Feed intake of sows during lactation has genetic relationships with growth and lifetime performance of sows

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Higher nutrient requirements of modern sows

Pig breeders have successfully selected for higher litter size, reduced backfat and improved growth rate (Hermesch, 2006). These outcomes imply that modern sows have higher nutrient demands in comparison to sows of 20 years ago. For example, genetic improvement of litter size has been 0.10 to 0.20 piglets per year in maternal lines. This implies that sows need to eat 50 to 100 grams more feed per day during lactation assuming the requirement of 0.5 kg feed per day per piglet.

Selection for lean meat growth has also altered maintenance requirements of sows. Ball *et al*. (2008) concluded that the existing dietary recommendation for daily maintenance energy requirement of sows (NRC 1998) is about 14% below current sow population requirements. Lactation has high catabolic effects on the body, however, it is difficult to study nutrient requirements during lactation since requirements change daily due to changes in voluntary feed intake, milk production, body weight loss and the composition of that body weight loss (Ball *et al*., 2008).

The sow will mobilise body reserved if feed intake during lactation is insufficient to meet nutrient demands. In the study by Mullan and Williams (1989) gilts were randomly assigned to three feeding levels at three months of age to manipulate body reserves at farrowing. At this age they had an average live weight of 43 kg and 12 mm backfat. Gilts with larger body reserves at farrowing (170 kg live weight and 32 mm backfat) lost 31 kg live weight during lactation without showing any impaired reproductive performance. In contrast, gilts with 'low' body reserves (127 kg with 20 mm backfat) were particularly sensitive to the mobilisation of body reserves during lactation. The authors concluded that mobilisation of body reserves affects fertility of first-litter sows, however, the response is determined by the amount of body reserves available at farrowing. In comparison, current commercial sows are considerably heavier and leaner as outlined by Bunter *et al*., (2008), which was also observed in another Australian commercial sow population (unpublished data). The conclusion by Mullan and Williams (1989) implies that relationships between sow feed intake, sow body reserves and sow reproductive performance need to be re-evaluated for modern sow genotypes.

Sow lactation feed intake is a heritable trait (Hermesch, 2007; Bunter *et al*., 2007; Bergsma *et al*., 2008). Hermesch (2007) suggested using a 5-day or 10-day measure of feed intake during lactation to reduce costs of recording for this trait. In this study we present genetic relationships between measures of lactation feed intake and performance of the growing pig and the sow along with the effect of feed intake of sows on subsequent reproductive performance.

Description of data

Daily feed intake was recorded in lactating sows from May 2002 until March 2007 at Neuendorf Farming in Kalbar (South-East Queensland), Australia. Until day five of lactation daily feed intake was gradually increased by, on average, one kg per day. Sows were then fed to appetite with a maximum daily feed allowance of nine kg per day from May 2002 until August 2004 or eight kg per day since September 2004. Sows were fed twice daily from Monday to Saturday and received only one meal on Sundays. The average lactation length was 21 days, ranging from four to 30 days for sows with lactation feed intake recorded.

Lactation feed intake was defined as the average feed intake (AFI) of sows per day over the complete lactation. An earlier study (Hermesch, 2007) had shown that heritabilities for feed intake averaged over 5-day periods from day six to 20 of lactation were similar to heritabilities for overall lactation feed intake. These 5-day feed intake records had high genetic correlations with total lactation feed intake and with each other. It was concluded that it may be sufficient for selection purposes to record lactation feed intake in sows from Monday to Friday in the second or third week of lactation. Therefore, the average daily feed intake recorded from the first and second (AWK1, AWK2) Monday to Friday period occurring after day four of lactation was analysed, provided the five daily records existed.

Creep feed was provided to the litter from day ten onwards. The amount of creep feed provided was estimated via a 7-point scoring system. Litter feed intake increased gradually as piglets grew older and results for feed intake of the litter on day 20 (FI20) are shown for illustration purposes.

