Consequences of selection for lean growth and prolificacy on piglet survival and sow attribute traits

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Understanding consequences of selection

Pig breeding programs focus on growth and carcase composition traits in the growing pig as well as higher reproductive performance of sows leading to considerable genetic gain in these traits. These changes in genetic potential have consequences for piglet survival and husbandry requirements of sows. For example, comparison of body composition and physiological state of piglets from boars born in 1977 versus 1998 showed that selection had resulted in lower maturity of piglets at birth Canario *et al.,* 2007). Further, Ball *et al*. (2008) reviewed nutrient requirements of sows concluding that recommendations have not kept pace with the increases in animal performance.

Lactating sow performance is a balance between meeting the demands of the litter and nutrients available from sow feed intake and the mobilization of body reserves. Understanding the consequences of selection on these components of sow performance is a first step towards optimizing both breeding programs that consider a wider range of traits, and management practices that continue to meet the changing needs of sow and piglet genotypes. It was the aim of this study to evaluate the effect of differences in estimated breeding values (EBVs) for traits that have been used as selection criteria on litter size, piglet birth weight, litter survival and litter weight gain as well as sow feed intake and weight and backfat of lactating sows.

Lean growth, sow performance and litter survival data

Data recorded between 2000 and 2009 on 54,089 grower pigs and 6,154 sows from two maternal and two sire lines were used to derive Estimated Breeding Values (EBVs) for growth rate (ADG), backfat (BF) and muscle depth (MD) as well as number born alive (NBA), litter weight (LWB) and average piglet weight at birth (PWB). In addition, information was available about number of piglets born dead (NBD), number of mortalities before and after weaning (MORTbw, MORTaw). These traits describing mortalities of piglets per litter were based on the birth litter and not the nurse litter of the piglet. Of course, the birth litter and nurse litter only differ for piglets that were cross-fostered.

Growth performance records were restricted to females and entire males whose end of test live weight (93.1±9.02) was recorded between 130 to 160 days of age (mean: 144±4.95). Sow litter records (N: 20,727) were limited to a maximum of eight parities and were restricted to sows with parity records from the first litter onwards. Litter birth weight was recorded within 24 hours after farrowing and only included pigs born alive.

Sow attributes data

Litter weight gain (LWG) and sow daily feed intake records from day five to day 14 of lactation along with the weight and backfat of sows prior to farrowing (SWF, BFF) and at weaning (SWW, BFW) have been recorded since 2007 in all four lines on 818 sows with 1,646 litters. A ten-day measure of feed intake during lactation was adopted in the current study, following the suggestion by Hermesch (2007). Average daily feed intake (SFI) was derived only for sows that had at least eight daily feed intake records. Body weight and backfat measures of sows were used to derive the weight loss (WL) and backfat loss (BFL) during lactation. Litter weight gain (LWG) included cross-fostered piglets. Observations that were outside three standard deviations from the mean were excluded for all traits of the growing pig and the sow.

Outline of models and statistical analyses

Year by month of recording, breed and sex were significant fixed effects ($P < 0.05$) for growth performance traits (ADG, BF, MD). Age at recording was fitted as a covariable for ADG (linear and quadratic) and BF (linear). Live weight was fitted as a linear and quadratic covariable for BF and MD.

Herd by month of recording, breed and parity were fitted for traits describing sow performance and litter survival (NBA, LWB, PWB, NBD, MORTbw, MORTaw). In addition, the model included status of birth litter (cross-bred versus purebred litter) and age at farrowing as a linear covariable for NBA and PWB.

Fixed effects for litter weight gain, lactation feed intake and sow body composition traits included month of recording and breed of the sow, parity and age at farrowing fitted as a linear covariable. Parity was not significant for BFL and LWG, while farrowing age was only fitted for SFI and SWW. Fixed effects were evaluated using Proc GLM (SAS, 1999) for all traits.

Variance components were estimated using ASReml (Gilmour *et al.* 2006) applying a univariate animal model with the addition of a random common litter effect for ADG, BF and MD and a permanent environmental effect of the sow for reproductive traits to take repeated records into account. The EBVs for ADG, BF and MD as well as the standard sow traits NBA, LWB, and PWB were then fitted as additional linear covariables for the sow traits describing lactation performance and sow body composition in order to obtain regression coefficients for EBVs (Proc GLM).

