Genetic parameters including the service sire effect for the sow traits stillbirth and piglet losses in Czech Large White and Landrace

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ABSTRACT: Genetic parameters including the proportion of variance for the service sire effect were estimated for number of piglets stillborn (including piglets died until 24 h after birth) and number of piglets died from 24 h after birth until weaning in Czech Large White (89 231 litters) and Czech Landrace (28 320 litters) pigs. Both traits were considered to be traits of the sow. Two two-trait animal models were evaluated for each breed including or excluding the service sire effect. Estimates of genetic parameters were very similar for the two models. The heritability for number of stillborn piglets was 0.06 in both breeds and both models and the heritability for number of piglets died until weaning was 0.07 in Czech Large White and 0.05 to 0.06 in Czech Landrace. The proportion of variance due to service sire was very low (between 0.8 and 1.6%). Therefore, there is no need to include the service sire effect in models for genetic evaluation. A selection against farrowing losses is recommended though only a slow improvement of the trait can be expected. Selecting against piglets died until weaning seems to be cumbersome. Probably a selection on number of piglets weaned could be helpful in minimizing piglet losses until weaning.

Keywords: pig; reproduction

The consequent application of the animal model on selection for litter size since the end of the 1990's has increased the genetic potential of Czech Large White or Czech Landrace sows by approximately 2 or 2.5 live born piglets per litter since 2000 to 2010. For taking full advantage of increasing litter size it is important to minimize piglet losses, i.e. both the number of stillborn piglets and piglets died until weaning. For a possible inclusion of these traits in the genetic evaluation program, factors influencing these traits have to be identified and knowledge on the genetic parameters is needed. Alternatively to piglet losses, traits describing piglet survival may be considered.

Piglet losses or piglet survival traits generally are lowly heritable (Stalder et al., 1998; Holm et al., 2004; Su et al., 2007). Therefore attempts should be made to include all important factors in the models for variance component and breeding value estimation. One of these factors may be the service sire.

The study of Wolf et al. (2008) is to our knowledge the only study which published heritability estimates for piglet losses for a Czech dam breed. However, this study was restricted to the hyperprolific line of Czech Large White analyzing only 2900 litters and did not consider the effect of the service sire. The objective of the present paper was therefore to estimate genetic parameters for stillborn piglets and piglets died until weaning on very large data sets of Czech Large White and Czech Landrace sows with special consideration of the service sire effect.

MATERIAL AND METHODS

Data

Litter size data were available from Czech Large White and Czech Landrace sows farrowing be-

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tween 1995 and 2008. The number of stillborn piglets including piglets died until 24 h after birth and the number of piglets died from 24 h after birth until weaning were analyzed as sow traits. There was no cross-fostering.

For data to be retained for analysis, the following conditions had to be met: litters were purebred Czech Large White or Landrace and had complete information on all litter size traits. Gestation length was in the interval from 105 to 125 days. The minimum sow age at first farrowing was 300 days. Parities greater than 12 were not considered. The age of the sow for parities 1–12 had to be in the following intervals (in days): 300–500, 450–750, 600–950, 750–1150, 900–1350, 1050–1550, 1200–1750, 1350–1950, 1500–2150, 1650–2350, 1800–2550, and 1950–2750. The total number of piglets born was between 4 and 22. The number of piglets that died from 24 h after birth until weaning and the number of stillborn piglets was not greater than the mean plus three standard deviations of the corresponding trait (see Table 1 for means and standard deviations). The farrowing interval was between 130 and 300 days. The service sire was known.

A flexible allocation of records to herd-year-season classes was applied as first described in Wolf et al. (2005) and adapted for litter size traits in Wolf and Wolfová (2012). Herd-year-season classes preferably were formed according to natural seasons (spring, summer, autumn, winter) on the basis of the farrowing date and normally had a length of three months. The minimum total number of records for each herd-year-season class was 20.

