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ANALYSIS OF GENETIC PARAMETERS OF REPRODUCTIVE TRAITS IN CONSERVED BREED SOWS RAISED IN POLAND*

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Abstract

The aim of the study was to estimate the genetic parameters for reproductive performance in native breed sows covered by genetic resource conservation programmes in Poland. The study used data on reproductive performance of 1,182 Złotnicka White sows, 1,648 Złotnicka Spotted sows and 1,180 Puławska sows. The following traits were analysed: age at first farrowing, number of piglets born alive, number of piglets at 21 days of age and farrowing interval. Covariance components and genetic parameters were estimated using an REML animal model with different combinations of fixed and random effects. Convergence of the iterative process was achieved by the selection of the AIREML algorithm. The estimated values of the coefficients of heritability for the number of piglets born ranged from $h^2 = 0.09$ in the Puławska breed to $h^2 = 0.30$ in the Złotnicka White breed. For the number of piglets reared, they varied between $h^2 = 0.09$ in the Złotnicka Spotted breed to $h^2 = 0.27$ in the Puławska breed. The heritability values for age at first farrowing and farrowing interval were higher, and ranged from 0.4 to 0.5. The significant positive and negative coefficients of phenotypic correlation, estimated between age at first farrowing and farrowing interval with the number of piglets born alive and reared per litter, suggest that the native pig breeds should be bred in keeping with their breed predispositions.

Key words: correlations, heritability, native pig breeds, number of piglets per litter

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The breeding of Złotnicka White, Złotnicka Spotted and Puławska pigs, which are part of a genetic conservation programme, is aimed at preserving their genetic distinctiveness. All three pig breeds native to Poland are characterised by good prolificacy, good mothering ability, as well as several breed-specific traits (Szyndler-Nędza et al., 2020), including a high quality of meat suitable for making valuable cured meat products (Florowski et al., 2006; Grześkowiak et al., 2009). However, traits related to reproductive performance are an essential characteristic of these breeds. In addition to being economically important, they allow for selective breeding of endangered breeds. A major concern in selective breeding of these breeds is the maintenance of adequate herd size and the risk of increased inbreeding in small breeding herds. The reasons include difficulties in the exchange of genetic material and a lack of interest in artificial insemination from the breeders of these breeds and from sow A.I. stations, which find it unprofitable to keep native breed boars. This phenomenon was also highlighted by Paixao et al. (2018), who studied the Portuguese Bisaro native breed.

The level of inbreeding in each of these breeds is monitored annually as part of the conservation programme. In the period 2011–2019, the inbreeding level averaged 4.9% in the Puławska and Złotnicka White breeds, and 3.9% in the Złotnicka Spotted breed (Szyndler-Nędza et al., 2020). Of concern is the considerable proportion of Puławska animals whose inbreeding exceeded 0.125 (4.37% of the studied population). In the Złotnicka White and Złotnicka Spotted breeds, the proportion of animals in this inbreeding group was even higher: 5.04% and 5.22%, respectively. The many years of breeding of these breeds, coupled with a considerable inbreeding level, may cause changes in genetic variation (Vicente et al., 2008) and thus reduce the values of reproductive traits in pigs (Bereskin et al., 1970). To date, the realised genetic progress for reproductive traits (number of piglets born and reared, weight of piglets born, sow longevity) has been very slow due to very low heritability of these traits (Su et al., 2007; Distl, 2007; Damgaard et al., 2003; Canario et al., 2010; Bergsma et al., 2008; Serenius and Stadler, 2004). It is one of the goals of the conservation programmes to maintain – and even improve – the traits related to reproductive performance in native pig breeds. In Poland, heritability values for reproductive traits were estimated mainly for high-producing pigs (Tyra and Różycki, 2004). The values of these parameters have received no study in Polish native breeds. The aim of the study was to analyse the genetic parameters of reproductive traits in native breeds of pigs raised in Poland, which could be used in breeding programmes.