Feed intake records of lactating sows were merged with growth and backfat records of grower pigs as well as reproductive traits of sows. The average live weight at recording of grower pigs was 98 kg. These data included Large White (26,507 pigs) and Landrace (7,362 pigs) male and female pigs. Sows with reproductive traits were predominantly Large White (3,833 litters), which has been developed as a Terminal Sire line, as well as Landrace (1,201 litters) and F1 females (261 litters). Reproductive traits of sows included the number of piglets born alive (NBA), average piglet birth weight (ABW), stillborn (SB), number of piglets weaned (NW) and pre-weaning mortalities (MORT). Number weaned was defined as zero when the sow was unable to complete lactation. Pre-weaning mortality was defined as the number of piglets dying prior to weaning.

Lifetime performance of sows was defined as the total number of piglets born alive (LNBA) and the number of parities achieved prior to culling (LPAR), up until the sixth parity. Only sows born before May 2004 were considered for these traits describing lifetime performance to ensure that they were able to complete six parities within the recording period.

Estimation of variance components

Variance components were estimated applying an animal model. Pedigree information was available from 1995 onwards and included 35,080 animals in total. The ASReml program (Gilmour *et al*. 2006) was used to estimate variance components, which were obtained from univariate and bivariate analyses. The fixed effect models were developed using the procedures GLM and MIXED (SAS, 1999).

The month of farrowing, breed of the sow and parity were fitted as fixed effects for all traits describing feed intake, litter size and mortality (repeated records). Only information from the first eight parities was included in analyses. The day a sow farrowed within a week was a significant fixed effect for average feed intake during the first and second week recorded (AWK1, AWK2) and reflected the effect of the interval from farrowing until recording. Age at farrowing was fitted as a linear covariable for average feed intake in the first recorded week and number born alive.

Season of farrowing was defined as year-season groups of three months periods combining December to February, March to May and so forth within each year of farrowing. Season of the first farrowing along with breed were the only two fixed effect fitted for sow longevity traits. Fixed effects fitted for lifetime growth rate and backfat were date of performance test, breed and sex. The weight at recording was fitted as a linear covariable for backfat.

Characteristics of the data

On average, sows ate 5.10 kg feed per day during lactation (Table 1) in comparison to higher average feed intake measures of 5.67 and 6.47 kg per day in the first and second week of recording, respectively. Restricted feeding at the beginning of lactation and inclusion of all lactation records, in particular incomplete lactation records with lower than average feed intake levels, contributed to the lower average lactation feed intake in comparison to the weekly measures of lactation feed intake. The mean feed intake of the litter at day 20 was 2.46 based on an arbitrary 7-point score from 1.0 to 4.0 with 0.5 steps. The score may be regarded as an estimate of the feed provided to a particular litter relative to other contemporary litters.

Table 1. Number of litters (N), means, standard deviations (SD) and coefficients of determination (R^2) for traits describing feed intake of lactating sows and their litters

Trait	**N**	**Means**	**SD**
Average lactation feed intake (kg/d; AFI)	2,389	5.10	1.11
Average feed intake during the 1st week after day 4 of lactation (kg/d; AWK1)	2,286	5.67	1.27
Average feed intake during the 2nd week after day 4 of lactation (kg/d; AWK2)	1,938	6.47	1.47
Feed intake of litter at day 20 (FI20; score)	2,095	2.46	0.75

Heritability estimates

Heritability estimates were 0.14 for lactation feed intake and slightly higher (0.17 and 0.18) for measures of average daily feed intake in the first and second week after day four of lactation (Table 2). Estimates of the permanent environment of the sow were 0.19 and 0.15. Consequently, repeatability estimates for feed intake measures of lactating sows were 0.33 and 0.32. Despite the use of a very simple scoring system for feed intake of the litter, a low heritability of 0.05(±0.02) was estimated. Heritability estimates for litter feed intake could be obtained from day 15 onwards showing an increase in estimates with higher age of the litter. Using mean litter feed intake over a number of days did not lead to higher heritability estimates in comparison to the 20 day measure of litter feed intake. Heritabilities for litter size, still born and pre-weaning mortalities were 0.15, 0.10 and 0.08, respectively. In comparison, average piglet weight at birth had a high heritability of 0.38 while number weaned was not heritable.

