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COEFFICIENTS OF HERITABILITY FOR FATTENING AND SLAUGHTER TRAITS INCLUDED IN A MODIFIED PERFORMANCE TESTING METHOD

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Abstract

A total of 272 336 young boars and gilts representing all performance-tested breeds and lines were investigated. In accordance with performance testing methodology, animals were tested at the age of 150–210 days. Backfat and muscle thickness was measured with a Piglog 105 ultrasonic device at the P2, P4 and P4M sites. Taking into account the age and body weight of the test animals, determinations were made of daily gain standardized to 180 days of age and lean meat percentage standardized to 110 kg body weight and 180 days of age. Coefficients of heritability for performance test traits were estimated in animals sired by 2525 boars, which produced offspring with at least two sows, each sow producing at least two offspring of one sex. Analysis of the results showed that generally the lowest coefficients of heritability within each breed studied were calculated for standardized loin eye height, followed by measurements of P4 and P2 backfat thickness. This tendency was observed for both young boars and gilts within almost each breed studied. It was also found that within each of the analysed breeds and sexes, the coefficient of heritability for standardized daily gain had the highest values. In consequence selection based on this trait may ensure improvement in fattening value of animals. No significant improvements should be expected for parameters of loin, for which low heritability of loin eye height was estimated.

Key words: pigs, coefficients of heritability, fattening and slaughter traits

Breeding value of pigs is determined, among others, from performance test results. It is well known that selection yields positive results if it includes genetic parameters that accurately reflect the value of the population being improved. This requires, among other things, calculating the coefficients of heritability for traits considered in selection. In the case of selection for the index used in Poland, these traits are daily gain and lean meat percentage. With the progress in animal performance, the coefficients of heritability change and should be periodically reestimated. For performance test traits of Polish Large White (PLW) and Polish Landrace (PL) breeds, these parameters were first estimated by Płonka in 1973 and again for the same breeds by Dawidek in 1991. The coefficients of heritability for components of the selection index were last updated by Różycki et al. (1998).

In 2004, the performance test was modified to make it more accurate. A new formula for standardization of daily gain and new regression equations for estimating lean meat percentage standardized for both body weight and age were used. In addition, separate selection indices were used for maternal and paternal lines. These indices have different economic weights, directing selection of the above lines towards improvement of fattening and slaughter traits (Eckert and Szyndler-Nędza, 2009). The introduction of these changes in performance tests could affect both phenotypic and genetic variation in the active population of pigs. The objective of the present study was to estimate new coefficients of heritability, which will be used to adjust selection indices while providing a basis for estimation of breeding value using a BLUP animal model.

Material and methods

A total of 272 336 young boars and gilts from all breeds and lines performance tested in 2005–2007 were investigated. In accordance with new performance testing methodology, animals were tested at the age of 150–210 days. A Piglog 105 ultrasonic device was used to measure backfat thickness at P2 (on the back behind the last rib, 3 cm off the dorsal midline) and P4 (on the flank behind the last rib, 8 cm off the dorsal midline) and loin eye height at P4 (P4M). The following parameters were determined with regard to age and body weight of the animals tested:

– daily gain standardized to 180 days of age,

– lean meat percentage standardized to 110 kg body weight and 180 days of age.

These parameters were estimated in accordance with the methods for performance testing of breeding boars and gilts (Eckert and Szyndler-Nędza, 2009).

Genetic parameters for performance test traits were estimated in animals sired by 2525 boars, which produced offspring with at least two sows, each sow producing at least two offspring of one sex. The number of sires, dams and offspring in different breeds is shown in Tables 1 and 2. As is evident from these tables, the above conditions were fulfilled by a total of 34 317 boars and 154 527 gilts of the Polish Large White, Polish Landrace, Duroc, Pietrain and Puławska breeds. Belgian Landrace, Hampshire and Line 990 pigs were excluded from further analysis because of the small number of farms. Tables 1 and 2 also include data on the number of farms in which the animals were performance tested.

