for sires;
δ^2_e – variation component for residual.

Genetic (r_G) and phenotypic (r_P) correlations were estimated according to the formulas:

$$r_G = \frac{cov_o}{\sqrt{\delta_{ox}^2 + \delta_{oy}^2}}$$

and

$$r_P = \frac{cov_o + cov_e}{\sqrt{(\delta_{ox}^2 + \delta_{ex}^2) \times (\delta_{oy}^2 + \delta_{ey}^2)}}$$

where :
o – random sire effects;
e – fixed effects;
x or y – traits which a given value refers to.

All computations were conducted using procedures from SAS programme package [SAS 1996].

Results and discussion

The h^2 of body condition score (BCS) in the examined 2012 cows was 0.37 (Tab. 2). In the Polish literature no data were found on BCS heritability in cows.

Veerkamp *et al*. [2001] estimated the share of genetic factors in the overall variation of body condition of Black-and-White cows in the Netherlands as 38%. According to Dechov *et al*. [2003] the h^2 for condition score of Holstein-Friesian cows in the USA amounted to 0.19 in primiparas and 0.22 in multiparas. Koenen *et al*. [2001] and Berry *et al*. [2002] reported the BSC h^2 as 0.27-0.37 and 0.24-0.38, respectively.

In the present study the h^2 of body conformation elements ranged from 0.16 (overall feet and legs) to 0.53 (rear udder height) – Table 2. Table 3 clearly indicates

Table 1. Heritabilities and genetic and phenotypic correlation coefficients for conformation traits and production and type of cows

No.	Trait	h^2	SE	Genetic correlation (rG)				Phenotypic correlation (rp)			
				milk yield	Fat %	protein %	conformation score	milk yield	Fat %	protein %	conformation score
1	Body depth	0.21	0.06	0.01	0.40	0.08	0.16	0.12	0.06	0.01	0.09
2	Chest width	0.21	0.09	0.00	0.19	-0.15	0.15	0.11	0.01	0.01	0.13
3	Rump angle	0.10	0.07	-0.19	-0.11	-0.18	-0.13	0.01	0.01	-0.01	-0.07
4	Rump width	0.21	0.11	-0.04	0.25	-0.10	-0.05	0.11	0.00	-0.01	0.05
5	Rear leg set	0.21	0.06	-0.14	-0.10	0.04	-0.05	-0.01	-0.01	-0.01	0.00
6	Foot angle	0.17	0.05	-0.11	0.04	-0.07	-0.01	-0.01	-0.01	-0.01	-0.10
7	Fore udder placement	0.11	0.08	-0.11	0.16	0.15	0.10	-0.08	0.04	0.00	0.05
8	Fore udder attachment	0.10	0.05	0.08	0.25	0.04	0.09	0.13	0.07	0.04	0.06
9	Rear udder height	0.17	0.08	0.11	0.05	0.10	0.16	0.09	0.05	0.07	-0.03
10	Udder support	0.14	0.06	0.14	0.30	0.14	0.15	0.01	0.05	0.04	-0.05
11	Rear udder height	0.31	0.07	-0.11	0.17	0.10	0.11	-0.16	0.01	0.00	-0.05
12	Udder width	0.14	0.08	0.14	0.14	-0.16	0.14	0.16	0.08	0.07	-0.01
13	Teat placement	0.19	0.05	0.13	-0.01	0.11	0.03	-0.01	0.05	0.08	0.00
14	Teat length	0.11	0.07	-0.08	-0.13	0.11	0.06	-0.01	-0.01	0.04	0.00
15	Muscularity	0.17	0.06	0.17	-0.05	0.17	-0.20	-0.01	0.01	0.01	-0.05
16	Angularity	0.19	0.07	0.14	-0.01	-0.11	-0.15	0.11	0.06	0.00	-0.07
17	Capacity	0.14	0.09	-0.13	0.24	0.18	-0.17	0.14	0.09	0.01	-0.06
18	Type & conformation	0.14	0.08	0.11	0.24	-0.17	0.17	0.19	0.10	0.00	-0.01
19	Overall fore & legs	0.16	0.05	0.10	0.19	0.09	-0.07	0.04	0.01	0.01	-0.01
20	Mammary system	0.11	0.06	0.11	0.11	0.11	0.04	0.13	0.08	0.01	0.00
21	Overall score	0.14	0.08	0.08	0.11	0.11	0.17	0.19	0.10	0.04	-0.01
22	Stature	0.14	0.09	-0.16	0.29	0.10	-0.09	0.09	0.04	0.04	-0.01
23	Head	0.19	0.07	0.13	-0.09	-0.07	-0.05	0.04	0.01	-0.01	-0.04
24	Loin	0.14	0.07	-0.01	0.11	0.17	-0.11	0.07	0.04	0.04	0.09
25	Bone quality	0.10	0.08	0.04	-0.07	-0.01	-0.07	0.01	0.08	0.08	-0.03
26	Udder texture	0.16	0.07	0.09	0.30	0.18	-0.01	0.14	0.05	0.01	-0.04
27	Conformation score	0.17	0.04	0.19	0.11	0.16	-	0.05	-0.01	0.00	-
28	Milk yield	0.25	0.06	-	-0.06	-0.13	0.19	-	0.01	-0.01	0.05
29	Protein content	0.18	0.07	-0.06	-	0.51	0.13	0.01	-	0.15	-0.01
30	Protein content	0.18	0.07	-0.13	0.28	-	0.16	-0.01	0.12	-	0.00

Table 3. Linear type trait heritability coefficients according to different evaluations