After applying all restrictions and forming herd-year-season classes, 91% of Large White sows and 88% of Landrace sows remained in the final data sets, with 85% and 80% of the original litter size records, respectively.

Summary statistics for the data sets of both breeds are given in Table 1. The data set for Large White was about three times as large as the data set for Landrace.

Statistical analyses

All calculations were carried out separately for each breed. For each trait, records in different parities were treated as repeated observations for the same trait. Two-trait models were applied for the joint analysis of number of stillborn piglets and number of piglets died until weaning. The basic

Table 1. Summary statistics for piglet losses for Czech Large White and Landrace breeds

Variable	Large White	Landrace
Number		
Sows	27 717	9 891
Sires/dams of sows	1 962/12 721	965/4 544
Service sires	2 447	1 280
Sires/dams of service sires	847/1 588	409/781
Litters	89 231	28 320
Average number of litters per sow	3.22	2.86
Average number of litters per service sire	36.47	22.13
Herds	101	45
Contemporary groups	2 599	952
Mean (standard deviation)		
Number of piglets born (piglets)	11.98 (2.704)	12.21 (2.819)
Number of piglets born alive (piglets)	11.24 (2.461)	11.43 (2.562)
Number of piglets weaned (piglets)	10.07 (2.017)	10.18 (2.021)
Number of stillborn piglets (piglets)	0.74 (1.078)	0.78 (1.081)
Piglets died until weaning (piglets)	1.16 (1.455)	1.25 (1.480)
Age at first farrowing (day)	374 (38.2)	368 (36.1)
Farrowing interval (day)	164 (24.8)	167 (25.6)

model equation (if animals were ordered within traits) was as follows:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \mathbf{X}_1 & 0 \\ 0 & \mathbf{X}_2 \end{bmatrix}\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} \mathbf{H}_1 & 0 \\ 0 & \mathbf{H}_2 \end{bmatrix}\begin{bmatrix} h_1 \\ h_2 \end{bmatrix} + \begin{bmatrix} \mathbf{Z}_{a_1} & 0 \\ 0 & \mathbf{Z}_{a_2} \end{bmatrix}\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} \mathbf{Z}_{s_1} & 0 \\ 0 & \mathbf{Z}_{s_2} \end{bmatrix}\begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} \mathbf{W}_1 & 0 \\ 0 & \mathbf{W}_2 \end{bmatrix}\begin{bmatrix} p_1 \\ p_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} \quad (1)$$

where:

y_i = vector of observations for trait i
b_1, b_2 = vectors of fixed effects
h_1, h_2 = vectors of random herd-year-season effects
a_1, a_2 = vectors of additive genetic effects of the sow
s_1, s_2 = vectors of random service sire effects
p_1, p_2 = vectors of random permanent environmental effects of the sow
e_1, e_2 = vectors of residual effects
$\mathbf{X}_1, \mathbf{X}_2, \mathbf{H}_1, \mathbf{H}_2, \mathbf{Z}_{a_1}, \mathbf{Z}_{a_2}, \mathbf{Z}_{s1}, \mathbf{Z}_{s_2}, \mathbf{W}_1, \mathbf{W}_2$ = corresponding incidence matrices

Throughout Eq. (1), index 1 referred to stillborn piglets and index 2 referred to piglets died until weaning.

The vector of fixed effects contained the effect of mating type (natural service or artificial insemination), the effect of parity number and quadratic regression on age at first farrowing (first parity) or the preceding farrowing interval (later parities). The vector of fixed effects also contained a class variable of total number of piglets born for the trait stillborn piglets and a class variable of number of piglets born alive for the trait piglets died until weaning. The following classes were formed for the number of piglets born: ≤ 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 to 19 and ≥ 20 for Czech Large White and ≤ 8, 9 to 10, 11, 12, 13, 14, 15, 16 to 17, 18 to 19 and ≥ 20 for Czech Landrace. The classes for the number of piglets born alive were equal for both breeds: ≤ 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 and ≥ 19.