Table 1. Number of boars of different breeds that followed the hierarchical design criteria

Breed	Boars	Dams	Sires	Farms
PLW	9864	3021	710	92
PL	21709	5951	1394	188
Duroc	1541	566	203	58
Pietrain	884	382	137	43
Puławska	319	176	81	47
TOTAL	34317	10096	2525	428

Table 2. Number of gilts of different breeds that followed the hierarchical design criteria

Breed	Gilts	Dams	Sires	Farms
PLW	51108	16152	1142	242
PL	99152	28913	2145	380
Duroc	2648	1230	204	59
Pietrain	1078	364	155	44
Puławska	541	246	109	64
TOTAL	154527	46905	3755	789

The performance test results of young boars and gilts were analysed statistically for each breed separately. Means and standard deviations were estimated using SAS software. Significant differences between the means were determined based on Duncan's test.

The coefficients of heritability (h^2) for performance test traits were estimated from the sire component, separately for boars and gilts. Genetic parameters were estimated by GEN3 software using variance and covariance analysis in a hierarchical design according to the formula:

$$Y_{ijkl} = m + a_i + s_{ij} + d_{ijk} + e_{ijkl}$$

where:
Y_{ijkl} – ijklth observation,
m – population mean,
a_i – fixed effect of HYS,
s_{ij} – random effect of jth sire,
d_{ijk} – random effect of kth dam,
e_{ijkl} – error.

Results

The means and standard deviations (S) of the performance test traits of boars and gilts are given in Tables 3 and 4, which present data on maternal breeds (PLW, PL), paternal breeds (Duroc, Pietrain) and the Puławska breed, which is included in the conservation programme. Data listed in Table 3 indicate that boars of maternal and paternal lines differed considerably in standardized backfat thickness measured on the back (P2) and flank (P4). The thinnest backfat at both measurement sites was found in Pietrain boars (P2 = 8.0 mm, P4 = 8.3 mm), and the thickest in PL boars (P2 = 9.5 mm, P4 = 9.4 mm). Differences in backfat thickness between the breeds were statistically significant ($P \leq 0.01$). As regards loin eye height (P4M) and standardized daily gain, no significant differences were observed between PLW, PL and Duroc boars. The highest loin eye height was found in Pietrain boars (P4M = 58.5 mm), with a statistically significant difference in relation to the mean values for the other breeds ($P \leq 0.01$). Daily gains of Pietrain boars were the lowest (675 g) with significant differences observed between this and other breeds ($P \leq 0.01$). The largest breed differences, also in statistical terms ($P \leq 0.01$) were found for lean meat percentage. Pietrain boars were characterized by the highest value of this trait (63%).

Compared to the breeds analysed previously, Puławska boars were characterized by significantly ($P \leq 0.01$) thicker backfat measured on the back and flank (P2 = 12 mm, P4 = 11.5 mm), by far the lowest ($P \leq 0.01$) gains (643 g), and the lowest ($P \leq 0.01$) lean content (56.6%). Only loin eye height in this breed was similar to that in maternal breeds (P4M = 54.3 mm) and differed significantly ($P \leq 0.01$) only in relation to Pietrain boars.

Like in boars, analogous differences were found between the breeds of gilts for the analysed traits (Table 4). All the differences were statistically significant ($P \leq 0.01$) except loin eye height. In this group of animals, a more pronounced difference was also observed between gilts of paternal breeds (Duroc, Pietrain) and gilts of maternal breeds (PLW, PL) compared to the boars. This was reflected mainly in fatness traits (P2, P4) and lean meat percentage. Compared to the above breeds, Puławska gilts had the thickest backfast measured on the back and flank (P2 = 13.8 mm, P4 = 12.9 mm, $P \leq 0.01$), the lowest daily gains (597 g, $P \leq 0.01$) and the lowest lean content (54.9%, $P \leq 0.01$).