Table 2. Number of records (N), coefficient of determinations (R^2), heritabilities (h^2) and permanent environment of the sow (pe_{sow}) with standard errors (se) along with phenotypic variance (V_P) for reproductive traits of the sow

Trait	**N**	**R^2**	**h^2 (se)**	**pe_{sow}(se)**	**V_P**
AFI	2,389	0.49	0.14(0.04)	0.19(0.04)	0.676
AWK1	2,286	0.50	0.17(0.05)	0.15(0.04)	0.870
AWK2	1,938	0.42	0.18(0.05)	0.15(0.04)	1.310
FI20	2,095	0.35	0.05(0.02)	0.01(0.03)	0.375
NBA	5,263	0.07	0.15(0.03)	0.05(0.02)	8.220
ABW	639	0.10	0.38(0.10)	0.09(0.09)	0.055
NW	2,419	0.08	0.04(0.03)	0.15(0.03)	7.060
SB	2,395	0.04	0.10(0.03)	0.03(0.03)	0.790
MORT	2,326	0.05	0.08(0.03)	0.03(0.03)	1.890

Abbreviations: **AFI**: Average lactation feed intake (kg/day); **AWK1**: Average feed intake during the 1st week after day 4 of lactation (kg/day); **AWK2**: Average feed intake during the 2nd week after day 4 of lactation (kg/day); **FI20**: Feed intake of litter at day 20 (score); **NBA**: Number of piglets born alive (piglets); **ABW**: Average piglet weight at birth (kg/piglet/litter); **NW**: Number of piglets weaned (piglets); **SB**: Number of still born piglets (piglets); **MORT**: Number of pre-weaning mortalities (piglets)

Heritability estimates for traits describing lifetime performance were 0.05 (±0.05) and 0.10(±0.05) (Table 3), which were not significant for the lower estimates and barely significant for the other estimate due to the low number of records. Estimates of heritabilities and permanent environment of the litter were 0.29±0.02 and 0.11±0.01 for growth rate and 0.40±0.02 and 0.05±0.004 for backfat, respectively.

Table 3. Number of records (N), coefficients of determination (R^2), heritabilities (h^2) with standard errors (se) and phenotypic variance (V_P) for traits of the sow describing sow lifetime performance (single records)

Trait	**N**	**R^2**	**h^2**	**se**	**V_P**
LNBA	1,080	0.06	0.10	0.05	466
LPAR	1,080	0.07	0.05	0.05	3.47

Abbreviations: **LNBA**: Number of piglets born alive until parity 6 (piglets); **LPAR**: Number of parities until parity 6 (parities)

Genetic and phenotypic relationships

1. Lactation feed intake and sow reproductive performance

The three measures of feed intake during lactation were genetically the same traits (not shown). Feed intake of lactating sows had no significant genetic relationships with other reproductive traits of the sow (Table 4). In contrast, feed intake of the litter at day 20 had a strong genetic correlation with number of piglets weaned of 0.89(±0.14), which is affected by a part-whole relationship between these traits. Feed intake of the litter is influenced by the number of piglets in the litter and will be higher if more piglets are weaned per litter. A higher feed intake of the litter was genetically associated with a higher average piglet weight at birth (0.43±0.22) and lower pre-weaning mortalities (-0.38±0.19).

Table 4. Genetic (first row; r_g) and phenotypic (second row, r_p) correlations between feed intake traits of the sow during lactation and reproductive traits of the sow

		AFI	**AWK1**	**AWK2**	**FI20**
NBA	r_g	0.06 (0.19)	-0.16 (0.17)	0.26 (0.18)	-0.06 (0.17)
	r_p	0.04 (0.02)	0.01 (0.02)	0.04 (0.03)	-0.08 (0.02)
ABW	r_g	0.33 (0.24)	0.17 (0.23)	0.23 (0.22)	0.43 (0.22)
	r_p	0.05 (0.05)	0.07 (0.05)	0.08 (0.05)	0.20 (0.05)
NW	r_g	0.24 (0.32)	-0.14 (0.30)	0.10 (0.30)	0.89 (0.14)
	r_p	0.35 (0.02)	0.12 (0.03)	0.32 (0.03)	0.23 (0.02)
SB	r_g	-0.27 (0.22)	0.04 (0.21)	-0.06 (0.21)	-0.33 (0.19)
	r_p	-0.03 (0.02)	-0.01 (0.02)	0.01(0.03)	-0.02 (0.02)
MORT	r_g	0.06 (0.25)	0.02 (0.23)	0.18 (0.22)	-0.38 (0.19)
	r_p	-0.03 (0.02)	-0.03 (0.02)	-0.06 (0.03)	-0.14 (0.02)

