Improving piglet survival: traits for piglet vitality at birth

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Introduction

Selection for improved litter size at birth has been part of most pig breeding programs throughout the last decade, with the objective to increase number of pigs weaned. However, litter size is unfavourably correlated to piglet survival until weaning (Högberg and Rydhmer, 2008; Hermesch, 2001b; Bunter, 2009), such that the gains in litter size are not fully realised in the number of piglets weaned. Selection has negative implications on the quality of the piglet at birth, which has been shown to influence its ability to survive until weaning. Leenhouwers *et al*. (2001) and Canario *et al*. (2007) have clearly demonstrated, using within line contrasts and the contemporary comparison of modern vs. historical lines, that body composition and physiological state of piglets at birth have been altered by selection practices. Further, selection criteria aimed at improving finisher pig performance could also lead to undesired consequences for sow performance and longevity (Bunter at al., 2010) and potentially piglet survival. Larger litter size in combination with piglets that have higher demands for resources, during both gestation and lactation, place strong pressure on the sow to provide adequate nutrition and a safe maternal environment for all its piglets (Prunier *et al.*, 2010). As a result, there has been a continuing increase in piglet mortality worldwide which is regarded as both a welfare and financial concern.

From a genetic perspective, breeding for a higher number of piglets weaned per sow per lifetime means balancing for a range of factors relating not only to litter size, but also to attributes of the sow and traits that contribute to improved piglet survival and performance. A number of studies identifying traits associated with improved piglet survival have been performed. However, some of the traits studied, such as farrowing order, latency to first suckle, and blood-chemical components (Edwards, 2002; Baxter *et al*. 2008; Tuchscherer *et al*., 2000; Herpin *et al*., 1996; Casselas *et al*., 2004) to name a few, were time consuming and expensive to record. Further, some traits, such as farrowing order, do not have a genetic component and therefore cannot be used as possible selection criteria for improving piglet survival. In addition, the use of these traits to identify piglets at risk at the farm level remains difficult.

In this research, we set out to investigate the associations between some novel traits measured on piglets and their subsequent survival.

Materials and Methods

Animals and Data Collection

Data were collected on primiparous and multiparous sows from two maternal (Large White and Landrace) and two terminal (Duroc and Large White) lines producing purebred progeny, recorded in a single herd in winter 2009 (September to October) and summer 2010 (February to March). Sows were transferred to the farrowing house at about 110 days after mating and were allowed to farrow naturally. Accompanying sow reproductive data recorded included total piglets born (TB) and gestation length (GEST).

Piglet processing was done within 12 hours after farrowing when individual piglets were tagged and weighed (BWT) prior to any cross-fostering. Additional data recorded on individual piglets for this study included:

- Crown to rump length (CRUMP, cm): was the measurement from the base of the piglets' skull to the base of its tail.
- Ponderal index (PINDEX, kg/m^3): as reported by Baxter *et al*. (2009), was calculated as $PI=BWT/(CRUMP/100^3)$
- Rectal temperature (RTEMP): was measured using a digital thermometer (BF-169 Flexible tip digital thermometer, Farlin Infant Products Corporation, ROC, Taiwan).
- Shivering (SHIV): was absent or present (0/1)
- Blood-shot eyes (EYES): were absent or present (0/1)
- The eruption of an incisor tooth (I_1, INCIS) on the mandible was absent or present (0/1)
- Respiration rate (RESP): was scored in three classes (0=normal/regular rate with no mucus; 1=increased breathing rate with or without mucus or rattling sound when breathing; 2=fast or irregular breathing with rattling sound and mucus present in nostrils).

For each litter an average value for piglet traits was calculated. The number of a sow's own piglets which survived until weaning (NSURV), regardless of whether they were fostered or not, was also known.

Data Analyses

Outliers were identified whereby trait values that either deviated by more than 1.5 times the inter-quartile range from the mean or exceeded biological norms were deleted. The final data represented 982 litters from 704 sows, daughters of 267 sires and 580 dams, producing 9135 piglets from 122 service sires. Four generations of additional pedigree were obtained for each sow; the total number of animals in the pedigree was 4893.

Univariate analyses were used to develop models for systematic effects and to obtain initial estimates of genetic parameters under an animal model using ASREML (Gilmour *et al*. 2006). Approximate F-tests were used to assess the significance of systematic effects and/or their interactions, effects significant at P<0.05 were retained. Systematic effects included transfer date (17 levels), sow line (4 levels) and parity group (4 levels), shown in Table 2 for each trait. Correlations between specific traits were estimated in a series of bivariate analyses using the univariate model for each trait.

Results and discussion

Characteristics of the data

Data characteristics for sow and piglet traits (averaged by litter) are shown in Table 1. Litter size and piglet weight traits provided a point of reference only, and it is important to note that these data represent the cross-section of larger litters of lighter piglets, characteristic of maternal line sows, and smaller litters of heavy piglets, characteristic of terminal line sows. The mean gestation length was 116 days, and approximately 9 of the sow's own piglets survived until weaning across lines and fostering patterns.