The following covariance matrices were assumed for the random variables in Eq. (1):

$$\mathbf{var}\begin{bmatrix} h_1 \\ h_2 \end{bmatrix} = \mathbf{I}\otimes\begin{bmatrix} \sigma^2_{h_1} & \sigma_{h_{12}} \\ \sigma_{h_{12}} & \sigma^2_{h_2} \end{bmatrix}, \mathbf{var}\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \mathbf{A}\otimes\begin{bmatrix} \sigma^2_{a_1} & \sigma_{a_{12}} \\ \sigma_{a_{12}} & \sigma^2_{a_2} \end{bmatrix}$$
$$\mathbf{var}\begin{bmatrix} s_1 \\ s_2 \end{bmatrix} = \mathbf{I}\otimes\begin{bmatrix} \sigma^2_{s_1} & \sigma_{s_{12}} \\ \sigma_{s_{12}} & \sigma^2_{s_2} \end{bmatrix}, \mathbf{var}\begin{bmatrix} p_1 \\ p_2 \end{bmatrix} = \mathbf{I}\otimes\begin{bmatrix} \sigma^2_{p_1} & \sigma_{p_{12}} \\ \sigma_{p_{12}} & \sigma^2_{p_2} \end{bmatrix} \quad (2)$$

where:

$\sigma^2_{h_i}$ = variance of trait i for herd-year-season
$\sigma^2_{a_i}$ = variance of trait i for additive genetic effect
$\sigma^2_{s_i}$ = variance components for the service sire
$\sigma^2_{p_i}$ = variance of trait i for permanent effect of the sow
$\sigma_{h_{12}}, \sigma_{a_{12}}, \sigma_{s_{12}}, \sigma_{p_{12}}$ = appropriate covariances between both traits
i = 1, 2
I = identity matrix
A = relationship matrix between animals

In Eq. (2), index 1 referred to stillborn piglets and index 2 referred to piglets died until weaning.

For comparison, model (1) was also used without the effect of the service sire. Pedigrees were traced back to approximately 1985. Variances and covariances were estimated using restricted maximum likelihood (REML) and optimization by a quasi Newton algorithm with analytical gradients (Neumaier and Groeneveld, 1998) as implemented in VCE 6.0 program (Groeneveld et al., 2008). The PEST program (Groeneveld et al., 1990) was used to estimate best linear estimates for some fixed effects (parity class, litter size class).

RESULTS

Estimates of genetic parameters for piglet losses are presented in Tables 2 and 3 for Czech Large White and Czech Landrace, respectively. The results were very similar for the model with and the model without service sire effect. Heritability estimates for both traits were in the range from 0.05 to 0.07 for both models and both breeds. Two percent of the total variance in piglets died until weaning was caused by permanent environmental effects of the sow, whereas the permanent environmental effect accounted for only 1% (Czech Large White) and 0.3% (Czech Landrace) of the total variance in the number of stillborn piglets. The herd-year-season effect was relatively substantial, accounting for 6 to 9% of the total variance.

Both for number of stillborn piglets and number of piglets died until weaning, the proportion of variance for service sire was 0.010 or less in Czech Large White. In Landrace, these proportions were 0.012 for the number of stillborn piglets and 0.016 for piglets died until weaning. The very high proportion of residual variance in both traits indicates that all random factors in the model explained only 14 to 18% of the total variance.

A positive additive genetic correlation (0.25 to 0.30) was estimated between the number of stillborn piglets and the number of piglets died until weaning, and the permanent environmental correlation between these traits was greater than the

Table 2. Estimates of genetic parameters (± their standard errors) for piglet losses in the Czech Large White breed

