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THE SHARE OF VARIANCE COMPONENTS AND CORRELATIONS BETWEEN SOW PRODUCTION TRAITS IN DIFFERENT TREATMENTS OF THE LITTER SIZE (THE REPEATABILITY AND MULTI-TRAIT MODELS)*

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Summary: *The share of variance components and correlations between the most important sow production traits (namely duration of fattening - DF, backfat thickness - BF and number of liveborn piglets - NBA) included in the pig breeding selection programme of the Republic of Serbia were estimated in this paper. The litter size at repeated farrowings (NBA1, ..., NBA6) was treated as a separate trait (the multi-trait model), whereas the litter size at birth was treated as a trait repeated a number of times (the repeatability model)). The estimation of dispersion parameters was performed using the Restricted Maximum Likelihood (REML) method. The heritability of DF accounted for 23.5%, i.e. 23.3% depending on the model used, whereas BF accounted for 40.4% in both cases. The heritability of the litter size in consecutive farrowings (the multi-trait model) were in intervals ranging between 0.104 (NBA1) and 0.136 (NBA5). The heritability of NBA in the repeatability treatment accounted for 0.106, whereas the common litter environment and the permanent sow influence contributed to the total variability with 1.1% and 5.6%, respectively. Genetic correlations between the traits examined were not determined, with the exception of consecutive farrowings in the multi-trait treatment of the litter size. The genetic correlations recorded in this case proved positive and complete, with the exception of the correlation between the first and subsequent farrowings (farrowings 3 to 6) and the correlation between the second and the last farrowings (farrowings 5 and 6), which proved very strong.*

Key words: *pigs, genetic parameters, traits of performance test, litter size, multi trait model, repeatability model*

INTRODUCTION

The estimation of breeding value in sows and their objective ranking are prerequisites for proper formation of parent pairs in selection and breeding programmes. This leads to maximising the effects of selection as breeding females transfer half of their hereditary basis onto their offspring. In many breeding and selection programmes, pig

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breeds are divided into the so-called prolific and meat type breeds or lines, resulting in different production traits on which the selection of sows is based.

Under such circumstances, it is necessary to raise more breeds in order to achieve the established breeding goals. This often entails complicated and time-consuming crossing schemes. Neglecting certain groups of traits in the selection of females can lessen the overall effects of selection. Modern approaches to selection include all groups of sow production traits in aggregate genotypes (Kovač et al., 1999).

Fertility traits are low heritable traits, the improvement of which is hindered by selection. They can be subjected to a negative maternal effect, whereas some of them (namely the litter size) can be measured only in breeding females and only after the first farrowing, affecting the length of the generation interval. In the process of crossing between different pig breeds, the heterosis effect is expressed to the highest degree in those traits which can affect the accuracy of the analysis of variance components and the estimation of breeding value. In addition, an undesirable correlation between the litter size and some slaughter traits (namely backfat thickness) is fairly common. Some fertility traits are manifested a number of times during the production life of breeding females (litter size at birth and weaning, periods from weaning until breeding/mating and insemination). This can cause a dilemma whether such traits should be regarded as traits occurring a number of times during the production life (the repeatability model) or as separate traits (the multi-trait model). Notwithstanding the limitations stated above, fertility traits are included in sow aggregate genotypes in many breeding and selection programmes (Radojković et al., 2012).

The application of mixed models for estimating the breeding value (BLUP-AM) enables successful surpassing of a majority of the restrictions stated above. The use of the relationship matrix enables the evaluation of breeding values for the litter size on the basis of the fertility of relatives and those animals that did not farrow, or for fattening and slaughter traits for those animals that were not included in the performance test. The genotype effect enables the correction of the possible heterosis effect. The possibility of including some effects into a model, which are known to be able to provoke variations of the traits, can maximise the accuracy of breeding value estimates (Merks, 2000).

The purpose of this paper is to estimate the variance components and correlations of the most important production traits included in the pig breeding and selection programme of the Republic of Serbia when the litter size at repeated farrowings is treated as a separate trait (the multi-trait model) and the litter size at birth is treated as a trait repeated many times (the repeatability model).

MATERIAL AND METHODS

The data included in the analysis were obtained from the data base of an industrial pig farm in the Republic of Serbia. The results of the performance test in gilts include a seven-year period and refer only to purebred animals (Swedish Landrace - SL and Large White - LW), whereas the data on fertility refer to a fifteen-year period and encompass the fertility results of purebred sows and reciprocal crossbreds of the aforementioned breeds (SL×LW, GJ×LW). The production data bases encompassed 38,201 animals, out of which 5,471 animals had records only of the performance test, and 26,250 animals had the data pertinent to the realized fertility. A total of 117,680 litters were analysed, i.e. 3.59 litters per sow on average.

