Sow body composition and its associations with reproductive and litter growth performance of the primiparous sow

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Introduction

The complex of desirable maternal traits includes litter size, mothering ability and milk production, combined with aspects of piglet viability or survival and sow rebreeding performance. There are two major contradictory elements within this trait complex. Firstly, larger litters will be, on average, lighter at birth, and result in an extended duration of farrowing. These characteristics may affect piglet viability and access to colostrum, along with sow recovery and health after farrowing. Piglets from these litters are therefore more vulnerable to environmental stressors that can result in piglet death. Secondly, the sow's ability to rear her litter must not compromise her own ability to rebreed for the next parity. So, increasing milk production *per se* to improve litter growth performance may be counterproductive if sow longevity is reduced by failure to rebreed. These areas of antagonism are likely strongest for primiparous sows, which balance their own growth and development against reproductive demands. This is generally illustrated by higher levels of piglet mortality and sow losses, and slower piglet growth, relative to litters and sows from later parities. Clearly a balance is required in performance attributes for phenotypic outcomes of both the sow and her offspring, and this may be particularly difficult to achieve in the first parity.

In contrast to the desired list of maternal characteristics above, breeding programs for maternal lines have historically been based primarily on selection for litter size. This is largely because total born or the number born alive are accurately and routinely recorded in most production systems, whereas other traits indicative of current and future reproductive outcomes are less amenable to recording. Unfortunately, since litter size is only one component of maternal merit as noted above, improved litter size does not guarantee the desired outcome of increasing numbers weaned and overall sow lifetime productivity. Breeding companies have therefore investigated a range of alternative traits for both sow and offspring performance that can be recorded during this time period with varying degrees of success. This particular study focuses on the relationships between sow body composition along with maternal and litter characteristics, which is an area where information for modern sow genotypes is scarce.

Data recorded

Approximately 2500 sows from two purebred maternal lines known to differ in both average body composition as finishers and reproductive performance as sows were recorded for their first gestation and farrowing outcomes between January 2007 and June 2008 at QAF Meat Industries, Corowa, Australia. Records available for this study included:

W110 (kg):	weight at day 110 (D110) of gestation
P2110 (mm):	fat depth at P2 site at D110
P4110 (mm):	fat depth at P4 site at D110
FAT110 (mm):	average fat depth at D110
TB (pigs/litter):	total piglets born (NBA+stillbirths+mummies)
NBA (pigs/litter):	number born alive
ABWT (kg):	average piglet birth weight
N1 (pigs/litter):	number piglets on day 1, after cross-fostering
APWD1 (kg):	average piglet weight after cross-fostering on day 1 (D1)
N10 (pigs/litter):	number piglets on day 10
APWD10 (kg):	average piglet weight on day 10 (D10)
LG10 (kg):	total litter weight gain to day D10
LFI35 (kg/day):	average daily feed intake during lactation (max. 35 days)
SWWT (kg):	sow weight at weaning
SOWWP2 (mm):	fat depth at P2 site at weaning
SOWWP4 (mm):	fat depth at P4 site at weaning
FATW (mm):	average fat depth at weaning
SWLOSS1 (kg):	weight lost between D110 and weaning date
SWLOSS2 (kg):	SWLOSS1 less litter weight (TB×ABWT)
SFLOSS (mm):	fat loss from D110 to weaning, averaged across measurement sites

Additional traits with a 0/1 incidence pattern were developed based on uncensored outcomes for individual sows. These included:

SHORT (0/1):	Sows with terminated (<21 days) or failed lactations (none weaned)
WEAN_R (0/1):	sows that weaned a litter and were rebred
WEAN_F (0/1):	sows that weaned a litter and farrowed in parity two
WCI≤7 (0/1):	mated sows that conceived within 7 days of weaning

Accompanying information included sow age at mating, gestational dietary treatment (A vs B) and whether litters were medicated during the suckling period. Fostering details were also partially available.

Analyses performed

Genetic parameters for all traits were estimated using ASREML (Gilmour et al., 2005). In addition, solutions for factors or regression coefficients for covariables of interest were derived from the uni-variate analyses using multiple regression in the mixed model context.

Factors significantly affecting the incidence of SHORT, WEAN_R, WEAN_F or WCI≤7 were identified using logistic regression. The LOGISTIC procedure (SAS Institute) establishes which factors are the most associated with a particular outcome (eg lactation terminated =1) under logistic regression using a backwards elimination procedure from a full model containing many possible effects. Any factor that was significant at P<0.10 was retained in the final model.