Genetic parameter	Model with service sire	Model without service sire
Number of stillborn piglets		
Residual variance	0.77 ± 0.038	0.77 ± 0.039
Heritability	0.06 ± 0.004	0.06 ± 0.004
Proportion of variance for service sire	0.010 ± 0.001	–
Proportion of variance for permanent effect	0.01 ± 0.003	0.01 ± 0.003
Proportion of variance for herd-year-season	0.07 ± 0.002	0.08 ± 0.003
Proportion of residual variance	0.85 ± 0.004	0.85 ± 0.004
Number of piglets died from 24 h after birth until weaning		
Residual variance	1.06 ± 0.055	1.07 ± 0.048
Heritability	0.07 ± 0.004	0.07 ± 0.004
Proportion of variance for service sire	0.008 ± 0.001	–
Proportion of variance for permanent effect	0.02 ± 0.003	0.02 ± 0.004
Proportion of variance for herd-year-season	0.08 ± 0.003	0.08 ± 0.003
Proportion of residual variance	0.83 ± 0.003	0.83 ± 0.004
Correlations between both traits		
Additive genetic correlation	0.29 ± 0.046	0.30 ± 0.047
Correlation caused by permanent effect	0.42 ± 0.120	0.40 ± 0.153
Correlation caused by herd-year-season	–0.27 ± 0.029	–0.24 ± 0.029
Residual correlation	0.04 ± 0.004	0.04 ± 0.004

Table 3. Estimates of genetic parameters (± their standard errors) for piglet losses in the Czech Landrace breed

Genetic parameter	Model with service sire	Model without service sire
Number of stillborn piglets		
Residual variance	0.79 ± 0.068	0.79 ± 0.065
Heritability	0.06 ± 0.005	0.06 ± 0.005
Proportion of variance for service sire	0.012 ± 0.002	–
Proportion of variance for permanent effect	0.003 ± 0.002	0.002 ± 0.003
Proportion of variance for herd-year-season	0.06 ± 0.004	0.07 ± 0.005
Proportion of residual variance	0.86 ± 0.006	0.86 ± 0.006
Number of piglets died from 24 h after birth until weaning		
Residual variance	1.00 ± 0.092	1.01 ± 0.087
Heritability	0.05 ± 0.007	0.06 ± 0.007
Proportion of variance for service sire	0.016 ± 0.002	–
Proportion of variance for permanent effect	0.02 ± 0.007	0.02 ± 0.006
Proportion of variance for herd-year-season	0.09 ± 0.006	0.09 ± 0.006
Proportion of residual variance	0.82 ± 0.007	0.83 ± 0.007
Correlations between both traits		
Additive genetic correlation	0.25 ± 0.069	0.27 ± 0.072
Correlation caused by permanent effect	1.00 ± 0.001	1.00 ± 0.001
Correlation caused by herd-year-season	–0.13 ± 0.048	–0.10 ± 0.051
Residual correlation	0.02 ± 0.007	0.03 ± 0.007

Table 4. Best linear estimates of parity class effects on number of stillborn piglets and number of piglets died until weaning. All effects were set to zero for parity class 1

Parity	Number of stillborn piglets		Number of piglets died until weaning	
	Czech Large White	Czech Landrace	Czech Large White	Czech Landrace
1	0.00	0.00	0.00	0.00
2	–0.05	–0.11	–0.09	–0.17
3	–0.01	–0.07	–0.02	–0.13
4	0.03	–0.02	0.07	0.00
5	0.08	0.06	0.14	0.10
6	0.18	0.17	0.22	0.13
7–8	0.25	0.18	0.29	0.20
≥ 9	0.36	0.20	0.39	0.36

genetic correlation (approximately 0.40 in Czech Large White and 1.00 in Czech Landrace). Because the proportion of variance in number of stillborn piglets for the permanent effect was very low, the extremely high genetic correlation in Czech Landrace may have been caused by numerical problems of the solving algorithm. The correlations between the two herd-year-season effects were consistently negative (–0.24 to –0.27 in Czech Large White and –0.10 to –0.13 in Czech Landrace). The magnitude of residual correlations was negligible.

In addition to the numbers of stillborn piglets and piglets died until weaning, the percentages of stillborn piglets and piglets died until weaning were analysed, too. Because the results for these two traits were very similar to the results for the traits based upon numbers of piglets, they are not presented.