Table 1. Data characteristics for sow and piglet traits averaged by litter

Traits	N	Mean (SD)	Min- Max	CV (%)
		Sow traits		
TB	982	12.2 (3.33)	2-21	27
GEST	980	116 (1.59)	110-123	1
NSURV	982	8.97 (3.08)	0-19	34
		Piglets traits averaged by litter		
BWT (kg)	839	1.59 (0.26)	0.8-2.4	16
CRUMP (cm)	846	22.9 (1.52)	18-28.6	7
RTEMP (^{0}C)	846	38.0 (0.75)	22.4-39.2	2
PINDEX (kg/m^3)	839	132 (19.2)	85-188	15
		Proportions (%) of normal (0) vs. abnormal		
SHIV (0/1)	846	0.29 (0.34)	0.0-1.0	116
EYES (0/1)	846	0.74 (0.27)	0.0-1.0	36
INCIS (0/1)	846	0.34 (0.31)	0.0-1.0	90
RESP (0-2)	846	0.10 (0.16)	0.0-1.0	168

See text for trait abbreviations

In contrast to litter size and litter survival traits, which had moderate coefficients of variation (CV), GEST, CRUMP and RTEMP had very low CV. Gestation length and RTEMP are tightly regulated physiologically, which reduces variation across sow lines, parities and/or seasons. From over 9,000 piglets recorded, 74% were observed to have blood-shot eyes, which could be a result of the farrowing process. Approximately 30 % of piglets were found to be shivering and 10% were observed to have some level of breathing difficulties. About 30% of piglets had I_1 erupted at birth. This value was higher than for Tucker and Widowski (2009) who reported that 3% of piglets had I_1 erupted at birth (total population: N=233). The difference between this study and that of Tucker and Widowski (2009) could be due to sample size, or to population differences arising from selection and management systems used in the two herds. For example, Meek *et al*. (2000) reported that maternal stress imposed in mice during late gestation resulted in delayed teeth eruption in their offspring. In our study, the extent of I_1 eruption was higher in winter (0.40±0.02) than in summer (0.24±0.02), when sows were more stressed due to increased ambient temperature. Higher piglet mortality was also observed in summer in this study.

Estimates of heritabilities

Total born and the number of piglets surviving until weaning were lowly heritable traits, consistent with a recent review by Bunter (2009) of estimates in the literature. However, repeatabilities of these traits were moderate (0.29 and 0.24, Table 2). The similarity of estimates for TB and NSURV is probably because TB sets the upper limit for NSURV. Heritability (h^2) estimates were also low (<0.10) for RTEMP, PINDEX, SHIV and EYES, and repeatabilities were of the same magnitude, indicating a negligible permanent environmental effect of the sow for these traits. In fact, a large proportion of the variation in PINDEX was explained by date of recording. In contrast, moderate heritability estimates were evident for BWT, CRUMP and INCIS (range h^2: 0.23 to 0.29), while the heritability estimate for RESP was slightly lower (h^2: 0.26). Repeatabilities for these traits were also larger (>0.40) indicating a significant permanent environmental effect of the sow on these piglet attributes. The heritability (h^2) estimate for BWT was slightly lower than 0.39 that reported by Damgaard *et al*. (2003). Despite low phenotypic variation, GEST was highly heritable at 0.37 and was slightly increased (0.38) when TB was fitted as a linear covariate in the model of analysis. High heritabilities for GEST have been observed previously (Hermesch, 2001a; Rydhmer *et al*., 2008).

Table 2: Heritability (h^2), permanent environment (pe^2) and repeatability (r)(all ×100), with phenotypic variance ($\sigma^2 p$) from single trait models, along with the model R^2

Traits	N	Model factors	h^2 ±se	pe^2	r±se	σ^2_p	R^2 (%)
			Sow traits				
TB	982	D, L, PG	7±9	22±10	29±5	10.0	8.9
GEST	980	D, PG	37±10	21±10	58±4	2.44	4.9
		D, PG, TB	38±10	22±10	59±4	2.35	7.5
NSURV	982	D, L, PG	5±8	19±9	24±6	8.12	8.8
			Piglet traits averaged by litter				
BWT	839	D, L, PG	23±11	30±12	53±5	0.052	13
CRUMP	846	D, L, PG	29±11	23±12	53±5	1.79	25
RTEMP	846	D	5±5	B	5±5	0.516	8.2
PINDEX	839	D, PG	8±8	1±10	9±7	183	57
SHIV	846	D, PG	7±7	1±10	8±7	0.090	29
EYES	846	D	9±5	B	9±5	0.053	29
INCIS	846	D, L	26±12	18±12	44±5	0.083	12
RESP	846	D, L	12±9	14±10	26±6	0.024	13

See text for trait abbreviations. Model factors are D: recording date; L: sow line; and PG: parity group. B: estimate was fixed on boundary.