Results and Discussion

1. Characteristics of the data

To place the data in context, sows were on average 231 days of age at first mating, weighed 157kg and averaged 15.7 and 18.5mm fat depth at the two measurement sites. The variability between sows in weight relative to the mean (coefficient of variation: CV=9%) or fat depths prior to farrowing was generally similar to the variability between sows in their weights at mating. However, the variability in gestational weight gain (CV=22%) and in particular the change in sow body fat (CV>200%) during gestation, were higher, as was the variability in litter size (CV=27%, Table 1). Thus, similar variability in weights and fat measurements at the start and end of gestation masks the much larger underlying variability between sows in how they transitioned between these time points, and what impact this pattern might have on subsequent performance.

Table 1. Raw data characteristics for primiparous sows

Trait	N	Mean (SD)	Min-Max	CV
		Sow condition at D110 of gestation		
W110	2303	224 (19.8)	150-289	9
P2110	2283	17.6 (3.95)	6-37	22
P4110	2283	21.0 (4.33)	9-41	21
		Reproduction and litter performance traits		
TB	2288	11.7 (3.18)	2-21	27
NBA	2288	10.4 (2.97)	0-18	29
ABWT	2223	1.41 (0.24)	0.63-2.42	17
N1	2167	10.3 (1.06)	2-14	10
APWD1	2167	1.50 (0.25)	0.78-2.42	17
N10	1980	9.23 (1.56)	1-13	17
APWD10	1980	2.75 (0.58)	1.11-5.17	21
LG10	1970	10.0 (6.10)	-12.4 to 32.5	61
LFI35	2034	4.99 (1.10)	0.50 - 9.00	22
		Sow condition at weaning		
SWWT	1963	197 (18.0)	129-265	9
SOWWP2	1922	15.7 (3.46)	6-32	22
SOWWP4	1922	19.1 (3.80)	6-36	20
SWLOSS1	1939	26.9 (15.4)	90 to -29	57
SWLOSS2	1890	10.7 (14.7)	74 to -112	137
SFLOSS	1890	2.00 (3.17)	16 to -8.5	159

See trait abbreviations in text

Gilts in this study averaged 11.7 total born in their first litter, with an average piglet weight of 1.41 kg. Thus, about 25% of gestational gain can be attributed to litter weight alone (more if conceptus products are also considered). Litters were subsequently standardised to average 10.3 pigs/litter on day 1 after farrowing using uni-directional cross-fostering. This substantially reduced variability between litters in the number suckled (CV=10 vs 29%) but had no impact on the variability in piglet weights (CV=17%). Piglet losses by day 10 were approximately 11% and variability between litters in the number remaining and their weights were increased compared to day 1.

Sows averaged 197kg at weaning, and variability with respect to the mean was again low (CV=9%). However, as with changes in sow weight and fat during gestation, the variability between sows in both the magnitude and direction of changes to their weight and condition (fatness) during lactation was very high. Therefore, although on average sow body weight and fat depth reduced by 10.7kg and 2mm, a proportion of sows lost substantially more weight and fat than this, and a proportion of sows achieved positive energy balance during their lactation, as evidenced by gains in both weight and fat depth. This potentially creates a wide range of physiological states and body condition at weaning for sows of a similar weight.

Approximately, 23% and 28% of primiparous sows had achieved positive weight and fat gain by the end of lactation (28-30 days) relative to their predicted body weight at farrowing. Thus, some primiparous sows are able to improve their own body condition under *ad-libitum* feeding during their lactation while rearing their litter. However, it should be noted that at least some of the weight gain is likely temporary and related to mammary growth and gut fill, rather than be "permanent" gain in the form of accumulated skeletal muscle or bone. Only 13% achieved a weight change of >5kg in this time period, which is an approximate weight attributable to mammary gland tissue alone. Sows nursing larger litters have more weight attributable to mammary tissue growth (Kim et al., 1999).

Thirteen percent of primiparous females were reported to have terminated lactations (SHORT=1), and many of these were culled without an opportunity to rebreed. Only 85% of sows given the opportunity to rebreed conceived (WEAN_R=1) and 73% of weaned sows farrowed (WEAN_F=1) in their second parity. Eighty one percent of the sows that conceived did so within 7 days of weaning (WCI≤7=1).