The impact of parity class on the number of stillborn piglets and on piglets died until weaning is summarized in Table 4. The number of stillborn piglets and piglets died until weaning was the lowest in the 2nd and 3rd parity. For parities greater than 2, the values of both traits increased with the parity number. The highest losses occurred therefore for parities ≥ 9.

Table 5. Best linear estimates of effects for classes of number born on the number of stillborn piglets and of effects for classes of number born alive on the number of piglets died until weaning. The effects for the classes with less than 8 piglets born or born alive were set to zero

Number of stillborn piglets				Number of piglets died until weaning		
Large White		Landrace		number born alive	estimate	
number born	estimate	number born	estimate		Large White	Landrace
≤ 8	0.00	≤ 8	0.00	≤ 8	0.00	0.00
9	0.10	9–10	0.15	9	0.26	0.22
10	0.17	–	–	10	0.43	0.40
11	0.32	11	0.37	11	0.76	0.74
12	0.45	12	0.51	12	1.11	1.07
13	0.68	13	0.74	13	1.53	1.50
14	0.88	14	0.91	14	2.04	1.99
15	1.14	15	1.17	15	2.68	2.52
16	1.38	16–17	1.56	16	3.23	3.16
17	1.68	–	–	17	3.85	3.84
18–19	2.06	18–19	2.01	18	4.64	4.42
≥ 20	3.01	≥ 20	2.84	≥ 19	5.68	5.41

Table 6. Heritability estimates presented in literature for the number of stillborn piglets and equivalent traits (percentage of piglets stillborn, farrowing survival of piglets). Traits different from the number of piglets stillborn are indicated in the Remarks column

Authors	Heritability	Remarks
Hanenberg et al. (2001)	0.02 0.05	first parity (*n* = 58 194) parities 2–6 (*n* = 144 205)
Holm et al. (2004)	0.04	Landrace, first parity (*n* = 6718)
Serenius et al. (2004)	0.12, 0.11	Landrace, number or percentage of stillborn piglets, first parity (*n* = 11 329)
	0.05, 0.05	Large White, number or percentage of stillborn piglets, first parity (*n* = 8362)
Arango et al. (2005)	0.09, 0.10, 0.11	first, second, and third litter (*n* = 46 629, 36 410, and 26 408), threshold model
Su et al. (2007)	0.13, 0.10	survival rate at birth for Landrace (*n* = 9300) and Yorkshire (*n* = 6861)
Kapell et al. (2009)	0.03, 0.07	sire line (*n* = 4713), dam line (*n* = 14 836), percentage of stillborn piglets
Chen et al. (2010)	0.05, 0.05 0.07, 0.08	animal model, first and later litters random regression model, first and later litters (*n* = 6575 and 6259 for the first parity and parities 2–5)

The number of piglets born had a large influence on the number of stillborn piglets (Table 5). The number of stillborn piglets increased with number of piglets born. Whereas for a litter size of 12 there were only by 0.45 stillborn piglets more than for litter sizes ≤ 8; in litter sizes ≥ 20 the number of stillborn piglets was increased by approximately 3 compared with litter sizes ≤ 8.

The number of piglets died until weaning increased with the number of piglets born alive (Table 5). Piglet losses were extremely high in litter sizes ≥ 20 (by about 5.5 piglets more than in litter sizes ≤ 8).

DISCUSSION

Only papers focusing on piglet losses (or piglet survival) as traits of the sow will be taken into account. A survey of literature estimates for the heritability of number of stillborn piglets or equivalent traits as percentage of stillborn piglets or farrowing survival is given in Table 6. The heritability estimates of 0.06 calculated for both breeds in our study are in good agreement with those literature values.

The heritability of piglets that died until weaning or piglet survival until weaning has been investigated only in a low number of papers. Our estimates (0.05 to 0.07) for this trait also correspond with the literature values which are in the range from 0.00 to 0.08 (Table 7).