Pedigree files contained the data on a total of 49,851 animals, out of which 65.65% were animals with the production data, whereas 34.35% represented the data of ancestors. Only somewhat more than 5% of the total number of animals in the pedigree files did not have a known origin. The pedigree files were kept for three generations.

The duration of fattening (DF) was considered an indicator of the genetic potential for growth in gilts, whereas the average backfat thickness was considered an indicator of meatiness, i.e. the median value of three backfat measurements (BF). Fertility was estimated on the basis of the number of liveborn piglets in the litter, i.e. the litter size at farrowing (NBA).

As the purpose of this study is to determine the parameters of dispersion and correlation of the traits studied in different treatments of the litter size (when the litter size at repeated farrowings (NBA1, ..., NBA6) is treated as a separate trait (the multi-trait model) and the litter size at birth is treated as a trait repeated a number of times (the repeatability model)), it was necessary to prepare the data bases in different manners. Therefore, two bases with production results were prepared. In the data base in which the litter size at repeated farrowings was treated as a separate trait, the sixth and remaining farrowings were grouped into one class due to possible problems regarding the size and complexity of the model so that the first six farrowings were actually analysed. In the second data base (where the litter size was treated as a trait repeated a number of times), the third and remaining farrowings were also grouped into the same class so that the order of farrowing had three levels.

Calculations of dispersion parameters were performed using the Restricted Maximum Likelihood method (REML) and the VCE-6 program (Groeneveld et al., 2010). The models used for estimating the variance components of all the traits studied in the case when the litter size at repeated farrowings was treated as a separate trait (the multi-trait model) in the matrix form can be expressed in the following way:

$$y = \mathbf{X}\beta + \mathbf{Z}_l\mathbf{l} + \mathbf{Z}_a\mathbf{a} + \mathbf{e}$$

where

y – is the vector of observation for DF, BF, NBA1 (first farrowing), NBA2, NBA3, NBA4, NBA5 and NBA6 (sixth farrowing),

β - vector of unknown parameters for systematic part of model,

l - vector of unknown parameters for the effect of common litter environment,

a - vector of unknown parameters for direct additive genetic effect – breeding value,

e - vector of residual (error),

X – matrix of events for systematic effects,

$\mathbf{Z}_l$ – matrix of events for common litter environment,

$\mathbf{Z}_a$ – matrix of events for direct additive genetic effect – breeding value.

With regard to the evaluation of variance components when the litter size at farrowing was treated as a trait repeated a number of times during the production life of breeding females (repeatability), a permanent effect of the environment on the litter (**Z***p* – matrix of events for a permanent effect of the environment) was also included in the model.

RESULTS

The estimation of dispersion parameters of the traits studied in two cases was performed when the litter size (NBA) at repeated farrowings was treated as a separate trait (the multi-trait model) and as a trait repeated a number of times during the production life of breeding females (the repeatability model). The share of the individual components of variance in the phenotypic variance of the traits analysed when the multi-trait model for NBA was applied is shown in Table 1.

Table 1. The share of the individual components of variance in the phenotypic variance of the duration of fattening (DF), the backfat thickness (BF) and litter size (NBA – the multi-trait model)

Trait	h^2	l^2	e^2
DF	0.235 ± 0.0042	0.1389 ± 0.0067	0.626 ± 0.0068
BF	0.404 ± 0.0050	0.0901 ± 0.0071	0.506 ± 0.0072
NBA1	0.104 ± 0.0051	0.0089 ± 0.0072	0.887 ± 0.0082
NBA2	0.131 ± 0.0052	0.0008 ± 0.0010	0.867 ± 0.0052
NBA3	0.111 ± 0.0043	0.0015 ± 0.0004	0.887 ± 0.0043
NBA4	0.119 ± 0.0047	0.0009 ± 0.0014	0.879 ± 0.0049
NBA5	0.136 ± 0.0042	0.0010 ± 0.0006	0.863 ± 0.0041
NBA6	0.131 ± 0.0037	0.0029 ± 0.0009	0.866 ± 0.0036

h^2 - heritability, l^2 - the share of the common litter environment variance, e^2 - the share of the residual variance

