Genetic Parameters of reproductive traits recorded at different parities in Landrace and Large White sows.

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Introduction

The use of relevant and reliable genetic parameters such as heritabilities and genetic correlations should be considered as a priority in any breeding program in order to "fine tune" the genetic evaluation procedures. It was suggested by Walters (1998) that nucleus breeders' should use in their breeding programs the specific parameters from the herd(s) of origin and recalculate those estimates periodically.

Therefore, knowledge of genetic parameters of reproductive traits is essential to estimate accurate breeding values by accounting for all correlations available in a multivariate BLUP analysis. In addition, Roehe and Kennedy (1995) suggested that genetic parameters will allow the breeder to combine different traits in selection, to optimise breeding schemes, and to predict genetic response to selection. Estimates of genetic parameters can be biased by involuntary and directional selection from parity to parity (Roehe and Kennedy, 1995). In order to avoid this possible biasness, parities 1, 2 and 3 were analysed as separate traits using residual maximum likelihood methods under a tri-variate animal model. The objective of this study was to estimate heritabilities and genetic correlations for reproductive traits.

Data description

Reproductive performance data were obtained from purebred Landrace (LR) and Large White (LW) sows at the nucleus and multiplier herds from MYORA Farm. Records of litters from the first, second and third parities born between January 1995 and May 2004 were analysed. Traits analysed are presented in Table 1.

Table 1 Abbreviation, description, and range of the reproductive traits analysed.

Trait	Abbreviation	Description	Range*
Total Number Born	TNB	Total number of piglets born, including stillbirth	2-20 (piglets)
Number Born Alive	NBA	Number of piglets born alive	2-20 (piglets)
Number of piglets weaned	NWEA	Number of piglets weaned	5-14 (piglets)
Average piglet weight at birth	AvBW	Ratio of litter weight at birth and NBA	0.9 -2.5 (kg)
Average piglet weight at 21 days of age	Av21dW	Ratio of litter weight at 21 days and NWEA	4.0 – 8.6 (kg)

* Records outside these ranges were excluded from the analyses.

Records from different parities within each reproductive trait were treated as separate traits. The reason for doing this was to estimate the genetic correlation among parities of a given trait. A genetic correlation among parities of 1 will assume that different parities are genetically the same. Several authors (Alfonso et al., 1997; Bizelis et al., 2000; Crump et al., 1997; Serenius et al., 2003) prefer to treat different parities as repeated measurements of a trait, assuming a genetic correlation of 1 among parities, implementing a repeatability model. On the other hand a number of authors (Hanenberg et al., 2001; Hermesch, 2000; Irgang et al., 1994; Noguera et al., 2002; Roehe, 1999; Roehe and Kennedy, 1995; Serenius et al., 2003; Tholen et al., 1996) prefer to treat at least parity one as a different trait assuming that the genes that regulate the expression of a trait at parity one are not necessarily doing the same influencing subsequent parities.

Means, phenotypic standard deviations and coefficient of variation for reproductive traits are presented in Table 2.

Table 2 Description of the dataset analysed. N (number of records); Mean (phenotypic mean), SD (phenotypic standard deviation) and CV (coefficient of variation)

	Large White				**Landrace**			
Parity	**N**	**Mean**	**SD**	**CV (%)**	**N**	**Mean**	**SD**	**CV (%)**
				Total Number of Piglets Born				
1	2514	11.47	3.04	26.5	1638	11.10	2.79	25.1
2	2075	12.00	3.3	27.5	1348	11.59	3.03	26.1
3	1717	13.28	3.33	25.1	1126	12.93	2.94	22.7
				Number of Piglets Born Alive				
1	2514	10.76	2.87	26.7	1638	10.47	2.66	25.4
2	2075	11.33	3.08	27.2	1348	10.93	2.86	26.2
3	1717	12.33	3.00	24.3	1126	11.86	2.70	22.8
				Numbers of Piglets Weaned				
1	2071	9.93	1.34	13.5	1341	10.08	1.32	13.1
2	1773	10.1	1.28	12.7	1171	10.22	1.25	12.2
3	1437	9.93	1.25	12.6	978	10.12	1.23	12.2
				Average Piglet Birth Weight				
1	1039	1.44	0.24	16.7	849	1.52	0.23	15.1
2	918	1.61	0.26	16.1	765	1.67	0.26	15.6
3	814	1.57	0.25	15.9	642	1.62	0.24	14.8
				Average Piglet Weight at 21 days				
1	2071	6.10	0.78	12.8	1341	6.26	0.80	12.8
2	1773	6.58	0.77	11.7	1171	6.74	0.76	11.3
3	1437	6.64	0.82	12.4	978	6.88	0.70	10.2