2. Estimates of heritability

Genetic parameters were estimated using models that did not include any of the alternative traits of interest as covariates. Sow weights and fat depths at all time points were moderately to highly heritable (0.28 to 0.35; Table 2), as expected for these types of traits. Piglet weights at birth were also highly heritable (0.27), even when litter size was not included in the model. Including litter size in the model increased h^2 for ABWT to 0.35±0.05. Heritability estimates for piglet weight traits decreased slightly between birth or day 1 and day 10. In contrast, reproductive traits were lowly heritable (≤0.10). Of note, heritability estimates for litter size traits declined with increasing human intervention (eg fostering) and environmental noise (eg litter treatments) accumulated over time. The magnitude of heritabilities for litter size traits followed the trend TB>NBA>N1/N10 or number weaned (not presented), a phenomenon also seen in other studies (eg Suárez et al., 2006). This outcome reinforces why genetic evaluation systems are generally based on early litter size measures rather than number weaned unless data inventories are complete at the level of individual piglets, and not litters, from birth.

Heritability estimates for live weight losses and sow feed intake during lactation were moderate at between 0.16 and 0.20, whereas estimates for sow fat loss (0.11) and litter weight gain (0.10) were substantially lower, showing the greater influence of both known and unknown environmental factors on the expression of these traits. It should be noted that variation in year season and the incidence of a shortened lactation length explained about 26 and 22% of the variation in lactation feed intake (LFI35), whereas any further variation around the targeted lactation length explained only 2% of the variation in feed intake during lactation.

Table 2. Estimates of heritability (h^2), additive genetic (σ^2a) and phenotypic (σ^2p) variances from single trait analyses, along with the proportion of variation (R^2) explained by the model effects

Trait	Model effects	h^2	σ^2a	σ^2p	R^2
W110	FYM,L,TMT,AGE	0.28±0.05	82.4	284	28%
P2110	FYM,AGE	0.35±0.05	4.38	12.5	20%
P4110	FYM,L,AGE	0.35±0.05	4.87	13.9	26%
TB	FYM,L,AGE	0.10±0.03	1.01	9.80	3%
NBA	FYM,L,AGE	0.03±0.03	0.24	8.59	3%
ABWT	FYM,L,TMT	0.27±0.03	0.015	0.055	5%
N1	FYM,L	0.0	0.0	1.09	3%
APWD1	FYM,L,TMT,N1	0.26±0.05	0.015	0.058	8%
N10	FYM,L,N1,PTMT	0.03±0.03	0.05	1.83	25%
APWD10	FYM,L,PTMT,FOST,N1	0.20±0.05	0.06	0.31	9%
LG10	FYM,PTMT,FOST,N1	0.09±0.04	3.25	34.9	6%
LFI35	FYM,S,LL,LLQ	0.16±0.04	0.097	0.603	50%
SWWT	FYM,TMT,AGE,N1	0.35±0.06	98.0	280	14%
SOWWP2	FYM,AGE	0.35±0.05	3.96	11.3	6%
SOWWP4	FYM,L,AGE	0.32±0.05	4.22	13.2	8%
SWLOSS1	FYM,L,TMT,AGE	0.20±0.05	40.7	200	16%
SWLOSS2	FYM,TMT,AGE	0.20±0.05	35.4	177	18%
SFLOSS	FYM,PTMT,AGE	0.11±0.04	0.94	8.52	15%

FYM: farrowing year month; L: line (2 levels); TMT: gestational diet and status group (4 levels); AGE: age at mating (linear covariate); PTMT: piglets medicated (yes/no); FOST: fostering code (4 levels); LL and LLQ: lactation length (linear and quadratic covariates)

3. Correlations between traits

Genetic correlations between trait combinations were estimated only for those traits with heritability estimates significantly different to zero (Table 3). To further simplify matters, correlations are presented only for average fat trait measurements. Litter gain to day 10 essentially accommodates the final outcome for sows of the combined differences in starting weight and number of piglets, along with accumulated piglet deaths and surviving piglet weight gain to this time point. For comparison with W110, which is the combined weight of the sow and her litter prior to farrowing, a new trait (SW110) was defined as the weight at D110 less the litter birth weight, calculated simply as TB×ABWT.

Table 3. Estimates of genetic correlations (above diagonal), along with residual (1st row) and phenotypic (second row) correlations below the diagonal