Heritabilities

Estimates of heritability for traits describing growth, leanness and performance of the litter (Table 1) corresponded well with estimates usually found in the literature (*e.g*. Bergsma *et al*. 2008, Bunter *et al*. 2010). The number of piglets born dead at birth had the highest heritability of 0.07 among traits describing survival of piglets from a litter (Table 2). In comparison, the number of stillborn piglets was not heritable in a previous Australian study (Hermesch, (2002). Bunter (2009) reviewed genetic parameters for traits describing piglet survival. Heritabilities for pre-weaning mortalities defined as a trait of the sow were higher in this recent review in comparison to an earlier review of Rothschild and Bidanel, 1998). In addition, the antagonistic relationship between number of piglets born in total and pre-weaning mortality has become stronger in recent studies. These changes indicate that selection for lean meat growth and sow prolificacy have affected genetic parameters traits describing prolificacy and pre-weaning mortalities as they are expressed in commercial environments.

Table 1. Number of records (N), means (with raw standard deviation, SD), heritabilities (h^2) along with standard errors (se), common litter effect (c^2) and phenotypic variances (V_P) for traits of the growing pig

Traits*	N	Means(SD)	$h^2_{(se)}$	$c^2_{(se)}$	V_P
ADG (g/day)	54,082	648 (62.0)	0.28 (0.01)	0.09 (0.009)	3347
BF (mm)	54,019	11.2 (2.47)	0.41 (0.01)	0.04 (0.003)	4.39
MD (mm)	46,375	62.3 (6.90)	0.39 (0.01)	0.03 (0.003)	28.3

*ADG: average daily gain, BF: backfat depth, MD: muscle depth.

Table 2. Number of records (N), means (with raw standard deviation, SD), heritabilities (h^2) along with standard errors (se), permanent environment of the sow (PE) and phenotypic variances (V_P) for traits of the sow

Traits*	N	Means(SD)	$h^2_{(se)}$	PE (se)	V_P
NBA (piglets)	20,212	10.4 (3.22)	0.10 (0.01)	0.09 (0.01)	9.22
LWB (kg)	19,912	14.6 (4.24)	0.10 (0.01)	0.09 (0.01)	15.6
PWB (kg/piglet)	19,880	1.44 (0.26)	0.22 (0.01)	0.06 (0.01)	0.060
NBD (piglets)	20,168	0.76 (1.18)	0.07 (0.01)	0.06 (0.01)	1.34
MORTbw (piglets)	20,212	1.08 (1.48)	0.04 (0.01)	0.02 (0.01)	2.01
MORTaw (piglets)	20,212	0.29 (0.64)	0.006(0.004)	0.01 (0.006)	0.380
LWG (kg)	665	20.5 (5.83)	0.07 (0.08)	0.02 (0.10)	30.9
SFI (kg/day)	1,369	6.08 (0.94)	0.10 (0.05)	0.10 (0.06)	0.574
SWF (kg)	764	237 (36.9)	0.35 (0.09)	0.14 (0.09)	619
SWFa (kg)	722	224 (35.5)	0.33 (0.10)	0.14 (0.10)	577
SWW (kg)	708	210 (35.3)	0.26 (0.10)	0.28 (0.10)	455
WL (kg)	418	27.7 (17.6)	0.21 (0.13)	0.01 (0.17)	292
BFF (mm)	1,218	17.2 (4.92)	0.23 (0.07)	0.34 (0.07)	21.9
BFW (mm)	1,132	15.8 (4.38)	0.40 (0.08)	0.20 (0.07)	16.4
BFL (mm)	959	1.30 (2.73)	0.05 (0.06)	0.07 (0.07)	6.91

* NBA: number of piglets born alive, LWB: litter weight at birth, PWB: average piglet weight at birth, NBD: Number of piglets born dead; MORTbw: mortalities before weaning; MORTaw: mortalities after weaning; LWG: litter weight gain from day 5 to 14 after farrowing, SFI: average sow daily feed intake from day 5 to 14 after farrowing, SWF: sow weight prior to farrowing, SWFa: SWF minus litter birth weight, SWW: sow weight at weaning, WL: lactation weight loss derived as SWF minus SWW, BFF: backfat of sows prior to farrowing, BFW: backfat of sows at weaning, BFL: backfat loss during lactation.