Statistical Analyses

Genetic parameters were estimated implementing residual maximum likelihood method with an animal model using the ASReml software (Gilmour et al., 1999). Heritabilities and phenotypic and genetic correlations in each trait were estimated for parities 1, 2 and 3 using tri-variate analyses. Genetic and phenotypic correlations across physiological traits and within parities were estimated using bi-variate analyses.

Fixed effects included were tested using PROC GLM in SAS (SAS Institute Inc., 1990) (Table 3). Farrowing season (FS) was defined as a three month period from December to February, March to May, June to August and September to November. Litter breed (LB) had two levels, purebred or crossbred, depending on the service sire used. Farrowing day (FD) was defined as the day of the week when the litter was born. Age of the sow at farrowing (AF) (in days) and weaning age of the piglet (WA) (in days) were fitted in linear and quadratic forms.

Table 3 Fixed effects and covariables used in the analyses.

		Fixed effects			**Covariables**			
Trait	**Breed**	**FS**	**LB**	**FD**	**AF**	**AF^2**	**WA**	**WA^2**
TNB_1	LW	*			***			
	LR	***			*	*		
TNB_2	LW	**	***	***	***	*		
	LR	*	ns	***	***			
TNB_3	LW	*	***	***	*			
	LR	**	ns	***	ns			
NBA_1	LW	ns			**			
	LR	***			ns			
NBA_2	LW	***	***	***	***	*		
	LR	**	ns	***	*	*		
NBA_3	LW	*	***	***				
	LR	ns	ns	**				
$NWEA_1$	LW	***					***	*
	LR	***					***	
$NWEA_2$	LW	***					**	
	LR	***					***	
$NWEA_3$	LW	***					***	
	LR	***					***	
$AvBW_1$	LW	***						
	LR	***						
$AvBW_2$	LW	ns	***					
	LR	***	ns					
$AvBW_3$	LW	***	***					
	LR	*	ns					
$Av21dW_1$	LW	***						
	LR	***						
$Av21dW_2$	LW	***			*			
	LR	***			***			
$Av21dW_3$	LW	***						
	LR	***						

For trait abbreviations see Table 1. **FS** = farrowing season (3 months periods); **LB** = litter breed (purebred or crossbred); **FD** = farrowing day (day of the week); **AF** = Age of the sow at farrowing (in days); Level of significance (*** P < 0.1%; ** P < 1%; * P < 5%); higher number of * increase the level of importance of the effect; **ns** (not significant at the 5% level but included in the model); ^{2} quadratic forms.

The only random effect used in the analysis was the additive direct genetic effect of the sow. Service sire effect was considered and later excluded from the model because the estimates were smaller than their standard errors, and thus not significant. Small service sire effects were fitted by Chen et al (2003), See et al (1993) and Serenius et al (2003), however the majority of studies did not include this effect. Maternal genetic effects and common family environmental effects were not included in the analyses. This approach is in agreement with some authors (i.e. Alfonso et al., 1997; Chen et al., 2003; Crump et al., 1997; Hermesch et al., 2001; Roehe and Kennedy, 1995).

Genetic Parameters across parities and within traits

Estimates of heritabilities, genetic and phenotypic correlations for reproductive traits across parities 1, 2 and 3 obtained by tri-variate analyses are presented for Large White and Landrace in Tables 4 and 5 respectively.