Trait	W110	SW110	FAT110	SWWT	SFW	TB	ABWT	LFI35	LG10
W110	-	ne	**29±11**	**79±5**	**30±12**	21±17	**32±12**	**34±16**	-1±18
SW110	ne	-	**30±11**	**75±6**	**52±12**	3±18	16±13	29±17	-4±17
FAT110	**40±4** **36±2**	**40±4** **37±2**	-	**27±11**	**90±4**	-5±16	6±12	-12±15	-9±16
SWWT	**58±3** **65±1**	**60±2** **64±1**	**23±5** **24±2**	-	**43±10**	26±17	**-31±13**	**52±13**	**-39±15**
SFW	**30±5** **30±2**	**37±4** **41±2**	**48±4** **66±1**	**48±4** **46±2**	-	17±17	-12±13	21±16	-21±18
TB	**20±4** **20±2**	-6±4 -5±4	**-10±4** **-8±2**	-2±4 3±2	-4±4 0±2	-	-7±18	18±23	-24±24
ABWT	4±5 **12±2**	**10±4** **11±2**	1±5 2±2	2±5 **-8±2**	**-10±5** **-10±2**	**-55±3** **-46±2**	-	21±17	33±19
LFI35	**-19±4** **-7±2**	**-21±4** **-10±2**	**-13±5** **-12±2**	**35±4** **38±2**	**14±5** **15±3**	**7±4** **8±2**	**-10±4** **-4±2**	-	10±24
LG10	4±4 3±2	4±4 3±2	2±5 -1±2	**-13±5** **-18±2**	**-20±4** **-19±2**	-1±4 -4±3	**10±4** **14±2**	**22±4** **20±2**	-

Models as per Table 2. Estimates that significantly differ from zero are in bold.

Genetic correlations between sow weights or fat depths at day 110 and weaning were very high (0.75-0.79 for weight and 0.90 for fat depth). Similarly, environmental and phenotypic correlations were also high between these time points. Thus, sow weight and condition prior to the first farrowing is strongly correlated with weight and fat, in particular, at the completion of lactation. Genetic and phenotypic correlations between sow weight and fat depths prior to farrowing and at weaning were moderate and positive, similar to estimates for comparable traits in growing pigs under *ad-libitum* feeding. However, correlations between weight and fat traits were stronger at weaning.

In contrast, genetic correlations between litter size (TB) and measures of sow weight or body fat prior to farrowing did not differ significantly from zero. This indicates that the genetic determinants of reproductive potential (eg ovulation rate and embryo survival) were independent of genetic determinants of sow weight and fatness measured prior to farrowing. However, phenotypic correlations between TB and W110 or FAT110 did significantly differ from zero. Sows gestating larger litters in their first parity were heavier and leaner prior to farrowing. The correlation between W110 and TB resulted from the part-whole relationship, since the phenotypic correlation was not different to zero for SW110 and TB. In contrast, a reduction in sow fat depth with increasing litter size suggests that sows have supported the larger litter during gestation at the expense of accumulating their own body reserves. Sow weight and fatness at weaning was not associated with TB. However, correlations between TB and sow live weight loss were positive (SWLOSS1) unless sow live weight was corrected for litter weight (SWLOSS2). For SWLOSS2 and SFLOSS, correlations with TB were negative (ra: -0.31 and -0.42), whereas phenotypic correlations were much lower (-0.05 and -0.07). This indicates that sows with large TB were less likely to lose weight and fat between day 110 and weaning. This could arise, amongst other things, due to a lower demand from the nursing litter of lighter piglets, increased intake following farrowing, and/or improved efficiency during lactation of sows which gestated larger TB.

The positive genetic and phenotypic correlations between sow weight and average piglet birth weight demonstrate that sows with higher genetic potential for lean body mass have heavier piglets (correlations with fat were negligible). However, negative correlations between ABWT and sow weaning weight or fat depth show that sows with heavier piglets at birth were subsequently lighter and leaner at weaning. Again, some of these correlations arise through the part-whole relationship (ie sows gestating heavier litters will lose more weight at farrowing). However, genetic correlations between ABWT and SWLOSS2 and SFLOSS were strongly positive (0.69±0.12 and 0.33±0.16) and phenotypic correlations were moderate (0.20 and 0.15) supporting the concept that sows with heavier piglets at birth (and therefore nursing heavier piglets from day 1) will lose more weight and fat during lactation, likely due to increased lactation demands.

The environmental and phenotypic correlations between total born and average piglet birth weight are strongly negative (-0.55 and -0.46), whereas the genetic correlation between these traits was negligible. The lack of a strong antagonistic genetic correlation between these traits has been observed previously in this population (Hermesch et al., 2001) and elsewhere in other populations (eg. Varona et al., 2007), implying that it is possible to select for both large litters and heavy piglets. However, the phenotypic correlation remains strongly unfavourable, such that larger litters will on average have smaller piglets. This association possibly arises due to the limitations imposed by uterine capacity but, as noted above, it might also arise partly through nutritional limitations, since all sows are fed the same regardless of their gestating litter size. Varona et al. (2007) reported that their analyses supported a one way causal path for litter size to linearly affect birth weight for Yorkshire but not Landrace sows. However, breed differences do not necessarily occur across all populations of sows representing the same breeds.