The results of Serenius et al. (2004) (see Tables 6 and 7) confirmed our findings that the heritabilities for the same trait expressed in number of piglets or as percentage are very similar.

There have been few literature sources on the effect of the service sire on piglet losses or survival rates. Su et al. (2007) analyzed the survival rate at birth and until weaning for the Landrace and Yorkshire breeds. Estimated proportions of variance for the service sire effect were 0.027 and 0.002 (Landrace and Yorkshire, respectively) for survival rate at birth and 0.006 (both breeds) for survival rate until weaning. Holm et al. (2004) found a variance ratio for the service sire of 0.01 for the number of stillborn piglets in Landrace and Landrace × Yorkshire sows. Stalder et al. (1998)

Table 7. Heritability estimates presented in literature for the number of piglets died from 24 h after birth until weaning or equivalent traits (percentage of piglets died until weaning, percentage survival until weaning)

Authors	Heritability	Remarks
Serenius et al. (2004)	0.07, 0.07	Landrace, number or percentage of piglets died until weaning, first parity (*n* = 11 329)
	0.03, 0.04	Large White, number or percentage of piglets died until weaning, first parity (*n* = 8362)
Su et al. (2007)	0.02, 0.01	survival rate from 5 days to weaning for Landrace (*n* = 9300) and Yorkshire (*n* = 6861)
Kapell et al. (2009)	0.08, 0.00	sire line (*n* = 4713), dam line (*n* = 14 836), percentage of piglets dead from birth till weaning

and Sobczyńska et al. (2007) analyzed the survival rate until weaning on less than 5000 litters and estimated proportions of variance for the service sire ranging from 0.00 to 0.03.

In contrast to the papers cited above, where no more than 10 000 litters were analyzed, results for 89 000 litters (Czech Large White) and 28 000 litters (Czech Landrace) were available in the present study, where proportions of variance due to service sire less than 0.02 were estimated for number of stillborn piglets and number of piglets died until weaning. Therefore the service sire effect on piglet losses (or alternatively on piglet survival traits) is probably of minor importance and may be omitted in models for breeding value estimation.

An alternative way of modelling the impact of litter size traits on number of stillborn piglets and number of piglets died until weaning may be the inclusion of the litter size traits as further traits and omitting the class variables for litter size traits. A certain disadvantage of this method is that a linear relationship between traits is assumed. The use of class variables has the advantage that any functional relationship may be modelled.

A central question is if selection against piglet losses may be effective. Farrowing losses are probably mainly caused by biological factors though the estimated heritability is very low. The problem is that nature does not work on the basis of linear models and until now the models used for describing the trait and the factors acting on it may be far from reality. Before having better models we should try to select against farrowing losses with an animal model. In long term, some selection progress may be achieved also for such low heritabilities when using information from a high number of relatives.

The number of stillborn piglets may be connected with the heterogeneity (within-litter standard deviation or variance) of individual piglet weight at birth. There are certain indications that a higher heterogeneity may cause a higher number of stillborn piglets (Huby et al., 2003; Wolf et al., 2008). However the practical application of this finding in selection is nearly impossible, because the individual weighing of piglets from a large number of litters is very costly and the heritability of within-litter heterogeneity in piglet weight is very low.

Canario et al. (2006) stated that selection for number of piglets born is likely to result in a noticeable increase in the percentage of stillborn piglets. Conversely, selection for number of piglets born alive should not result in a deterioration of the percentage of stillborn piglets.

A further problem is if there should be also a selection against piglets died from birth until weaning. This is a very complex trait influenced both by mothering ability of the sow and the viability of the piglets. A genetic improvement of the trait will be very difficult. May be it would be helpful to select on the number of piglets weaned, because this trait is of high economic importance. A decrease in the number of piglets died until weaning should increase the number of piglets weaned which has higher heritability than piglets died until weaning and will ensure a quicker progress in selection. However, selection on the number of piglets weaned will not necessarily decrease piglet losses until weaning.

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