The heritability of the duration of fattening accounted for 23.5%, whereas the share of the mutual litter environment variance in the phenotypic variance accounted for 13.89%, leading to a total of 37.4% variability in this trait. The heritability of the backfat thickness was higher and accounted for 0.404%, whereas the variance of mutual litter environment accounted for 9.01% of the total variability of this trait (which, in addition to the direct additive genetic variance, accounted for 49.4% of the total variability). The heritability of the litter size in the first six farrowings was, as expected, low and ranged from 10.4% for the first litter up to 13.6 % for the fifth (and did not increase equally with repeated farrowings). The variance of the mutual litter environment accounted for 0.08% in the second farrowing and up to 0.89% in the first farrowing of the total variability of the litter size. The share of the remainder trait variance in the total variability of the litter size was fairly even and ranged from 86.3% in the fifth up to 88.7% in the first and third farrowing, which suggests that, regardless of the order of farrowing, the additive genetic variance and the variance of mutual litter environment account for a small part of the total variability altogether.

Special attention in this paper was devoted to the genetic correlation between the traits examined, which is presented in Table 2.

Table 2. Genetic (above diagonal) and phenotypic (below the diagonal) correlation between the properties analyzed – the multi-trait treatment of the litter size

Trait	DF	BF	NBA1	NBA2	NBA3	NBA4	NBA5	NBA6
DF		-0.016 (0.0410)[1]	-0.039 (0.1261)	-0.063 (0.1520)	-0.054 (0.1368)	-0.085 (0.3422)	0.115 (0.1559)	0.189 (0.1061)
BF	-0.0995		-0.032 (0.0655)	-0.070 (0.2618)	-0.010 (0.1002)	0.115 (0.1461)	0.089 (0.1630)	0.033 (0.1301)
NBA1	-0.0244	0.0033		0.922 (0.1264)	0.864 (0.3278)	0.797 (0.0310)	0.718 (0.3625)	0.756 (0.2813)
NBA2	-0.0642	-0.0082	0.1850		0.972 (0.2849)	0.912 (0.2838)	0.830 (0.3485)	0.833 (0.1675)
NBA3	-0.0395	0.0113	0.1674	0.2130		0.974 (0.3781)	0.917 (0.0690)	0.903 (0.1886)
NBA4	-0.0208	0.0284	0.1432	0.2007	0.2060		0.976 (0.3044)	0.959 (0.4579)
NBA5	0.0493	0.0424	0.1205	0.1777	0.1996	0.212		0.991 (0.3171)
NBA6	0.0454	0.0089	0.1255	0.1505	0.1928	0.216	0.2223	

[1] - The brackets show the correlation coefficient errors (where available)

There were virtually no correlations between the duration of fattening and other traits, neither at a genetic nor at a phenotypic level. Nevertheless, it is noteworthy that a negative correlation would be desirable between the duration of fattening and the litter size, whereas such correlation would be undesirable between the duration of fattening and the backfat thickness. However, the extent of errors in these parameters suggests their (un)reliability and use(lessness) in analysis. Similar results were recorded in the correlation between the backfat thickness and the remaining traits. The correlation between the litter size at repeated farrowings was, as expected, positive and in most cases complete, with the exception of the correlation between the first and subsequent farrowings (farrowings 3 to 6) and the correlation between the second and the last farrowings (farrowings 5 and 6), which proved very strong. In most cases, the phenotypic correlation was not determined or it was very weak between all the traits.

The dispersion parameters of the traits studied in the case when the litter size (NBA) at repeated farrowings was treated as a trait repeated a number of times (the repeatability model) during the production life of breeding females. Table 3 shows the share of the individual components of variance in the phenotypic variance in the repeatability treatment of the litter size.

Table 3. The share of the individual components of variance in the phenotypic variance of the duration of fattening (DF), the backfat thickness (BF) and the litter size (NBA – the repeatability model)

Trait	h^2	l^2	p^2	e^2
DF	0,233 ± 0,0163	0,140 ± 0,0063	-	0,627 ± 0,0151
BF	0,404 ± 0,0053	0,089 ± 0,0074	-	0,507 ± 0,0060
NBA	0,106 ± 0,0038	0,011 ± 0,0020	0,065 ± 0,0033	0,817 ± 0,0036

h^2 - heritability, l^2 - the share of the common litter environment variance, p^2 - the share of the permanent effect of the sow environment variance, e^2 - the share of the residual variance

The heritability of the litter size when it was treated as a trait repeated a number of times (the repeatability model) accounted for 10.6%. The share of the variance of the mutual litter environment in the phenotypic variance was 1.1%, whereas the share of the variance of the permanent environment of pigs in the phenotypic variance accounted for 6.5%, which caused a decrease in the share of the variance of the remainder traits in the phenotypic variance in the case when the litter size at individual farrowings was treated as a separate trait.