Tables 5 and 6 show the coefficients of heritability and errors of their estimation for the boars and gilts. Analysis of the results obtained showed that generally the lowest coefficients of heritability within each breed studied were found for standardized loin eye height, followed by P4 and P2 backfat thickness. This tendency was observed in both boars and gilts within almost each breed studied. The only exception were Pietrain boars and PL gilts, for which the coefficients of heritability for loin eye height were slightly higher than for P4 backfat thickness. In the case of heritability of backfat thickness, boars had a slight advantage over gilts. It was also found that within each analysed breed and sex, the coefficient of heritability for standardized daily gain had the highest values. The heritability of this trait ranged from $h^2 = 0.166$ (Pietrain) to $h^2 = 0.585$ (Duroc) for gilts, and from $h^2 = 0.345$ (PLW) to $h^2 = 0.578$ (Pietrain) for boars. The last parameter analysed was lean meat percentage, which reflects previously analysed traits (backfat thickness and loin eye height). In all boar and gilt breeds under analysis, the coefficients of heritability for this trait were in between the values for daily gain and other measurements.

The lowest coefficients of heritability for the analysed traits were found in Puławska animals, ranging from $h^2 = 0.013$ to $h^2 = 0.079$. For P2 backfat thickness and standardized daily gain, almost identical h^2 values were observed within both sexes analysed. For the other traits, higher coefficients were found in the group of gilts compared to boars.

Table 3. Basic characteristics (means and standard deviations) of the performance test traits of boars representing different breeds

Breed	Body weight		P2		P4		P4M		Standardized daily gain		Lean percentage	
	x	S	x	S	x	S	x	S	x	S	x	S
PLW	116.8 Da	13.8	9.2 BEHI	1.9	9.1 BEH	1.9	54.2 A	5.1	684 EF	88.7	58.9 BEHa	2.5
PL	115.5 AEb	14.9	9.5 AEFG	1.9	9.4 AEFG	1.9	54.6 B	4.9	696 CD	84.4	58.6 CFIa	2.6
Duroc	118.6 ABa	16.1	8.9 CFHJ	1.9	8.9 CFI	1.9	55.0 C	5.1	687 AB	88.7	59.5 AEFG	2.4
Pietrain	117.8 Cb	15.9	8.0 DGIJ	2.0	8.3 DGHI	2.0	58.5 ABCD	5.6	675 ACEG	99.9	63.0 ABCD	1.7
Puławska	109.4 BCDE	11.6	12.0 ABCD	2.1	11.5 ABCD	2.0	54.3 D	3.7	643 BDFG	79.7	56.6 DGHI	2.2

Means with the same capital letters differ significantly at P≤0.01.
Means with the same small capital letters differ significantly at P≤0.05.

Table 4. Basic characteristics (means and standard deviations) of the performance test traits of gilts representing different breeds

Breed	Body weight		P2		P4		P4M		Standardized daily gain		Lean percentage	
	x	S	x	S	x	S	x	S	x	S	x	S
PLW	104.7 BEH	12.6	10.6 BEHI	2.1	10.5 BEHI	2.1	53.5 Cb	5.5	630 CFI	75.4	57.2 BEHI	2.62
PL	105.5 ADG	12.3	11.0 AEFG	2.2	10.8 AEFG	2.1	53.0 DEa	5.6	633 BEH	72.6	56.7 CFHJ	2.76
Duroc	111.9 DEFa	15.5	9.4 CFHJ	2.2	9.4 CFHJ	2.2	53.8 Ba	4.6	658 ABCD	86.7	58.5 AEFG	2.4
Pietrain	116.9 ABCa	14.4	9.1 DGIJ	2.3	9.1 DGIJ	2.2	55.9 ABCD	5.8	655 AEFG	97.4	62.3 ABCD	1.5
Puławska	101.2 CFGH	12.7	13.8 ABCD	2.3	12.9 ABCD	2.3	53.8 AEb	4.5	597 DGHI	74.4	54.9 DGIJ	2.6

Means with the same capital letters differ significantly at P≤0.01.
Means with the same small capital letters differ significantly at P≤0.05.