The heritability estimate for SFI was 0.10±0.05, which was slightly lower than the range of estimates (0.14 to 0.30) reported previously (Hermesch 2007; Bergsma *et al*. 2008; Bunter *et al*. 2010). Moderate heritability estimates for sow weight and backfat traits, and a higher heritability (0.20) for weight loss in comparison to the heritability for backfat loss (0.05) confirm estimates presented by Bergsma *et al*. (2008) and Bunter *et al*. (2010). The lack of genetic variation between sows to mobilize backfat during lactation, despite varying influences of the environment during lactation (*e.g*. health status, climate), may be regarded as a lack of genotype by environment interaction. Similarly, no genotype by environment interaction was found for backfat in the growing pig by Cameron and Curran (1995).

Consequences of selection

1. Sow performance and litter survival

Regression coefficients quantify the change in the dependent variable (i.e. litter size, sow feed intake) per one unit change in the independent variable (EBVs for selection criteria). Litter size decreased (- 0.006 piglets / g EBV_{ADG}), average piglet weight at birth increased (0.001 / g EBV_{ADG}) and piglet mortalities before weaning decreased (-0.003) / g EBV_{ADG}) with higher EBVs for growth rate (Table 3). An increase in EBVs for growth rate by 100 grams implies a genetic change of -0.6 for piglets born alive and 0.1 kg for average piglet weight at birth. The increase in piglet weight at birth may explain the reduction in pre-weaning mortalities due to selection for higher growth rate. Reduction in EBVs for backfat were associated with higher piglet weight at birth (-0.013 kg / mm EBV_{BF}) and higher number of piglets born dead (-0.05piglets/ mm EBV_{BF}).

Higher EBVs for litter size had unfavourable associations with average piglet weight at birth (-0.11 kg / piglet EBV_{NBA}) and mortalities per litter before and after weaning. The regression coefficient for pre-weaning mortality was 0.39 piglets / piglet EBV_{NBA} which was slightly lower than the predicted correlated response in pre-weaning mortality of half a piglet per response in litter size of one piglet based on a selection strategy that considers litter size only (Hermesch, 2001). Favourable correlated response in piglet survival until weaning was demonstrated for a selection strategy that considered litter size and average piglet weight at birth. In the current study, higher EBVs for piglet weight at birth had favourable associations with all three traits describing survival of piglets.

The extensive review by Bunter (2009) highlighted the need to consider piglet survival in breeding goals to avoid further deterioration in survival of piglets due to selection for lean meat growth and litter size. Average piglet weight at birth is a key selection criterion for piglet survival. However, the genetic relationship between weight and survival of piglets appears to be weaker if piglets are heavy due to selection for lean meat growth or in situation where a good environment is provided to the sow and her piglets (Bunter, 2009). In these situations, other factors affecting survival of piglets including maturity of piglets at birth gain importance for the development of selection strategies to improve piglet survival.

Table 3. Coefficients from the regression of litter size, piglet birth weight and litter survival on EBVs of sows with standard deviations of EBVs (SD) for EBV traits

	ADG[1]	BF	MD	NBA	LWB	PWB
SD	(25.4)	(0.952)	(2.71)	(0.475)	(0.845)	(0.094)
NBA	**-0.006**	**0.072***	-0.007	-	**1.35**	**-8.36**
PWB	**0.001**	**-0.013**	**-0.005**	**-0.11**	**0.04**	-
NBD	0.000	**-0.052**	**-0.009***	0.00	**-0.05**	**-0.63**
MORTbw	**-0.003**	0.003	0.001	**0.39**	**0.10**	**-2.67**
MORTaw	0.000	0.003	0.000	**0.06**	**0.03**	-**0.21**

[1] For abbreviations see Tables 1 and 2. Significant regression coefficients are highlighted in bold P < 0.0001; * P < 0.05

2. Lactation feed intake and sow body composition

Higher EBVs for growth rate were significantly associated with increased lactation feed intake of the sow (0.004 kg / g EBV_{ADG}), sow weights (0.30 to 0.32 kg / g EBV_{ADG}) and sow backfat (0.02 mm / g EBV_{ADG}) (Table 2). Given that EBVs predict differences in performance (Hermesch *et al*. 1997), the inferred underlying genetic correlations were derived for these regression coefficients using the additive genetic standard deviation of each trait. Inferred genetic correlations between ADG, and sow feed intake, weight and fat depth (range: 0.20 to 0.84) corresponded well with estimates reported by Bunter *et al*. (2010).