Table 4. Genetic (above diagonal) and phenotypic (below diagonal) correlation between the traits analyzed – the repeatability treatment of the litter size

Trait	DF	BF	NBA
DF		-0,022 ± 0,0436	-0,078 ± 0,0264
BF	-0,100		0,053 ± 0,0243
NBA	0,002	0,03	

The relationship, at both genetic and phenotypic levels, between the traits examined when the repeatability model of the litter size was applied is shown in Table 4. There were no genetic and phenotypic correlations between the traits examined.

DISCUSSION

The heritability of the duration of fattening values obtained in our study is within the limits of those reported elsewhere in the literature, although they differ considerably. Skorupski et al. (1996) reported the values of this parameter between 0.09 and 0.46, whereas Chen et al. (2003) obtained the values between 0.36 and 0.43 in different breeds. A somewhat lower heritability of 20% was reported by Vincek et al. (2004). The share of the variance of the mutual litter environment in the phenotypic variance in this paper was lower than in other studies (Skorupski et al., 1996; Vincek et al., 2004).

Similar results were obtained in this study relative to the heritability of backfat thickness. Skorupski et al. (1996) reported the values of this parameter between 0.12 and 0.77, whereas Cluter and Brascamp (1998) stated that the heritability of this trait was mostly about 0.50, which is in accordance with the values obtained by Chen et al. (2003) from 0.47 to 0.50 depending on the genotype. Malovrh et al. (1999) reported heritabilities ranging from 0.14 to 0.35 in different breeds, which is consistent with the results of Vincek et al. (2004). The share of the variance of the mutual litter environment in the phenotypic variance in this study is close to the value for the Large White breed reported by Malovrh et al. (1999), wheras the values were much higher in other breeds (Skorupski et al., 1996; Vincek et al., 2004).

The heritability of the litter size at farrowing is mostly low and accounts for about 10%, although different values can be found in the literature. When litter size at birth in repeated farrowings was treated as a separate trait then the heritability values increased from the first to the subsequent farrowings. Thus Sadek (1994) determined an increase in the heritability from the first to the sixth farrowing, whereas the value of this parameter in our study increased up to the fifth farrowing (although this increase was not even). Costa et al. (2016) reported that the NBA heritability increased in the second farrowing (4.71% vs. 11.46%), whereas in the third farrowing it was 6.49%. When the litter size at farrowing was treated as a trait repeated a number of times in the course of the animal production life, the determined heritability was close to the lower limit of the interval determined for the litter size in the first six farrowings. In such case, the additive genetic component of variance accounted for 10.06% of the phenotypic variance, whereas the shares of the variance of the mutual litter environment and the permanent environment of pigs accounted for 1.1% and 6.5%, respectively. These results are in accordance with the results obtained by Costa et al. (2016), who reported the NBA heritability in the repeatability model of 7.01%, whereas the permanent effect of sow accounted for 11.92% of the NBA variability. Similar relationships between the components of variance of this trait were reported by Logar (2000) and Urankar et al. (2004). Somewhat different values were presented by Crump et al. (1997), who reported a heritability of 9% and that the mutual environment in the litter accounted for 2% of the total variability, whereas the permanent environment of pigs accounted for 8% of the total variability.

The genetic correlation between the duration of fattening and the backfat thickness recorded was practically not established and proved undesirable from the selection perspective. Similar results relative to such negative correlation were reported by Arango et al. (2005), although the value of the correlation coefficient was considerably higher (0.22). Moreover, Skorupski et al. (1996) and Vincek et al. (2004) found positive correlations between these traits in intervals ranging between 0.32 and 0.40, depending on the genotype, and 0.02 to 0.19, depending on the population.

In addition, there was no genetic correlation between the traits of the performance test conducted and the litter size regardless of the litter size treatment. The only difference was observed in the correlation coefficients obtained, which in the case of the multi-trait treatment of the litter size were negative (relative to the correlation between both