1. Heritabilities

Heritabilities for litter size obtained in this study (TNB 0.14 to 0.25 and NBA 0.15 to 0.27) were higher than the mean estimates of 0.09 presented by (Rydhmer, 2000) in a review of 96 studies. Heritabilities for TNB and NBA increased slightly with parity number in Large White; on the other hand estimates were slightly lower in parity 2 and highest in parity 3. Somewhat higher heritabilities were found for NBA in Landrace (0.16 to 0.27) than in Large White (0.15 to 0.20).

Table 4 Large White heritabilities (diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) across parities.

Trait	Parity	1	2	3
TNB	1	**0.14 (0.03)**	0.82 (0.12)	0.73 (0.12)
	2	0.20 (0.02)	**0.19 (0.04)**	0.99 (0.07)
	3	0.22 (0.02)	0.32 (0.03)	**0.25 (0.05)**
NBA	1	**0.15 (0.03)**	0.84 (0.12)	0.74 (0.12)
	2	0.19 (0.02)	**0.18 (0.04)**	1.00 (0.08)
	3	0.20 (0.03)	0.30 (0.02)	**0.20 (0.04)**
AvBW	1	**0.35 (0.06)**	1.02 (0.06)	0.87 (0.09)
	2	0.39 (0.03)	**0.36 (0.07)**	0.91 (0.08)
	3	0.42 (0.04)	0.48 (0.03)	**0.39 (0.07)**
Av21dW	1	**0.20 (0.04)**	0.86 (0.13)	0.70 (0.20)
	2	0.18 (0.03)	**0.17 (0.04)**	0.98 (0.17)
	3	0.13 (0.03)	0.23 (0.03)	**0.11 (0.04)**
NWEA	1	**0.03 (0.03)**	0.59 (0.48)	1.08 (0.74)
	2	0.08 (0.03)	**0.08 (0.04)**	1.26 (0.48)
	3	0.06 (0.03)	0.11 (0.03)	**0.04 (0.03)**

Due to the strong influence of non-genetic factors such as cross-fostering practices in the trait number of piglets weaned (NWEA) the parameters estimated should be interpreted cautiously taking into account the size of their standard errors. The fact that good milking sows are generally fostered with extra piglets, systematically introduces a source of bias to the trait.

Similar heritabilities were obtained in LR (0.04 to 0.09) and in LW (0.03 to 0.08) sows. Rothschild and Bidanel (1998) reviewed 42 studies and found a mean heritability for number of piglets weaned of 0.07, slightly higher than the results of this study.

Average birth weight had a moderate heritability with similar results for LR (0.34 to 0.47) and LW (0.35 to 0.39). A review of 6 studies made by Rydhmer (2000) presented heritabilities in the range of 0.1-0.6 with a mean value of 0.4. Average 21 day piglet weight showed low to moderate heritabilities (0.11 to 0.23) which was similar for both breeds; cross-fostering practices are influencing these results.

Table 5 Landrace heritabilities (diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) across parities.

Trait	Parity	1	2	3
TNB	1	**0.20 (0.04)**	0.94 (0.14)	0.85 (0.13)
	2	0.17 (0.03)	**0.15 (0.05)**	0.78 (0.16)
	3	0.23 (0.03)	0.21 (0.03)	**0.24 (0.06)**
NBA	1	**0.19 (0.04)**	1.00 (0.13)	0.81 (0.13)
	2	0.17 (0.03)	**0.16 (0.05)**	0.72 (0.16)
	3	0.2 (0.03)	0.14 (0.03)	**0.27 (0.06)**
AvBW	1	**0.47 (0.08)**	1.02 (0.06)	0.92 (0.10)
	2	0.41 (0.04)	**0.34 (0.07)**	0.85 (0.10)
	3	0.34 (0.05)	0.44 (0.04)	**0.37 (0.08)**
Av21dW	1	**0.2 (0.05)**	0.96 (0.13)	0.74 (0.18)
	2	0.23 (0.03)	**0.22 (0.05)**	0.88 (0.14)
	3	0.21 (0.04)	0.29 (0.03)	**0.23 (0.06)**
NWEA	1	**0.04 (0.04)**	0.87 (0.52)	ne
	2	0.05 (0.03)	**0.09 (0.05)**	ne
	3	0.01 (0.04)	0.11 (0.04)	**0.06 (0.03)**

ne (the estimate was outside the expected range and exceeded the boundary)

2. Genetic Correlations across parities

In Landrace, genetic correlations between parities 1-2 and 1-3 were higher for all traits in comparison to those in Large White. On the other hand genetic correlations between parities 2-3 were higher in Large White than in Landrace. In addition there is a clear indication that parities 1 and 2 as well as 1 and 3 in Large White tend to be genetically different. In contrast parity 3 was genetically different than parities 1 and 2 in Landrace.