Material and methods

This study did not require the approval of the Ethics Committee. The study used reproductive performance records of Złotnicka White and Puławska pigs (collected from 2010 to 2015) and Złotnicka Spotted pigs (collected from 2006 to 2015). Databases were compiled based on the results collected by the Poznań University of Life Sciences (Złotnicka breeds) and the Polish Pig Breeders and Producers Association

POLSUS (Puławska breed). The obtained databases were filtered for pedigree correctness and for minimum and maximum values of the analysed traits. The animal pedigrees were complete and included four generations. The coefficient of inbreeding was around 4% for all the breeds (Szyndler-Nędza et al., 2018). The following traits were analysed: age at first farrowing, number of piglets born alive, number of piglets at 21 days of age, and farrowing interval. To estimate genetic parameters for these traits, data were extracted from the databases for pigs from houses in which after each boar of the Złotnicka White, Złotnicka Spotted and Puławska breeds the reproductive capacity of at least 5 gilts (daughters) was assessed. The number of herds and the number of sires and dams of the tested offspring (sows) – which served as a basis for further calculations – are presented according to breed in Table 1. The above criterion was met by 1,182 Puławska sows, 1,180 Złotnicka White sows and 1,648 Złotnicka Spotted sows. These sows provided information about 3,983 Puławska litters, 3,778 Złotnicka White litters and 7,689 Złotnicka Spotted litters.

Table 1. Number of herds, sires, dams, sows and litters

Breed	Herds	Sires	Dams	Sows	Litters
Złotnicka White	38	53	414	1,180	3,778
Złotnicka Spotted	62	67	478	1,648	7,689
Puławska	54	93	472	1,182	3,983

The calculations were performed separately for each breed. The components (co) variance and genetic parameters were estimated using the REML method for the animal model taking into account different combination of fixed and random effects. Convergence of the iterative process was achieved by the selection of the AIREML algorithm. To estimate genetic parameters for their individual use in breeding programmes of each of these breeds, the two models below were used; the components of the model were chosen based on the effects estimated from analysis of variance (ANOVA):

For the traits age at first farrowing:

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

where:

Y_{ijkl} – ijklth observation,
m – population mean,
a_i – fixed effect of year,
b_j – fixed effect of herd,
s_{ijk} – random effect of kth sire,
d_{ijkl} – random effect of lth dam,
e_{ijkl} – error.

For the traits number of piglets born, number of piglets reared to 21 days and farrowing interval:

$$Y_{ijklm} = m + a_i + b_j + c_k + s_{ijkl} + d_{ijklm} + e_{ijklm}$$

where:

Y_{ijklm} – ijklmth observation,
m – population mean,
a_i – fixed effect of year,
b_j – fixed effect of herd,
c_k – fixed effect of kth parity order,
s_{ijkl} – random effect of lth sire,
d_{ijklm} – random effect of mth dam,
e_{ijklm} – error.

The genetic parameters were calculated using the DFREML package (Karin Meyer, v. 3.0) and statistical analyses were performed using the STATISTICA 12 package (StatSoft Polska).

Results

The means and standard errors for the analysed traits of reproductive performance of the sows are shown in Table 2. The results differ among the breeds; Złotnicka Spotted sows took the longest, and Puławska sows took the shortest time to produce their first litters. For the length of farrowing interval, the Złotnicka White and Złotnicka Spotted breeds showed a similar value, which was higher than for the Puławska breed. When analysing the number of piglets born per litter and reared to 21 days, it was found that Puławska sows produced and reared the greatest number of piglets, and Złotnicka Spotted sows the smallest number of piglets. Intermediate values were observed in the Złotnicka White breed.

Among the estimated coefficients of heritability (h^2) (Table 3), the highest values were noted for age at first farrowing and mean farrowing interval for all the breeds. The lowest h^2 values were estimated for the mean number of piglets born in the Puławska breed and the mean number of piglets reared to 21 days in the Złotnicka Spotted breed.