Table 5. Coefficients of heritability (h^2) and their errors (se) estimated for boars

BOARS		P2	P4	P4M	Standardized daily gain	Lean percentage
PLW	h^2	0.196	0.153	0.050	0.345	0.224
	se	0.0082	0.0077	0.0059	0.0115	0.0092
PL	h^2	0.239	0.163	0.084	0.421	0.266
	se	0.0062	0.0056	0.0048	0.0087	0.0069
Duroc	h^2	0.343	0.313	0.240	0.472	0.453
	se	0.0219	0.0211	0.0201	0.0294	0.0266
Pietrain	h^2	0.333	0.210	0.298	0.578	0.242
	se	0.0258	0.0210	0.0253	0.0405	0.0318
Puławska	h^2	0.045	0.018	0.042	0.070	0.013
	se	0.0271	0.0238	0.0280	0.0295	0.0255

Table 6. Coefficients of heritability (h^2) and their errors (se) estimated for gilts

GILTS		P2	P4	P4M	Standardized daily gain	Lean percentage
PLW	h^2	0.124	0.117	0.045	0.298	0.097
	se	0.0042	0.0041	0.0039	0.0058	0.0044
PL	h^2	0.169	0.140	0.158	0.390	0.185
	se	0.0035	0.0034	0.0034	0.0045	0.0036
Duroc	h^2	0.310	0.297	0.166	0.585	0.303
	se	0.0197	0.0196	0.0198	0.0258	0.0204
Pietrain	h^2	0.118	0.086	0.029	0.166	0.124
	se	0.0230	0.0225	0.0219	0.0260	0.0296
Puławska	h^2	0.036	0.072	0.076	0.079	0.032
	se	0.0157	0.0163	0.0165	0.184	0.0168

Discussion

As expected, the analysed young boars and gilts of maternal, paternal and conservation breeds showed typical mean values of performance test traits. The results obtained were similar to the results obtained by these breeds subjected to standard performance testing in 2008 (Eckert and Szyndler-Nędza, 2009; Eckert and Żak, 2009). The considerable differences between muscularity and fatness of gilt and boar carcasses are confirmed by the results of studies comparing the fatness of boars and gilts measured on live animals (Szyndler-Nędza and Mucha, 2004) and postmortem (Szyndler-Nędza and Eckert, 2008). These authors demonstrated that compared to boars, gilts are characterized by significantly thicker backfat and lower lean meat percentage.

Analysis of the estimated coefficients of heritability between the breeds within individual traits shows that the h^2 parameters obtained were higher for the boars of paternal than maternal breeds. An analogical relationship was reported by Zumbach et al. (2007), who obtained much higher coefficients of heritability for backfat thickness and loin eye height in purebred Duroc pigs compared to Duroc crosses with Large White and Landrace breeds.

Such a conclusive statement cannot be made for gilts because Pietrain gilts obtained much lower coefficients of heritability compared to PLW and PL gilts. It should be noted, however, that the parameters estimated for the Pietrain breed were burdened with very large errors. In an extreme case, the error of estimation for loin eye height almost equalled that of h^2 value for this trait. Both the low h^2 values and their high errors for the gilts of this breed resulted from the small number of animals (Table 2), which is the main factor determining the accuracy of estimating parameters of this type. The errors calculated for the maternal lines were low and less than 5% and 1% of the values of corresponding heritability coefficients for boars and gilts, respectively. As the number of animals included in the calculations decreased, the estimation errors increased considerably (sire lines) among both gilts and boars. These observations are confirmed when analysing the coefficients of heritability for the Puławska breeds, where very low h^2 values, burdened with a larger error, were estimated for a group of 319 boars and 514 gilts.