Genetic correlations across traits and within parities

Estimates of genetic and phenotypic correlations for reproductive traits within parities 1, 2 and 3 obtained by bi-variate analyses are presented for Large White and Landrace in Tables 6 and 7 respectively.

Estimated genetic correlations between litter size traits (TNB and NBA) ranged from 0.96 to 0.99 among parities and breeds. High negative genetic correlations were found between litter size traits (TNB and NBA) with AvBW (-0.47 to -0.75) across parities and breeds showing a higher antagonistic relationship than previous studies (i.e. Tholen et al., 1996). These results indicate that selection for litter size will result in lighter piglets at birth. Av21dW was negatively correlated with litter size traits (TNB and NBA). Estimates were moderate (-0.19 to -0.26) for Landrace across all three parities, and increased with parity in Large White (-0.29, -0.47 and -0.72). This increase may be due to sampling error. A high positive genetic correlation was found between AvBW and Av21dW (0.51 to 0.73) leading to the conclusion that selecting for higher average piglet weights at birth will lead to heavier piglets at 21 days post farrowing.

Table 6 Large White genetic correlations (above the diagonal) and phenotypic correlations (below diagonal) within parities.

Parity	Trait	TNB	NBA	NWEA	AvBW	Av21dW
1	**TNB**		0.96 (0.02)	0.01 (0.32)	-0.53 (0.12)	-0.25 (0.17)
	NBA	0.93 (0.003)		0 (0.32)	-0.59 (0.12)	-0.29 (0.16)
	NWEA	0.01 (0.02)	0.04 (0.02)		0.35 (0.31)	0.6 (0.33)
	AvBW	-0.6 (0.02)	-0.6 (0.02)	0.11 (0.03)		0.66 (0.13)
	Av21dW	-0.15 (0.02)	-0.15 (0.02)	-0.06 (0.02)	0.34 (0.03)	
2	**TNB**		0.98 (0.01)	-0.57 (0.24)	-0.5 (0.13)	-0.41 (0.19)
	NBA	0.95 (0.003)		-0.66 (0.26)	-0.47 (0.15)	-0.47 (0.19)
	NWEA	-0.02 (0.03)	0 (0.03)		0.25 (0.24)	0.73 (0.3)
	AvBW	-0.61 (0.02)	-0.62 (0.02)	0.05 (0.04)		0.59 (0.16)
	Av21dW	-0.16 (0.02)	-0.16 (0.02)	-0.09 (0.03)	0.35 (0.03)	
3	**TNB**		0.99 (0.02)	-0.46 (0.43)	-0.44 (0.14)	-0.72 (0.20)
	NBA	0.92 (0.004)		-0.67 (0.52)	-0.57 (0.14)	-0.72 (0.22)
	NWEA	-0.01 (0.03)	0.01 (0.03)		0.38 (0.36)	0.71 (0.51)
	AvBW	-0.58 (0.02)	-0.59 (0.02)	0.08 (0.04)		0.73 (0.22)
	Av21dW	-0.18 (0.03)	-0.16 (0.03)	-0.04 (0.03)	0.33 (0.04)	

Number of piglets weaned (NWEA) had a very low genetic correlation with litter size traits (TNB and NBA) at parity 1 (0 and 0.01 in LW and 0.07-0.08 in LR). At parities 2 and 3, the correlations between NWEA and litter size traits were highly negative (-0.45 to -0.67) in both breeds. This could indicate that sows with larger litters at farrowing are not necessarily weaning more piglets, showing a high influence of the cross-fostering practices especially in later parities. On the other hand the genetic correlations between AvBW and NWEA were positive (0.1 to 0.38) across breeds and parities indicating that sows that farrow heavier piglets tend to wean more of them. Av21dW was strongly correlated with NWEA (0.44 to 0.73) across breeds and parities, indicating that sows with heavier piglets at 21 days after farrowing tend to wean more of them.