Phenotypic correlations (r_p) among the traits for the three breeds are shown in Table 4. In all the breeds, as expected, the highest significant positive correlations were obtained between the number of piglets born per litter and the number of piglets reared per litter to 21 days. Moreover, significant positive correlations were estimated in the Złotnicka White breed between age at first farrowing with farrowing interval and number of piglets born alive per litter. In both Złotnicka breeds, a negative correlation was estimated between farrowing interval and the number of piglets born and reared to 21 days. In the Puławska breed, the correlations between age at first farrowing and the number of piglets born and reared assumed negative values, and those between farrowing interval and the number of piglets born and reared were significantly positive.

Table 2. Effect of sire, dam, herd, year and parity order on traits of reproductive performance in the Złotnicka White, Złotnicka Spotted and Puławska breeds. Basic statistical parameters for the analysed traits

	N	mean	se	min	max	R2	P-value				
							sire	dam	herd	year	parity order
Złotnicka White											
Age (days)	1,180	394.9	2.95	258	893	0.76	ns	**	**	ns	-
Interval (days)	763	219.4	3.12	116	878	0.76	ns	ns	**	ns	**
Piglets (head)	1,180	9.29	0.06	2	16	0.64	**	ns	**	ns	ns
Piglets21 (head)	1,180	8.43	0.06	1	14	0.63	*	ns	**	ns	**
Złotnicka Spotted											
Age (days)	1,648	432.00	2.90	263	865	0.70	**	**	**	**	-
Interval (days)	1,343	219.7	2.00	119	766	0.66	ns	**	**	**	*
Piglets (head)	1,648	8.79	0.04	1	22	0.59	ns	ns	**	ns	**
Piglets21 (head)	1,648	7.83	0.04	1	15	0.51	ns	ns	**	ns	**
Puławska											
Age (days)	1,182	352.9	1.18	267	809	0.68	*	**	**	ns	-
Interval (days)	805	189.2	1.20	112	447	0.70	ns	ns	ns	ns	*
Piglets (head)	1,182	10.53	0.05	2	15	0.73	ns	ns	**	**	ns
Piglets21 (head)	1,182	9.62	0.04	2	13	0.75	ns	**	**	**	ns

Age: age at first farrowing, Interval: farrowing interval, Piglets: number of piglets born per litter, Piglets21: number of piglets at 21 days. R^2 – coefficient of determination, *statistically significant at P≤0.05, **statistically significant at P≤0.01.

Table 3. Coefficients of heritability (h^2) for reproductive traits of the native breed sows

Trait	Złotnicka White	Złotnicka Spotted	Puławska
Age at first farrowing (days)	0.39	0.48	0.52
Farrowing interval (days)	0.49	0.50	0.50
Number of piglets born (head)	0.30	0.18	0.09
Number of piglets at 21 days (head)	0.16	0.09	0.27

Table 4. Phenotypic correlations (r_p) among reproductive traits of the three studied breeds

Trait × trait	Złotnicka White	Złotnicka Spotted	Puławska
Age × Interval	0.204*	–0.033	–0.134*
Age × Piglets	0.074*	–0.048	–0.072*
Age × Piglets21	0.006	–0.027	–0.079*
Interval × Piglets	–0.124*	–0.163*	0.293*
Interval × Piglets21	–0.149*	–0.190*	0.302*
Piglets × Piglets21	0.794*	0.684*	0.807*

Age: age at first farrowing, Interval: farrowing interval, Piglets: number of piglets born per litter, Piglets21: number of piglets at 21 days, *statistically significant at P≤0.05.

Table 5 shows only genetic correlations (r_g) for which the estimation error was lower than the estimated coefficient of correlation. Statistically significant correlations were found between the number of piglets born and the number of piglets at 21 days of age in all the native breeds under analysis.

