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ESTIMATES OF GENETIC PARAMETERS FOR REPRODUCTIVE TRAITS AT DIFFERENT PARITIES IN AUSTRALIAN HYPERPROLIFIC LARGE WHITE SOWS

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SUMMARY
Heritabilities and genetic correlations were estimated for number of piglets born alive (NBA), average piglet weight at birth (BW) and at 21 days (Wt21d), and number of piglets at 21 days (N21d) for parities 1, 2 and 3 using data from an hyperprolific purebred Large White (LW) herd. Genetic parameters were estimated using residual maximum likelihood methodology under an animal model, using 6,801 records of litters from the first three parities recorded between January 1995 and May 2004. Records from different parities were treated as separate traits. The heritability estimates for parities 1 to 3 were 0.18, 0.17 and 0.19 for NBA, 0.35, 0.34 and 0.41 for BW, 0.23, 0.16 and 0.09 for Wt21d and 0.05, 0.07 and 0.05 for N21d. For the genetic correlations between parities 1 and 2, the only ones that were near to significantly different from unity were NBA (P=0.09) and Wt21d (P=0.1). Between parities 1 and 3, only that for BW was significantly different from unity (P<0.05), while for parities 2 and 3, no correlations were significantly different from unity. Genetic correlations were generally negative between NBA and all three other traits: BW (-0.61, -0.64 and -0.59), Wt21d (-0.36, -0.72 and -0.92) and N21d (-0.23, -0.96 and 0.01). Positive genetic correlations were found between BW and Wt21d (0.63, 0.44 and 0.78) across parities as well as between N21d with weight traits: BW (0.35, 0.33 and 0.37) and Wt21d (0.17, 0.59 and 0.58). The results obtained in this study indicate that enhancing the reproductive performance of hyperprolific sows should be done by selecting other traits as well as litter size. Performance in parity one should be considered as a separate trait for NBA, BW and Wt21d traits.
Keywords: Litter size, litter weights, heritability, genetic correlations, pigs

INTRODUCTION
The importance of litter size in pig improvement programs has increased at the same time as the economic weight of backfat thickness and, to a lesser extent, feed conversion ratio have decreased. The number of piglets born or born alive per litter is still the only reproduction trait used in most breeding programmes (Rydhmer, 2000). An increase in litter size will decrease the average piglet birth weight, leading to an increase in pre-weaning mortality (Hermesch *et al*. 2001; Knol *et al*. 2002). Knowledge of genetic parameters for reproductive traits is essential to estimate accurate breeding values by accounting for all correlations available in a multivariate BLUP analysis. Estimates of genetic parameters can be biased by involuntary and directional selection from parity to parity (Roehe and Kennedy, 1995). In order to account for this possible bias, reproductive traits of the sow recorded in parities one to three were treated as separate traits. The aim of this study was to estimate genetic parameters for litter size and litter weight traits at birth and at 21 days in hyperprolific Large White sows.

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MATERIALS AND METHODS

Reproductive data were obtained for the first three parities of hyperprolific purebred Large White (LW) sows from Myora Farm. A total of 6,801 litter records of sows that farrowed between January 1995 and May 2004 were used. Only sows with complete litter records were included. Traits analysed were: number of piglets born alive (NBA), average piglet birth weight (BW), number of piglets at 21 days (N21d) and average piglet weight at 21 days (Wt21d). Over the last ten years this herd averaged 11.8 piglets born alive. A common practice at Myora Farm was to cross-foster piglets across litters to even out the number of piglets per litter and to maximize the total number of piglets weaned. BW was recorded within 18 hours after birth (before any cross-fostering was done) and Wt21d was recorded at exactly 21 days of age (weighing all piglets currently in the litter). The trait N21d included piglets fostered-on but no records were available to establish fostered from non-fostered pigs in each litter.