Table 7 Landrace genetic correlations (above the diagonal) and phenotypic correlations (below diagonal) within parities.

Parity	Trait	TNB	NBA	NWEA	AvBW	Av21dW
1	**TNB**		0.96 (0.02)	0.08 (0.34)	-0.73 (0.10)	-0.25 (0.18)
	NBA	0.92 (0.004)		0.07 (0.35)	-0.75 (0.10)	-0.26 (0.18)
	NWEA	0.02 (0.03)	0.03 (0.03)		0.38 (0.30)	0.64 (0.37)
	AvBW	-0.53 (0.03)	-0.55 (0.02)	0.1 (0.04)		0.61 (0.11)
	Av21dW	-0.16 (0.03)	-0.15 (0.03)	-0.05 (0.03)	0.43 (0.03)	
2	**TNB**		0.97 (0.03)	-0.62 (0.37)	-0.69 (0.19)	-0.19 (0.27)
	NBA	0.94 (0.003)		-0.45 (0.35)	-0.70 (0.17)	-0.20 (0.25)
	NWEA	0.02 (0.03)	0.05 (0.03)		0.10 (0.27)	0.44 (0.27)
	AvBW	-0.58 (0.02)	-0.58 (0.02)	0.05 (0.04)		0.51 (0.16)
	Av21dW	-0.12 (0.03)	-0.12 (0.03)	-0.1 (0.03)	0.41 (0.03)	
3	**TNB**		0.99 (0.02)	ne	-0.52 (0.17)	-0.23 (0.22)
	NBA	0.90 (0.006)		ne	-0.53 (0.16)	-0.25 (0.21)
	NWEA	0.03 (0.03)	0.05 (0.03)		ne	ne
	AvBW	-0.49 (0.03)	-0.52 (0.03)	0.06 (0.04)		0.61 (0.15)
	Av21dW	-0.14 (0.03)	-0.14 (0.03)	-0.20 (0.03)	0.39 (0.04)	

ne (the estimate was outside the expected range and exceeded the boundary)

Implications

The importance of litter size has increased in pigs owing to the decreasing economic weight of backfat thickness and, to a lesser extent of feed conversion ratio in the selection goal (Perez-Enciso and Bidanel, 1997). The number of piglets born or born alive per litter is still the only reproduction trait used in most breeding programmes

(Rydhmer, 2000). The genetic parameters obtained in this study indicate that there are opportunities for improving reproductive performance of the sow by selecting on more traits than litter size.

An increase in litter size will decrease the average piglet birth weight as shown in this study, leading to a consequent increase in pre-weaning mortality as shown in previous studies (Hermesch, 2002; Knol et al., 2002). Therefore, to avoid this, the inclusion of average birth weight as a trait in the selection criteria is recommended in agreement with Hermesch (2002).

The procedure of weighing litters within 12 hours after farrowing for recording birth weight, therefore before any cross-fostering is done, makes the trait AvBW more reliable than litter weight recorded 3 weeks after farrowing with the consequent cross-fostering influence in the trait.

Acknowledging the fact that AvBW and NBA are antagonistic traits and there is a positive correlation between AvBW and NWEA as well as AvBW and Av21dW will reinforce the need of including AvBW in the selection criteria. The weighting of NBA and AvBW in the total merit index should be done cautiously in order not to overemphasize birth weight traits and unintentionally decrease litter size by selecting heavier piglets from smaller litters.

The results indicate that the hypothesis of genetic homogeneity between reproductive traits in different parities of the same sow could not be clearly rejected due to the size and structure of the data set used. However a few exceptions like litter size traits TNB and NBA in LW were observed where parities 1 and 3 were significantly different from one and therefore different traits genetically.

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