At the phenotypic level, average daily feed intake during lactation was lower for heavier and fatter sows prior to farrowing, and to a lesser extent sows with heavier piglets at birth. Sows with larger total born had higher intakes, and sows with higher intakes during lactation subsequently had higher weaning weights and fat depths at weaning. However, genetic correlations between lactational feed intake and weight were opposite (0.34 and 0.29 vs -0.19 and -0.21) suggesting genetically larger sows have higher intake capacity but are less likely to express this. This difference is likely because genetically heavy sows are likely to be large and lean, whereas phenotypically heavy sows will also be fatter, which depresses intake. The genetic correlation between sow weaning weight and lactational feed intake was high (0.52), similar to the high correlations observed between lean meat growth and feed intake in grower pigs.

Litter weight gains to day 10 of lactation were uncorrelated with sow weight or fatness prior to farrowing. This absence of association is possibly not expected over a complete lactation and might result from the short lactation interval here, when lactation output is not at its peak. It should also be noted that cross-fostering decisions after farrowing are not totally independent of observations made post-farrowing on sow body condition. Overall, sows whose litters made higher gains to day 10 subsequently had lower weight and fat depths at weaning, which is consistent with expectation (eg see review by Whittemore, 1998). Sows with higher average piglet birth weight and higher lactation feed intake also had litters with greater gain to 10 days. However, genetic correlations between these traits were favourable but did not significantly differ from zero.

Genetic and phenotypic correlations between average piglet birth weight and piglet weight at 10 days were 0.67±0.10 and 0.41±0.02. The very high genetic correlation indicates that piglet birth weight, either directly through growth potential, or indirectly through their stimulation effects on lactation, explains a large part of the genetic variability in piglet weight at day 10. Since the heritability of piglet weight gain to 10 days is much lower, it seems likely that genetic variability amongst sows in lactation yield to 10 days is of less significance than the weight of the piglets at the start of lactation. Thus, maternal contributions to litter gains through milk yield are probably better assessed using data recorded after 10 days.

4. Phenotypic associations between traits

Phenotypic correlations between traits can be easier to visualise as solutions to regressions. A range of models including additional factors and covariates were investigated for each trait. Solutions for these effects are presented from multi-variate models which accommodate several effects simultaneously. For reference, the difference between the top and bottom 50% of sows, based on the difference between the first and third quantiles (interquartile range), is provided for linear covariates. Solutions for some factors (not herd-year-season) are also outlined.

Breed (Line 1 vs Line 2). Line differences were significant for litter size traits, weight and fatness at D110, and average piglet birth weight. The differences between Line 2 and Line 1 primiparous sows were 0.59±0.18 and 0.56±0.14 pigs/litter for TB and NBA, 5.82±1.21kg and 0.76mm (P4 site) at D110, and 0.146±0.016kg for ABWT. Line differences in litter size or piglet weights were reduced but not entirely removed by cross fostering (N1: 0.14±0.05; APWD1: 0.121±0.017). Line 2 sows lost more weight during lactation (1.88±0.82kg) such that line differences in weaning weight were no longer significant. However, Line 2 sows remained slightly heavier and significantly fatter at weaning (0.66±0.28mm). Breed differences in average piglet weights at D10 were not significant, but slightly favoured piglets reared by Line 2 sows.

Age at mating (conception). Increasing mating age increased total born by 0.030±0.005 pigs/litter and NBA by 0.024±0.004 pigs/litter. This is equivalent to differences of 0.63 and 0.50 pigs/litter for TB and NBA, based on an interquartile range of 21 days. Older sows were also heavier and fatter at D110, with differences between the top and bottom 50% of sows of 11.4kg and ~0.86mm at the P2 and P4 sites. Older sows lost about 25% of this additional weight and condition during lactation. Sow weaning weights and fat depths differed by 8.38kg and 0.56-0.50mm between older and younger sows.

Total born. Every extra piglet gestated increased sow weight at D110 by 1.05kg, which is less than the average weight of a piglet at birth. Sow fat depths were significantly reduced with increasing total born: -0.10±0.02 and -0.09±0.18. For an interquartile range of 4mm (10-14mm) this equates to a difference of around 0.5mm in fat depth, whereas the top and bottom 10% for TB will differ by ~1mm. This does not sound much, but if a 1mm change is associated with 2.54 kg of body fat (our data) to 3.3kg (Mullan and Williams, 1990), and the body fat mass at weaning for primiparous sows is approximately 40kg, higher gestating litter size reduced sow body fat available as an energy reserve during lactation by 3-4% for the top versus bottom 50% of sows. This difference expands to 6-8% for the top and bottom 10% of sows. Our data showed that sows buffered changes in piglet weights, on average, up until the point where they were unable to accumulate their own body fat during gestation, at which point piglet weights were also reduced.