Genetic and phenotypic correlations

The phenotypic correlations between NSURV and GEST, BWT, CRUMP, RTEMP, EYES and INCIS were all positive and significantly different from zero. Piglets were more likely to survive until weaning when the gestation length was longer. A longer GEST provides sufficient time for piglets to be fully developed, as much of this development takes place during the last few days of gestation (Rydhmer *et al*., 2008). Gestation length itself was positively correlated with BWT and RTEMP, PINDEX and INCIS (not presented in Table 3). Positive phenotypic correlations between NSURV and BWT, CRUMP and RTEMP showed that piglets with higher weight, crown to rump length and rectal temperature at birth were more likely to survive until weaning. This outcome supports the previous recommendation by Hermesch (2001a) that piglet birth weight is a useful selection criterion for improving piglet survival.

The phenotypic correlation between NSURV and RESP was negative, indicating that piglets with breathing difficulties evident shortly after farrowing were less likely to survive until weaning. However, the presence or absence of shivering was uninformative of subsequent piglet survival, presumably since shivering is a temporary and an appropriate response of the piglet to generate warmth. Traits such as BWT, CRUMP and PINDEX (Baxter *et al*., 2009), along with RESP (Alonso-Spilsbury *et al*., 2007) and INCIS are considered to provide some indication of physiological maturity at birth. Piglets which are more physiologically mature at birth are better able to handle their new external environment (Knol *et al*., 2002). Additionally, heavier piglets are less likely to suffer from hypothermia, are less prone to crushing and compete well during suckling (Baxter *et al*., 2009; Arango *et al*., 2006). Similarly, piglets with higher PINDEX and higher RTEMP were probably better able to regulate their body temperature (Baxter *et al*., 2008) and survive better than their weaker cohorts.

NSURV and EYES were positively correlated. This association would not be expected if EYES is indicative of birth difficulties (Herpin *et al*., 1996; Holm *et al*., 2004). However, there was also a positive phenotypic correlation between BWT and EYES (not shown) which could be the underlying reason for the positive phenotypic relationship between NSURV and EYES.

Table 3: Genetic (r_G), sow (permanent environment and genetic, r_{SOW}) environmental (r_E) and phenotypic (r_P) correlations between NSURV and other traits

Traits	r_G	r_{SOW}	r_E	r_P
		Sow trait		
NSURV and GEST	-0.23±0.53	**0.31±0.11**	-0.05±0.06	**0.09±0.04**
		Piglet traits averaged by litter		
NSURV and BWT	0.22±0.52	0.10±0.11	**0.43±0.06**	**0.28±0.04**
NSURV and CRUMP	0.38±0.48	0.01±0.13	**0.16±0.07**	**0.10±0.04**
NSURV and RTEMP	0.0±0.0	0.14±0.58	**0.21±0.06**	**0.19±0.04**
NSURV and PINDEX	ns	0.13±0.32	0.10±0.06	**0.10±0.04**
NSURV and SHIV	ns	-0.16±0.33	0.00±0.06	-0.01±0.04
NSURV and EYES	0.27±0.76	ns	0.04±0.06	**0.17±0.04**
NSURV and INCIS	-0.19±0.64	0.19±0.14	**0.17±0.07**	**0.17±0.04**
NSURV and RESP	-0.17±0.73	**-0.36±0.16**	**-0.24±0.06**	**-0.27±0.04**

See text for trait abbreviations. ns: not supplied as se of estimate >0.9.

The positive phenotypic correlation between NSURV and INCIS indicates that piglets with erupted incisor (I_1) were more likely to survive until weaning. Dentition is routinely used for aging in most livestock species but it has not previously been used to indicate physiological maturity of piglets at birth. This study suggests that tooth eruption at birth can indicate variation in physiological maturity and therefore piglet survival. Tucker and Widowski (2009) also highlighted that piglets with early dental eruption adapted more easily to eating creep feed and were more likely to perform better at weaning.

Phenotypic correlations suggest that specific attributes of individual piglets at birth contribute to the number of piglets that subsequently survive until weaning. However, when averaged by litter, the number of sows and records is relatively low. Therefore, the standard errors on estimates for heritabilities and genetic correlations are large, making estimates for genetic correlations imprecise. Standard errors on estimates for genetic correlations are particularly high given survival traits with low heritabilities (Table 2), and given a moderate sampling correlation which also affects the accuracy of partitioning between genetic and permanent environmental effects of the sow. Nevertheless, estimates for correlations between NSURV and the other traits were consistent in direction and/or magnitude for all traits at the sow level (which reflects the combination of genetic and permanent environmental effects). Therefore, culling sows with poor piglet attributes at birth (assessed over at least a couple of litters) would likely improve current herd performance, and may improve future herd performance if the genetic correlations are consistent with sow level or phenotypic correlations. Further analyses of the data at the piglet level, using statistical methodology appropriate for threshold traits, will be performed.

Conclusions

Several traits recorded on sows or piglets at birth are phenotypic indicators of piglet survival. The most promising traits are those that are moderately heritable, such as GEST, BWT, CRUMP and INCIS. In addition to GEST and BWT, which have previously been indicated as important traits which affect piglet survival, incisor eruption offers an opportunity to evaluate physiological maturity at birth. Further data and analyses are required to confirm whether the extent of incisor eruption could be a useful selection criterion to add to pig breeding programs targeting improved piglet survival in their breeding goal.

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