traits of the performance test and the litter size in the first four farrowings (DF), i.e. first three farrowings (BF)), turning positive in later farrowings. In the repeatability treatment of the litter size, the correlation with the test duration was negative, whereas the correlation with the backfat thickness was positive (an undesirable outcome), which is approximately in accordance with the results reported by Chen et al. (2003) (the only difference was noted in the correlation coefficients between BF and NBA ranging from 0.183 to 0.201). Skorupski et al. (1996) stated a greater number of references suggesting a lack of correlation between the production and reproductive traits, whereas Arango et al. (2005) argued a positive correlation of the litter size at farrowing with the duration of fattening and the backfat thickness in intervals ranging between 0.08 and 0.05, respectively. Holm et al. (2004) determined a median negative correlation between the duration of fattening and the litter size in the first (0.60) and second farrowing (0.42), whereas the correlation between the backfat thickness and the litter size in this research was not determined.
As expected, the genetic correlation between repeated farrowings was complete: the weakest relationship was found between the first and subsequent (third and other) farrowings, as well as the second and subsequent (fifth and sixth) farrowings. Similar results regarding the genetic correlation of repeated farrowings were obtained by Sadek (1994) and Luković et al. (2004) as well.
The results obtained in this research indicate that the breeding value of gilts can be successfully estimated using the multi-trait animal model, in which the aggregate genotype would include the duration of fattening, the backfat thickness and the litter size at birth. On the basis of the determined genetic correlation between the litter size at repeated farrowings and the lack of correlation between the litter size and the performance test traits, the application of the model in which the litter size is treated as a trait repeated a number of times during the production life of breeding females (the repeatability model) seems to be completely justified.

CONCLUSION

The heritability values of the traits analyzed ranged within the limits of the literature references. In the variation of the duration of fattening recorded, the additive genetic component of variance accounted for 23.5%, i.e. 23.3% depending on the models applied, whereas this share accounted for 40.4% in both cases relative to the variation of the backfat thickness recorded. The contribution of the mutual litter environment to the total variability of these traits was somewhat lower than the values often reported in the literature.
The heritability values of the litter size at repeated farrowings, when treated as a separate trait (the multi-trait model), ranged from 0.104 in the first farrowing to 0.136 in the fifth farrowing, which is within the limits of the most often reported values in the literature. In this litter size treatment, the share of the mutual litter environment varied within fairly wide limits from 0.08% to 0.89%, which is most likely attributable to the displacement of piglets and the extended scope of the procedure at different farrowings. The heritability of the litter size, when treated as a trait repeated a number of times during the production life (the repeatability treatment), was 0.106, whereas the mutual litter environment and the permanent environment of pigs contributed to the total variability with 1.1% and 5.6 %, respectively.
The genetic correlation between the traits studied was not determined, with the exception of the genetic correlation between repeated litters in the multi-trait treatment of the litter size. Such correlations were found positive and complete, with the exception of the correlation between the first and subsequent farrowings (farrowings 3 to 6) and the second and the last farrowings (farrowings 5 and 6), which proved very strong.
The breeding value of gilts can be successfully estimated using the multi-trait animal model, in which the aggregate genotype includes the duration of fattening, the backfat thickness and the litter size at farrowing. On the basis of the determined genetic correlation between the litter size at repeated farrowings and the lack of correlation between the litter size and the performance test traits, the application of the model in which the litter size is treated as a trait repeated a number of times during the production life of breeding females (the repeatability model) seems to be completely justified.

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UDEO KOMPONENTI VARIJANSE I POVEZANOST PROIZVODNIH OSOBINA KRMAČA PRI RAZLIČITOM TRETMANU VELIČINE LEGLA (REPEATABILITY I MULTI TRAIT)

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Izvod: U ovom radu ocenjen je udeo komponenti varijanse i povezanost najvažnijih proizvodnih osobina (trajanje tova - DF, debljina leđne slanine - BF i broj živorođene prasadi - NBA) koje su uključene u selekcijski program u svinjarstvu Republike Srbije, kada bi se veličine legla pri uzastopnim prašenjima tretirale kao posebne osobine (multi trait) ili kada bi se veličina legla pri rođenju tretirala kao osobina koja se više puta ponavlja (repeatability). Izračunavanje parametara disperzije izvršeno je metodom ograničene najveće verovatnoće.

Heritabilitet DF iznosio je 23,5% odnosno 23,3% u zavisnosti od primenjivanih modela, dok je za BF iznosio 40,4% u oba slučaja. Naslednost veličine legla u uzastopnim prašenjima (multi trait model) se kretala u intervalu od 0,104 (NBA1) do 0,136 (NBA5). Heritabilitet NBA pri repeatability tretmanu iznosio je 0,106 dok su zajednička okolina u leglu i permanentno okruženje svinje doprinele ukupnoj varijabilnosti sa 1,1% odnosno 5,6%. Genetska povezanost između posmatranih osobina nije utvrđena osim između uzastopnih legala pri multi trait tretmanu veličine legla. Genetske korelacije su tada bile pozitivne i potpune osim povezanosti prvog i kasnijih prašenja (od trećeg do šestog) i drugog i poslednjih prašenja (petog i šestog) kada su bile u kategoriji vrlo jake.

Ključne reči: svinje, genetski parametri, osobine performans testa, veličina legla, multi trait model, repeatability model

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