Total born was also associated with average feed intake of the sow during lactation, even when nurse litter size was accommodated in the model. For every additional pig gestated sows ate 0.092±0.027kg /day, with a small but significant quadratic solution of -0.003±0.001. This additional intake might be the sow’s mechanism to compensate for her lower body condition prior to farrowing, or an adaptation to sow appetite resulting from gestating a larger litter size.

Number of suckling piglets. For the top versus bottom 50% of sows the interquartile range on day 1 was only 1 (10 vs 11). Cross-fostering on day 1 was mostly uni-directional: litters were either not adjusted (11%), had piglets fostered off (66%) or fostered on (23%). Fostered litters were larger than un-fostered litters on day 1, although additional fostering also occurred after day 1 on a proportion of litters. Against this background, a higher number of piglets on day 1 was associated with a lower average piglet weights on day 1 (-0.013±0.005kg), day 10 (-0.052±0.012kg), and day 21 (-0.159±0.038kg). Thus, average piglet weight at any time point was lower with larger litter size. In contrast, total litter gain was increased by 1.64±0.15kg and 1.75±0.52kg at days 10 and 21, demonstrating that milk production of the sow was increased in response to nursing larger litter sizes.

The number of piglets on day 1 was also associated with an increased number of piglets at days 10 (0.75±0.03) and 21 (0.65±0.07). Data limited only to the subset of sows where the count of piglets at day 10 was confirmed independently (thus complete fostering details and deaths are likely recorded) gave higher regression coefficients of 0.82±0.03 (D10) and 0.70±0.11 (D21) pigs/litter. Please note, fostering after day 10 reduces the reliability of estimates for day 21, and this will be re-examined at a later date with more data.

The number of piglets on day 1 (N1) was associated with sow lactation intake. However, the number of piglets at day 10 (N10) was more strongly associated with lactation feed intake than N1, which is consistent with greater adaptation in sow feed intake to piglet demands during late lactation. The average number of piglets at day 10 was 9.23 pigs/litter and the interquartile range was 2 (8 vs 10 pigs/litter). For each additional piglet at D10, sows consumed an additional 0.075±0.012kg/day, or about 2kg more over the complete lactation. This increase per piglet is negligible from an energetic viewpoint but consistent with the 0.088 to 0.072 kg/day predicted for multiparous sows (Noblet et al., 1998). The top and bottom 50% of sows for N10 differed by 150g/day, or over 4kg for the complete lactation. Primiparous sows thus adapted their intake to litter demands, but only to a relatively small degree.

Piglet health. Data were available to establish whether piglets were treated for scours prior to the day 10 weighing. In a model that corrected for N1, and where piglet numbers were confirmed as above, the number of piglets at D10 or D21 was reduced in treated litters by -0.21±0.07 and -0.83±0.20 pigs/litter at each age. Average piglet weights were also reduced by -0.241±0.026kg (9% of the average weight at this age) and -0.340±0.086kg (7%) at days 10 and 21. Piglet scours clearly increases piglet losses and decreases piglet weight gains.

Sows with treated litters also ate less during their lactation: -0.119±0.036kg/day. Whether low sow intake occurred prior to piglets scouring needs to be examined. Alternatively, lower intake could be due to reduced demand for milk from their fewer slower growing piglets, but may also reflect co-treatment of sows with their piglets for sow health issues, or possibly a reduction in feed delivery by staff to sows with smaller litters.

Terminated lactations. Shortened or unsuccessful lactations (where all piglets were fostered onto another sow rather than weaned) were identified in the data. Sows with terminated lactations ate -0.472kg/day less during lactation and were substantially less likely to be remated, although the latter was largely a management decision. Based on reasons for and timing of removals, a high proportion of sows identified with shortened lactations either had pre-existing conditions prior to farrowing or developed conditions immediately after farrowing that resulted in rapid removals. Lower intake is also consistent with puerperal disease, which has been demonstrated to occur at a higher incidence in primi- compared to multiparous sows (32 vs 26%: Hoy, 2006). However, causes of lactation failure were unconfirmed in this herd.

Lactation feed intake. Sows that ate more during lactation produced heavier piglets and were themselves heavier with better body condition at weaning. For every additional kg/day of feed eaten during lactation there was an extra 0.30 pigs/litter at D10 or 0.72 pigs at D21, and piglets weighed on average 0.136±0.020kg or 0.198±0.072kg extra. Litter weight gains of +2.11kg or +5.08kg by D10 and D21 were of larger magnitude than is suggested by changes in piglet numbers and average weights. Sows were approximately 9kg heavier and 0.7mm fatter at weaning per additional 1kg of daily intake during lactation. The interquartile range was 1.31 kg (4.4 vs 5.7kg/day).