The coefficients of heritability estimated in the present study were similar to the findings of Różycki et al. (1998), who reported heritability of $h^2 = 0.174$ for daily gain and $h^2 = 0.431$ for lean meat percentage. For performance test traits of different breeds, Tänavots et al. (2002) obtained slightly higher heritabilities for backfat thickness ($h^2 = 0.55–0.77$) and lean meat percentage ($h^2 = 0.49–0.73$) and lower heritabilities for loin eye area ($h^2 = 0.16–0.34$). Based on ultrasonic measurements, Lo et al. (1992) for Duroc and Landrace, Cai et al. (2008) for Yorkshire, and Gilbert et al. (2007) for Large White pigs also obtained high values of this parameter for backfat thickness and loin eye area. They were $h^2 = 0.54$, $h^2 = 0.68$ and $h^2 = 0.63$ for backfat thickness and $h^2 = 0.46$ and $h^2 = 0.57$ (Lo et al., 1992; Cai et al., 2008) for loin eye area, respectively. In addition, Gilbert et al. (2007) estimated the coefficient of heritability for daily gains of boars to be $h^2 = 0.35$, which was identical to that obtained in our study for PLW boars.

Similar heritabilities for backfat thickness as in our study were reported based on postmortem measurements by Newcom et al. (2002), Gilbert et al. (2007) and Wijk et al. (2005). For loin eye area, Serenius et al. (2004) and Wijk et al. (2005) obtained low coefficients of heritability ($h^2 = 0.13$), which is consistent with the tendency, also observed in our study, for low values of this parameter for the trait characterizing *longissimus dorsi* muscle (P4M).

In conclusion, the highest coefficients of heritability were observed for standardized daily gains. In consequence selection based on this trait may ensure improvement in fattening value of animals. No significant improvements should be expected for parameters of loin, for which low heritability of loin eye height was estimated.

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Współczynniki odziedziczalności dla cech tucznych i rzeźnych uwzględnionych w zmodyfikowanej metodzie oceny przyżyciowej

STRESZCZENIE

Badaniami objęto łącznie 272 336 młodych knurków i loszek wszystkich ras i linii, które były oceniane przyżyciowo. Zwierzęta zgodnie z założeniami metodyki oceny przyżyciowej oceniane były w wieku 150–210 dni. Dokonano na nich pomiarów grubości słoniny i mięśnia aparatem ultradźwiękowym Piglog 105 w punktach: P2, P4, P4M. Następnie uwzględniając wiek i masę ciała osobników poddanych ocenie określono przyrost dzienny standaryzowany na 180. dzień życia i procentową zawartość mięsa

w tuszy, standaryzowaną na masę ciała 110 kg oraz na 180. dzień życia. Do oszacowania współczynników odziedziczalności dla cech uwzględnionych w ocenie przyżyciowej zostały wybrane zwierzęta po 2525 ojcach, które dały potomstwo przynajmniej z dwiema lochami, a każda z tych loch dała co najmniej dwie sztuki potomstwa jednej płci. Analiza uzyskanych wyników wykazała, że generalnie w obrębie każdej z uwzględnionych w badaniach ras najniższe wartości wskaźników odziedziczalności obliczono dla standaryzowanej wysokości „oka" polędwicy. Następne w kolejności pod względem wielkości tego wskaźnika były pomiary grubości słoniny w punkcie P4 i w punkcie P2. Taką tendencję obserwowano niemal w obrębie każdej z badanych ras zarówno dla knurków, jak i loszek. Stwierdzono także, że w obrębie każdej z analizowanych ras i płci najwyższe wartości przyjmował współczynnik odziedziczalności dla standaryzowanego przyrostu dziennego. W związku z tym, selekcja prowadzona w oparciu o tę cechę może gwarantować poprawę wartości tucznej zwierząt. Nie należy natomiast oczekiwać znacznych efektów w poprawie parametrów polędwicy, dla której oszacowana odziedziczalność wysokości „oka" jest niska.