Table 5. Genetic correlations (r_g) among reproductive traits of the three studied breeds

Trait × trait	Złotnicka White	Złotnicka Spotted	Puławska
Piglets × Piglets21	0.833*	0.293*	0.938*

Piglets: number of piglets born per litter, Piglets21: number of piglets at 21 days, *statistically significant at P≤0.05.

Discussion

Reproductive performance of sows depends, among other things, on breed, age, health status, diet and housing system. Other important factors include intensity of use, diligent stockmanship, and rearing method. All of these factors influence farrowing frequency, or the number of litters and piglets per sow per year. The observed differences in reproductive performance of the Złotnicka White, Złotnicka Spotted and Puławska sows are specific to these breeds. In contradistinction to the Złotnicka breeds, Puławska is an early maturing breed and therefore Puławska sows produce their first litter much earlier than Złotnicka sows. The results obtained for the studied breeds are consistent with those obtained for the pedigree populations of these breeds (Szyndler-Nędza et al., 2020). As expected, the results for the number of piglets born and reared per litter in native breed sows were lower than the results obtained from the sows of the two domestic maternal breeds – the Polish Large White and Polish Landrace (Mucha, 2019).

In all the breeds, medium coefficients of heritability were estimated for age at first farrowing and farrowing interval. These traits, notably the farrowing interval, are dependent on the sow's predispositions but also on the breeder's decisions. In Polish breeding, local breeds included in conservation programmes are not intensely used. In 2016, sows produced, on average, from 1.4 litter (Złotnicka Spotted) to 1.6 litter (Puławska and Złotnicka White) (Szyndler-Nędza, 2018), with farrowing intervals ranging widely depending mostly on the farm. The observed high phenotypic variation of this trait (Table 2) likely had an effect on the heritability coefficients of this trait, which could have been slightly overestimated. It is expected – based on the results obtained – that breeding progress for these traits can be accelerated with the appropriate intensity of sow use. Similar findings were reported for a local Portuguese breed by Paixao et al. (2019), who also estimated a high coefficient of heritability for the age at first farrowing ($h^2 = 0.349$). However, they obtained a distinctly lower coefficient for the farrowing interval ($h^2 = 0.002$). In a study with commercial crossbred pigs, Punya Kumari and Sreenivasa Rao (2010) estimated the heritability coefficients for these two traits to be $h^2 = 0.11 – 0.14$. In a study with intensively used Polish maternal breeds, Sobczyńska et al. (2013) reported the h^2 value

for a different trait related strictly to the farrowing interval, namely the number of litters per year, to be very low at around 0.1.

When analysing h^2 for the number of piglets per litter, we found the highest values for the number of piglets born in the Złotnicka White breed, and for the number of piglets at 21 days in the Puławska breed. Intermediate and lowest coefficients of heritability were estimated for the number of piglets born per litter in the Złotnicka Spotted and Puławska breeds, respectively, and for the number of piglets reared to 21 days in the Złotnicka White and Złotnicka Spotted breeds, respectively. The intermediate h^2 values obtained for these traits were at a similar level to the values estimated for the Polish Large White breed ($h^2 = 0.14$) by Tyra and Różycki (2004). In turn, the lowest coefficients of heritability were in line with the h^2 values estimated for the South African White breed (Dube et al., 2012), which for the number of piglets born per litter and reared to 21 days were $h^2 = 0.07$ and $h^2 = 0.03$, respectively. Paixao et al. (2019) estimated even lower values of these coefficients for the small population of Bisaro pigs, namely $h^2 = 0.014$ and $h^2 = 0.010$, respectively.

For all the breeds, the high and significant phenotypic and genetic correlations between the number of piglets born alive per litter and the number of piglets at 21 days are supported by the study of Dube et al. (2012) with Large White pigs ($r_p = 0.64$ and $r_g = 0.88$, respectively). Similar relationships between these traits were also obtained by Paixao et al. (2019) for Bisaro pigs ($r_p = 0.623$ and $r_g = 0.974$, respectively) and, in the case of genetic correlations, by Popovac et al. (2012) for commercial breed pigs (around 0.7).