5. Factors significant for incidence traits

Rebreeding performance. In the first instance, factors that were evaluated for incidence traits included only uncensored data recorded prior to or at farrowing, and regardless of whether a sow ultimately weaned her litter or not. For WEAN_R, WCI≤7 and WEAN_F these potential effects included farrowing year quarter (FYQ), sow line, gestational diet, mating weight (2 levels: below or above average), gestational gain (4 levels), fat depth at each site at D110 (5 levels), lactational feed intake (7 levels in 0.5kg increments), stillbirths category (2 levels: normal or excessive relative to TB) and whether the lactation was terminated early or not (2 levels) along with W110, NBA, N1 and total litter weight at D1 as linear covariates. Factors that were significant are outlined in Table 4 (only P<0.05 presented).

Sows must have all information to be included in analyses, so the number of records and the incidence rate differs slightly compared to Table 1. Only season and weight class at mating were significant for predicting whether the weaning to conception interval was ≤7 days after weaning. Sows in the bottom 50% of sow weights at mating were 1.45 times more likely to successfully rebreed within 7 days of weaning, but this effect did not translate through to a significant difference associated with 1st mating weight in the outcome for WEAN_F.

The odds ratio close to zero for sows with shortened lactations demonstrates the very low probability with which primiparous sows with terminated lactations were likely to be rebred, and this outcome was predominantly a mixture of both management decisions and sow health issues. Sows with heavier litters on D1 were less likely to rebreed and farrow in their second parity, and heavier sows at D110 were also slightly less likely to farrow in their second parity (the interquartile range was 27kg). However, weight *per se* was not independent of gain during gestation: sows with gestational gains of more than 57kg (maternal + conceptus to D110) were 1.6 to twice as likely to farrow in their second parity. Primiparous gilts with larger litters on D1 were 40 and 20% more likely to rebreed and farrow in their second parity.

Sow weight or fatness at D110 by themselves were not significant factors affecting whether sows rebred or not, but as LFI35 is positively correlated with sow weaning weights and fat depths (Table 3), it is likely that the significance of lactation feed intake is at least partially through its effects on sow weight and fatness at weaning. Sows that ate more than 3.5kg per day, on average, during their lactation were approximately 1.5 to 3 times more likely to farrow in their second parity. An intake of <3.5kg is very low considering sows in this herd ate approximately 2.5 to 2.6 kg on average as non-pregnant finishers, and approximately 3kg per day in late gestation; <3.5kg implies there was very little increase post-farrowing in feed intake, or a significant period with low intake. In addition, sows that had more than 17mm fat at the P4 site were more than

1.4 to twice as more likely to farrow in their second parity. Fat at D110 is strongly correlated with fat at weaning (Table 3). This demonstrates how important it is in the context of longevity for sows to be in good condition, with adequate fat levels, prior to their first farrowing.

For comparison, sow weight and body condition at weaning were added to the list of possible effects (NB. weaning data is censored). Sow weight and fatness at weaning displaced litter weight at D1 for WEAN_R and WEAN_F, which is consistent with correlations between these sow and litter traits from Table 3.

Table 4. Factors that were significantly associated with the outcome (event=1). Value presented is the odds ratio estimate

	WEAN_R	WCI≤7	WEAN_F
N records	1803	1414	1559
Frequency event=1	87%	20%	24%
p-value for significant factors			
FYQ	<0.0001	<0.0001	<0.0001
Mating weight	ns	0.01	ns
Short lactation	<0.0001	<0.0001	<0.0001
Lactation FI	0.0008	ns	0.01
N1	0.0001	ns	0.03
Litter weight D1	0.02	ns	0.02
W110	ns	ns	0.01
Gain in gestation	ns	ns	0.02
P4110	ns	ns	0.02
Odds ratios for non-seasonal effects			
Mating weight Light versus heavy	ns	1.45	ns
W110	ns	ns	0.99
Gest. gain 57-67 vs <57	ns	ns	1.65
67-76 vs <57			1.60
76+ vs <57			2.04
P4110 18-20 vs ≤17	ns	ns	1.44
21-23 vs ≤17			1.59
24-26 vs ≤17			2.08
27+ vs ≤17			1.71
N1	1.40	ns	1.19
Litter weight D1	0.93	ns	0.94
Short lactation Failed versus normal	0.08	0.09	0.14
Lactation FI 4 vs <3.5	2.29	ns	1.62
4.5 vs <3.5	1.77		1.55
5.0 vs <3.5	1.50		1.69
5.5 vs <3.5	2.82		2.59
6.0 vs <3.5	4.32		2.60
>6 vs <3.5	4.13		3.10