Table 4. Coefficients from the regression of litter weight gain as well as sow feed intake and body condition traits on EBVs of sows with standard deviations of EBVs (SD) for EBV traits

	ADG*	BF	MD	NBA	LWB	PWB
SD	(25.4)	(0.952)	(2.71)	(0.475)	(0.845)	(0.094)
LWG*	0.00	-0.48	0.07	0.44	0.49	3.83
SFI	**0.004**	-0.026	-0.010	0.040	0.030	0.259
SWF	**0.32**	-0.79	**-1.59**	**6.05**	**7.16**	**43.4**
SWFa	**0.32**	-0.12	**-1.55**	3.28	**4.89**	**35.1**
SWW	**0.30**	1.82	**-1.93**	2.76	**2.25**	5.67
WL	0.06	**-2.04**	-0.03	1.98	**4.21**	**47.0**
BFF	**0.02**	**1.56**	**-0.16**	-0.29	**0.49**	**6.57**
BFW	**0.02**	**1.47**	**-0.15**	0.28	**0.60**	**4.44**
BFL	0.00	0.08	-0.00	**-0.56**	-0.03	**2.43**

*For abbreviations see Tables 1 and 2. Significant regression coefficients are highlighted in bold $P < 0.05$.

A one mm reduction in EBV for backfat in the grower pig increased sow weight loss during lactation by 2.04 kg and reduced fat depth of sows by approximately 1.5 mm, supporting the high positive genetic correlations between backfat measures in grower pigs and in sows shown by Bunter *et al*. (2010). Regression coefficients indicate that selection for higher muscle depth will lead to reduced sow weights and backfat measures. These genetic associations were not observed by Bunter *et al*. (2010) in maternal lines.

During gestation the demands of the sow and her litter have to be met, which implies that EBVs for NBA, LWB and PWB may not be fully independent of sow traits recorded at farrowing. Regression coefficients for each trait EBV were reduced once the influence of the litter on sow weight was considered (SWFa) and decreased further for SWW. Bunter *et al*. (2010) used more elaborate corrections for the effect of the litter on sow weight at farrowing and found no significant genetic correlations between litter performance and sow body weight at farrowing. The inferred genetic correlations between PWB and sow traits were high for WL (0.69) and BFL (0.47), showing that selection for heavier piglets will draw more heavily on the reserves of sows as discussed by Bunter *et al*. (2010).

Conclusions

Current selection practices affect survival of piglets, sow body weight and body composition as well as sow feed intake. Genetic improvement for backfat and litter size will increase litter mortalities at birth (0.05 piglets / -1 mm genetic gain in backfat) and prior to weaning (0.39 piglets / piglet genetic gain in litter size). Genetic improvement of growth and backfat leads to larger sows (~ 30 kg per 100 g/d genetic gain in ADG) and leaner sows (~ -1.5 mm per mm genetic gain in BF). Placing selection emphasis on piglet weight at birth to reduce mortalities until weaning (-0.267 piglets / 0.1 kg genetic gain PWB) increases the demands on the sow, resulting in larger weight loss (4.7 kg / 0.1 kg genetic gain in PWB) and backfat loss (0.24 mm per 0.1 kg genetic gain in PWB) during lactation. These genetic associations should be considered in pig breeding programs and may be used to predict future requirements of sow genotypes.

Acknowledgements

Preparation of data for analyses by Rob Jones and collaborations with Kim Bunter and Hélène Gilbert are gratefully acknowledged. Analyses of data were funded by Australian Pork Limited under project APL2133. These workshop notes are an extension of a paper presented at the 9th World Congress for Genetic Applied to Livestock Production.

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