Fixed effects were tested using PROC GLM in SAS (SAS Institute Inc, 1990), but only significant effects are reported. Farrowing season (FS) was defined as a three month period: summer (Dec to Feb), autumn (Mar to May), winter (Jun to Aug) and spring (Sep to Nov) and was fitted for all traits. Litter breed (LB) had two levels, purebred (LW) or crossbred with Landrace (LWxLR), and was modelled for NBA in all parities and BW in parities two and three. Farrowing day (FD) was defined as the day of the week when the litter was born (Mon to Sun) and was fitted in the model for NBA. Age of the sow at farrowing (AF) (in days) was fitted as a linear covariable for the trait NBA. The only random effect used in the analysis was the additive direct genetic effect of the sow. Genetic parameters were estimated using a residual maximum likelihood method with an animal model, using the ASReml software (Gilmour *et al.* 2002). Heritabilities, phenotypic and genetic correlations across traits and within parities 1, 2 and 3 were estimated using tri-variate analyses. Genetic and phenotypic correlations for different traits across parities were estimated using bi-variate analyses.

RESULTS AND DISCUSSION

Heritabilities. The heritabilities for NBA were 0.18, 0.17 and 0.19 for parities 1 to 3 (Table 1). These estimates are higher than the mean estimate of 0.09 presented by Rothschild and Bidanel (1998) in their review of 96 studies. BW had a moderate heritability across parities, with values (0.35, 0.34 and 0.41) similar to those reviewed by Rydhmer (2000). Wt21d showed moderate to low heritabilities (0.23, 0.16 and 0.09), decreasing with parity. The trait N21d was lowly heritable (0.05, 0.07 and 0.05) across parities similar to the mean heritability of 0.07 reported by Rothschild and Bidanel (1998) in their review of 42 studies. Estimates for traits recorded at 21 days reflect a combination of maternal ability, piglet performance and cross-fostering practices and due to the influence of the latter should be interpreted with caution.

Genetic correlations between parities, within traits. The genetic correlations between parities 1 and 2 only tended to differ from unity for the traits NBA ($P=0.09$) and Wt21d ($P=0.1$) (Table 1). The genetic correlation for BW between parities 1 and 3 was different from unity ($P<0.05$). No significant differences from unity were obtained between parities 2 and 3 for any trait combination. These results are supported by earlier studies (Roehe and Kennedy 1995; Tholen *et al.* 1996). These results indicate that the hypothesis of genetic homogeneity of reproductive traits in different parities of the same sow could be rejected. Therefore parity one should be treated as a separate trait, while parities two and three should be analysed together using a repeatability model.

Table 1. Heritability estimates (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlations (standard errors in brackets), number of records -N- and phenotypic variances (Vp)

Trait	N	Parity	1	2	3	V_P
Number Born	2,657	**1**	**0.18 (0.03)**	0.83 (0.10)	0.84 (0.11)	7.42
Alive	2,276	**2**	0.21 (0.02)	**0.17 (0.04)**	1.07 (0.07)	8.89
(NBA)	1,868	**3**	0.22 (0.02)	0.30 (0.02)	**0.19 (0.04)**	8.38
Average Piglet	1,109	**1**	**0.35 (0.06)**	1.02 (0.06)	0.82 (0.09)	0.06
Birth Weight	979	**2**	0.38 (0.03)	**0.34 (0.06)**	0.99 (0.06)	0.07
(BW)	870	**3**	0.41 (0.04)	0.44 (0.03)	**0.41 (0.07)**	0.06
Number of piglets	2,657	**1**	**0.05 (0.02)**	0.89 (0.27)	0.00 (0.35)	14.62
at 21 days	2,276	**2**	-0.01 (0.02)	**0.07 (0.03)**	0.72 (0.32)	13.57
(N21d)	1,868	**3**	0.02 (0.02)	0.09 (0.02)	**0.05 (0.03)**	14.75
Average Piglet	2,152	**1**	**0.23 (0.04)**	0.80 (0.12)	0.84 (0.20)	0.68
Weight at 21 days	1,916	**2**	0.20 (0.03)	**0.16 (0.04)**	1.16 (0.17)	0.70
(Wt21d)	1,536	**3**	0.13 (0.03)	0.21 (0.03)	**0.09 (0.04)**	0.66