Abbreviations: **AFI**: Average lactation feed intake (kg/day); **AWK1**: Average feed intake during the 1st week after day 4 of lactation (kg/day); **AWK2**: Average feed intake during the 2nd week after day 4 of lactation (kg/day); **FI20**: Feed intake of litter at day 20 (score); **NBA**: Number of piglets born alive (piglets); **ABW**: Average piglet weight at birth (kg/piglet/litter); **NW**: Number of piglets weaned (piglets); **SB**: Number of still born piglets (piglets); **MORT**: Number of pre-weaning mortalities (piglets)

The strongest phenotypic correlations were observed between number of piglets weaned and measures of feed intake of lactating sows. Estimates were higher for feed intake during the whole lactation and the second recorded week of lactation in comparison to average feed intake in the first recorded week of lactation. The number of piglets weaned per litter is influenced by cross-fostering practices and piglets may have been cross-fostered to sows with higher feed intake rates throughout lactation. In addition, sows with larger litters may be expected to eat more and therefore may have been given more feed.

Phenotypic correlations of litter feed intake with other reproductive traits were consistent between traits. A higher feed intake of the whole litter was associated with lower number born alive, higher average piglets birth weight, more piglets weaned and lower pre-weaning mortalities. Only an estimate of litter feed intake was available in this study, however, these first results indicate that a more accurate measure of litter feed intake after day 20 of lactation warrants further investigations.

2. Sow reproductive performance

Litter size had unfavourable genetic correlations of -0.44(±0.18) and 0.54(±0.16) with average piglet weight at birth and pre-weaning mortalities, respectively. The estimate of the genetic correlation between litter size and average piglet weight at birth found in this study was within the range and not significantly different to estimates obtained in two previous Australian studies. Hermesch *et al*. (2001) found no significant genetic relationship between litter size and average piglet birth weight in contrast to stronger genetic correlations of -0.64 to -0.59 between these two traits in the study by Suárez *et al*. (2005). A strong unfavourable genetic correlation between litter size and pre-weaning mortality was also found in another Australian study (Hermesch *et al*., 2001), as were negative genetic correlations between number born alive and number weaned (Suárez *et al*., 2005).

A higher average piglet weight at birth had a strong positive genetic correlation with number of piglets weaned. This confirms positive genetic correlations between these two traits presented by Suárez *et al*. (2005).

Table 5. Genetic (above diagonal) and phenotypic (below diagonal) correlations between reproductive traits of the sow

	NBA	**ABW**	**NW**	**SB**	**MORT**
NBA		-0.44 (0.18)	-0.19 (0.28)	-0.13 (0.18)	0.54 (0.16)
ABW	-0.45 (0.03)		0.77 (0.35)	-0.38 (0.22)	-0.51 (0.21)
NW	0.07 (0.02)	0.13 (0.04)		-0.59 (0.24)	-0.95 (0.19)
SB	-0.07 (0.02)	-0.09 (0.04)	-0.12 (0.02)		0.28 (0.23)
MORT	0.38 (0.02)	-0.37 (0.03)	-0.25 (0.02)	0.06 (0.02)	

Abbreviations: **NBA**: Number of piglets born alive (piglets); **ABW**: Average piglet weight at birth (kg/piglet/litter); **NW**: Number of piglets weaned (piglets); **SB**: Number of still born piglets (piglets); **MORT**: Number of pre-weaning mortalities (piglets)

3. Lactation feed intake and sow lifetime performance

Genetic relationships

Lactation feed intake had high genetic correlations with both sow lifetime performance traits (Table 6), which were not significantly different to one. Five-day measures of feed intake during lactation had also positive genetic correlations with sow lifetime performance ranging from 0.21(±0.34) to 0.46(±0.31). Differences in estimates of genetic correlations were not significant between measures of feed intake of sows during lactation. Overall, they were all positive showing that selection for higher feed intake of lactating sows will improve lifetime performance.