Terminated lactations. The basic effects examined were as above (excluding information at weaning). In addition, effects added to the model included farrowing and piglet details, such as manual intervention (2 levels: yes or no), whether piglets were treated (2 levels), whether a new litter replaced the birth litter on day 1 (2 levels), the number of fostering events (4 levels) along with average piglet birth weight, gestation length, and the number of piglet deaths recorded by day 5 as linear covariates. Significant effects retained from the complete list of possible effects are shown in Table 5.

Lactation failures in primiparous sows appeared to be multifactorial in origin and/or effects. Increasing feed allowance and dietary protein (ie increased CP%) in the first gestation to increase body protein by D110 increased the incidence of lactation failure (gestation diet B vs A). Higher N1, more piglet deaths and increased numbers of fostering events were also associated with an increased incidence of reported lactation failure. However, heavier sows with heavier litters and higher intakes in the first three days after farrowing were less likely to have a failed lactation. Perhaps surprisingly, sows with manual intervention in the farrowing process or with treated progeny were less likely to be recorded with a lactation failure. This might the positive effects of appropriate medication, or potentially a reduced likelihood of staff to attribute poor litter performance in these circumstances to poor maternal characteristics of the sow.

Table 5. Factors that were significantly associated with a failed lactation outcome. Value presented is the odds ratio estimate

		SHORT
N records		1803
Frequency event=1		87%
p-value for significant factors		
FYQ		0.03
Gestational diet		0.01
Manual assistance		0.02
Progeny treated		<0.0001
N1		0.02
Litter weight D1		0.003
W110		0.006
Number of fostering events		0.004
Dead by day 5		0.01
Total intake in first three days		0.0002
Odds ratios for non-seasonal effects		
Gestational diet	B vs A	1.65
W110		0.99
Manual help	yes vs no	0.17
N1		1.31
Litter weight D1		0.84
Progeny treated	yes vs no	0.05
Piglets dead by day 5		1.20
Sow feed intake in first three days		0.91
Number of fostering events	1 vs 0	1.91
	2 vs 0	3.20
	3 vs 0	0.81 ns (too few sows)
	4 vs 0	<0.0001 ns (too few sows)

In light of recorded reasons for removal, sows with failed lactations associated with lower intake (Table 5) and diminished ability to successfully rebreed and farrow for the next parity (Table 4), with shortened lactations or lower intake, are consistent with the observations by Hoy (2006). That is, feed intake of sows during lactation is not only an indicator of underlying differences in appetite for healthy sows, but low feed intake is also an indicator of poor sow health, which has consequences for reproductive performance in both the current and next parity. In addition to the effects of gestation on sow body condition prior to farrowing, health of primiparous sows post farrowing is an area that warrants attention.

Conclusions

Results to date show that there are no strong antagonistic genetic correlations between sow body size or condition, lactation feed intake and litter size. Genetic correlations indicate that sows that produce heavy piglets at birth will have higher litter gains and lose more body weight, which for some sows can be (partially) offset by higher appetite and intake during lactation.

However, gestating litter size is associated with altered body composition of primiparous sows prior to farrowing, with consequences for longevity, supporting the importance of pregnancy feeding to adequately meet the sows needs in the first parity, as was proposed by Whittemore (1998) and reinforced by Ball et al. (2008). Under current gestational feeding systems, sows are unable to adapt intake to meet both their own and litter requirements on an individual as-needs basis. Even with electronic sow feeding stations, knowledge of, and therefore adjustment of feeding to the individual demands of the growing conceptus is not possible without accurate knowledge of gestating litter size. Secondly, sows vary considerably in how they transit between the time points of mating and farrowing, or farrowing and rebreeding, and this has important implications for the physiological state of a sow at weaning. Healthy sows are able to adapt their lactation feed intake to some extent according to their own body condition at farrowing and to the demands of the litter which they nurse. However, this adaptability is small relative to energetic requirements and may be of less benefit for first compared to multiparous sows, which have a higher intake capacity generally. Thirdly, aspects of sow health are implicated in culling following the first parity, and in addition to the direct effects of feed intake on sow body composition at weaning, reductions in feed intake are potentially an indirect indicator of problems in sow health (eg see Hoy, 2006). Further research into achieving the best farrowing outcomes and treatment in the first parity are implicated for improving sow longevity.

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