Genetic correlations between traits, within parities. Moderate to high negative genetic correlations were found between NBA and weight traits across parities 1 to 3: BW (-0.61, -0.64 and -0.59) and Wt21d (-0.36, -0.72 and -0.92) (Table 2). The antagonistic relationships between NBA and weight traits was stronger than those found by Hermesch *et al.* (2000) and Tholen *et al.* (1996). A high positive genetic correlation was found between BW and Wt21d (0.63, 0.44 and 0.78) in all parities, leading to the conclusion that selecting for heavier piglets at birth will also lead to heavier piglets at 3 weeks of age. A negative genetic correlation was obtained between NBA and N21d for parities 1 (-0.23) and 2 (-0.96), these traits were not correlated in parity 3 (0.01). These unusual results suggest that selection of sows with larger litters at farrowing will lead to sows that wean fewer piglets, particularly at earlier parities. Cross-fostering practices seem to be influencing these correlations. On the other hand, the genetic correlations between N21d with weight traits BW (0.35, 0.33 and 0.37) and Wt21d (0.17, 0.59 and 0.58) were positive across parities indicating that sows that farrow heavier piglets tend to have more piglets at three weeks, which are heavier on average.

IMPLICATIONS

The genetic parameters obtained in this study indicate that there are opportunities for improving reproductive performance of the sow by selecting on traits additional to litter size. The extreme negative genetic correlation between NBA and N21d may have been influenced in part by the cross-fostering practices used in this herd. Given that the only reproductive trait included in the breeding programs of most piggeries is litter size (Rydhmer, 2000), it should be a priority that this antagonism is considered in the design of pigs breeding programs. Piggeries that have been selecting for litter size and have reached a point where the number of piglets weaned is not increasing as expected, should include other traits in their breeding program to enhance the number of piglets weaned.

Table 2. Estimates of genetic (above diagonal) and phenotypic (below diagonal) correlations between traits and within parities (standard errors in brackets). For trait abbreviations refer to Table 1

Parity	Trait	NBA	BW	N21d	Wt21d
1	**NBA**		-0.61 (0.10)	-0.23 (0.22)	-0.36 (0.14)
	BW	-0.57 (0.02)		0.35 (0.22)	0.63 (0.12)
	N21d	0.01 (0.02)	0.11 (0.03)		0.17 (0.24)
	Wt21d	-0.16 (0.02)	0.36 (0.03)	-0.24 (0.03)	
2	**NBA**		-0.64 (0.11)	-0.96 (0.24)	-0.72 (0.17)
	BW	-0.60 (0.02)		0.33 (0.23)	0.44 (0.18)
	N21d	-0.02 (0.02)	0.04 (0.03)		0.59 (0.33)
	Wt21d	-0.16 (0.02)	0.35 (0.03)	-0.33 (0.03)	
3	**NBA**		-0.59 (0.13)	0.01 (0.28)	-0.92 (0.19)
	BW	-0.58 (0.02)		0.37 (0.25)	0.78 (0.26)
	N21d	0.02 (0.02)	0.05 (0.03)		0.58 (0.45)
	Wt21d	-0.16 (0.02)	0.31 (0.04)	-0.23 (0.03)	

The antagonistic relationship between litter size and piglet weight is confirmed. Subsequently the inclusion of BW as selection criteria is recommended. This trait is recorded before any cross-fostering is made and it coincides with the handling of the piglets at birth so will require only a slight increase in labour to be implemented. This trait has a moderate heritability and is positively correlated with N21d and Wt21d. Acknowledging that NBA and BW are antagonistic traits, the weighting of both traits 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. Parity one should be treated as a separate trait for NBA and BW.

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