Analysis of the relationships (phenotypic correlations) between age at first farrowing and number of piglets born and reared per litter led us to conclude that the estimated positive coefficients of correlation suggest that the later age at first farrowing is associated with the greater number of piglets born alive in the Złotnicka White breed, and with the smaller number of piglets born and reared in the Puławska breed. These differences may be specific to these breeds. Złotnicka White and Spotted are late-maturing breeds, whilst Puławska is an early maturing breed. Therefore, the later first mating in the Złotnicka breeds probably coincides with the reproductive readiness of the sow and contributes to the number of piglets born, while Puławska sows are ready to breed earlier and it is not recommended to delay the first mating. Le Cozler et al. (1998) demonstrated that increasing the age at first farrowing from 317 to 404 days increases the number of piglets born and weaned. Likewise, Tummaruk et al. (2007) showed that older gilts (mated between 181 and 200 days of age) produced more piglets, which agrees with our results for the Złotnicka White breed. Saito et al. (2011) reported that sows mated at a later age had the smallest total number of piglets born. Babot et al. (2003) showed that the optimum age at first mating for gilts is 221–240 days when these sows produce the greatest total number of piglets. It should be added that in addition to age, the other factors affecting successful first mating of the gilts include appropriate body weight and backfat thickness, the optimum values of which vary from breed to breed (Joab, 2019).

In the case of farrowing interval, negative coefficients of correlation were found in the two Złotnicka breeds and positive coefficients in the Puławska breed. Their

significant values indicate that increasing the farrowing interval is associated with a smaller number of piglets born and reared to 21 days in both Złotnicka breeds, and with a greater number in the Puławska breed. In our study, length of the farrowing interval was dependent mainly on lactation length (generally 28–35 days in native breeds) and the number of unproductive days of sow, due to repeated ovulation in the period between weaning and successful mating, or pregnancy loss. The differences observed between the Złotnicka breeds and the Puławska breed may result from different approaches to breeding. On most farms, breeders keep Złotnicka sows up to 878 days despite unsuccessful matings, while such Puławska sows are eliminated from the herd and the maximum farrowing interval for this breed is 414 days. The results obtained for the Złotnicka breeds are reflected in the studies of Hoshino and Koketsu (2008) and Tummaruk et al. (2010), who showed that sows with an extended period between weaning and conception produce fewer live piglets than sows mated 3–6 days after weaning. Extension of this period may be related to the short duration of oestrus and shorter interval between the onset of oestrus and ovulation (Weitze et al., 1994; Kemp and Soede, 1996). One of the consequences is an increased risk that the sow will not be fertilised at the optimum time. This may be the main cause for the smaller number of piglets born in the Złotnicka breeds. In the Puławska breed, shortening the farrowing interval may be one of the reasons for the reduced number of piglets born per litter, which has been observed in recent years (Szyndler-Nędza, 2020).

Conclusions

In summary, it may be stated that the estimated coefficients of heritability for the number of piglets born ranged from $h^2 = 0.09$ in the Puławska breed to $h^2 = 0.30$ in the Złotnicka White breed. For the number of piglets reared, they varied between $h^2 = 0.09$ in the Złotnicka Spotted breed and $h^2 = 0.27$ in the Puławska breed. The heritability values for age at first farrowing and farrowing interval were higher and had values in the range of 0.4–0.5. The high and statistically significant phenotypic and genetic correlations estimated for the number of piglets born and reared are indicative that they could be used in breeding programmes for genetically conserved breeds. Significant positive coefficients of phenotypic correlation were also obtained between age at first farrowing and the number of piglets born alive per litter in the Złotnicka White breed. Both Złotnicka breeds showed a negative correlation between farrowing interval and the number of piglets born and reared to 21 days. In the Puławska breed, the phenotypic correlations between age at first farrowing and farrowing interval with the number of piglets born and reared assumed significant negative values. The obtained genetic parameters vary with breed, which would indicate that the breeds have different predispositions.

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