Trait	Legarra (1971)	Visscher and Bruchemüller (1997)	Van Doormaal et al. (1987)	Funk et al. (1991)	Weigel et al. (1989)	Lawlor et al. (1987)	Dürrenberger (1991)	Wilcox (2001)	This study
Overall score	0.28	0.10	0.16	0.18	–	0.11	–	–	0.11
Angularity	0.15	0.18	0.11	0.16	0.11	0.11	–	–	0.19
Capacity	0.06	–	0.11	–	–	–	–	–	0.11
Chest width	–	0.19	–	–	–	–	0.18	–	0.11
Body depth	–	0,18	–	0.11	0.11	0.15	0.19	0.18	0.11
Udder depth	0.17	0.19	0.16	0.17	0.15	0.11	0.11	–	0.11
Stature	0.16	0.30	0.18	0.11	0.17	0.13	0.11	0.31	0.11
Head	0.09	–	–	–	–	–	–	–	0.19
Rump angle	–	0.16	–	0.10	0.19	0.11	0.18	0.16	0.10
Rump width	0.10	0.11	0.10	0.11	0.11	0.17	0.16	0.11	0.11
Rear legs set	0.11	0.18	0.11	0.17	0.16	0.16	0.09	0.10	0.11
Foot angle	0.11	0.15	0.11	0.11	0.10	0.11	–	0.17	0.17
Fore udder attachment	0.19	0.19	0.16	0.11	0.18	0.13	–	–	0.10
Rear udder height	0.19	–	0.16	0.11	0.18	0.13	–	–	0.17
Udder support	0.13	0.13	0.16	–	–	0.11	–	–	0.11
Udder texture	–	–	0.09	–	–	–	–	–	0.16
Teat placement	0.11	0.16	0.11	0.11	0.11	0.18	0.16	–	0.19
Teat length	–	0.18	–	–	–	–	0.18	–	0.11

small differences to exist in h^2 estimates between this study and values reported in the literature. It should be emphasized that the highest values were reached for capacity traits. Estimates of h^2 range from 0.46 for capacity [Legates 1971] to 0.50 for stature [Veerkamp and Brotherstone 1997]. Similar h^2 were estimated by authors working on Polish dairy cattle. Grabowski and Dymnicki [1974] in their studies on 1534 Black-and-White cows reported the h^2 for 10 body dimensions to range between 0.157 and 0.406, while Wójcik [2002] gave the values ranging from 0.26 to 0.51.

The main objective of this study was to estimate the r_G and r_P between BCS and body conformation and dairy performance in cows. Results are presented in Table 2. The r_G estimates ranged from -0.30 (between BCS and musculature) to 0.45 (between BCS and mammary system).

Out of 26 conformation traits considered, as many as 13 were genetically negatively correlated with the cows´ subcutaneous fat. Pryce *et al*. [2000] found the r_G between body condition and dairy character in cows to reach 0.47. Berry *et al*. [2002] reported the highest r_G (0.50) between body condition and live weight of animals. Dechov *et al*. [2003] estimated the r_G between condition and overall conformation of cows at 0.08. They also reported a high and negative r_G (-0.73) between condition and dairy character of cows.

The r_G estimates between BCS and production traits (Tab. 2) amounted to 0.13, 0.16 and 0.19 for fat per cent, protein per cent and 305-days milk yield, respectively.

Low r_P were estimated between BCS and analysed production traits of cows (Tab. 2). The r_P values ranged from -0.02 (between BCS and fat per cent of milk) to 0.05 (between BCS and milk yield).

Veerkamp and Brotherstone [1997] reported the negative r_G between body condition and 305-days milk yield (-0.46) and both fat and protein yield (-0.33 and -0.29, respectively). Also Gallo *et al*. [2001] and Berry *et al*. [2002] in their reports on dairy cows populations in Ireland and Italy, respectively, give similar r_G between body condition and milk performance.

The r_G estimates between BCS and milk performance traits presented in this report, are higher than those reported in other studies, what is most likely related to lower mean productivity (4701 kg milk, 4.15 % fat, 2.90% protein) of the analysed population of cows.

In conclusion, the data from this study showed that condition scores are traits of medium heritability and could be used in breeding programmes for dairy cattle. Genetic relationships between measures of body condition score and type traits were low and partly negative. Therefore, selection for increase of cows type traits indexes might result in unfavourable decrease in body condition score.

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Odziedziczalność oraz korelacje genetyczne i fenotypowe między kondycją, cechami budowy a użytkowością mleczną krów rasy czarno-białej

S t r e s z c z e n i e

Celem pracy było określenie wartości współczynników odziedziczalności oraz wartości korelacji genetycznych i fenotypowych dla ocen kondycji, użytkowości mlecznej i budowy zewnętrznej czarno-białych krów mlecznych utrzymywanych w gospodarstwach wschodniej Polski. Wymienione wskaźniki oszacowano dla 2012 zwierząt będących potomstwem 55 ojców. Badania dotyczyły zwierząt, które ukończyły laktacje 305-dniowe w latach 1997-1999. Odziedziczalność (h^2) oceny kondycji wyniosła 0,37. Badania ponadto wskazały na istnienie ujemnej zależności między ocenami kondycji a cechami budowy krów. Wartości korelacji fenotypowych w 17, a genetycznych w 13 spośród 26 ocenianych cech budowy i kondycji miały wartość ujemną. Wartości korelacji genetycznych zamknęły się w granicach od -0,30 (umięśnienie) do 0,45 (wymię).