Table 6. Genetic (r_g) and phenotypic (r_p) correlations between sow reproductive traits and sow lifetime performance

		LNBA	LPAR
AFI	r_g	0.67 (0.21)	0.73 (0.29)
	r_p	0.10 (0.03)	0.08 (0.03)
AWK1	r_g	0.39 (0.24)	0.46 (0.31)
	r_p	0.06 (0.03)	0.05 (0.03)
AWK2	r_g	0.36 (0.25)	0.21 (0.34)
	r_p	0.05 (0.04)	0.02 (0.03)
NBA	r_g	*	0.70 (0.17)
	r_p		0.22 (0.03)
SB	r_g	-0.53 (0.24)	-0.67 (0.32)
	r_p	-0.15 (0.05)	-0.12 (0.05)
Mort	r_g	0.73 (0.28)	-0.36 (0.43)
	r_p	0.09 (0.06)	0.00 (0.06)

* Estimate could not be obtained; Abbreviations: **AFI**: Average lactation feed intake (kg/day); **AWK1**: Average feed intake during the 1st week after day 4 of lactation (kg/day); **AWK2**: Average feed intake during the 2nd week after day 4 of lactation (kg/day); **NBA**: Number of piglets born alive (piglets); **SB**: Number of still born piglets (piglets); **MORT**: Number of pre-weaning mortalities (piglets) **LNBA**: Number of piglets born alive until parity 6 (piglets); **LPAR**: Number of parities until parity 6 (parities)

Phenotypic relationships

A good lifetime performance is only achieved by sows that have large litters and consistent rebreeding success. The effect of lactation feed intake of sows was evaluated for a number of reproductive traits that contribute to lifetime performance.

A high number of piglets weaned in the first (P<0.0001) and second (P=0.09) parity increased the probability that the sow would successfully rebreed (stayability, defined as a 0/1 trait). This relationship may reflect a certain management practice of allowing sows that wean larger litters more opportunities to rebreed, in particular after the first parity. However, the number of piglets weaned and lactation feed intake were positively correlated and this relationship may also reflect the higher feed intake of sows that wean larger litters. Including number of pigles weaned as a linear covariable in the model to estimate the effect of feed intake on stayability decreased the effect of feed intake on stayability (Figures 1 and 2).

Gilts eating less than 3.5 kg per day during lactation were 32% (number weaned not fitted) or 17% (number weaned fitted) less likely to stay in the herd in comparison to the highest feed intake class of 5.5 kg. Differences in stayability between subsequent feeding classes were not significant (Figure 1).

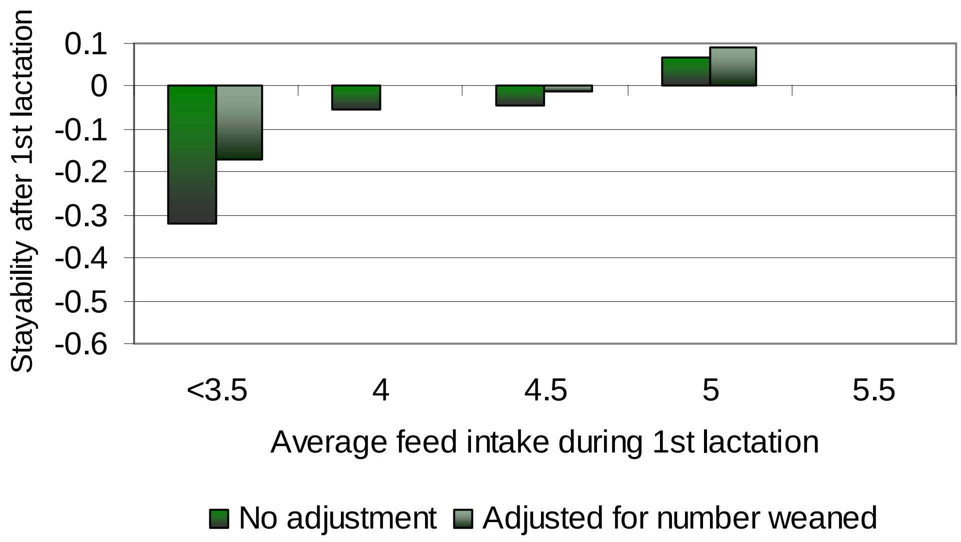

Figure 1. Solutions for stayability after the first parity for different lactation feed intake classes expressed relative to the highest lactation feed intake class

A low average feed intake of below 4.0 kg per day in second parity sows decreased stayability after the second parity by 50% (number weaned not fitted) or 33% (number weaned fitted) (Figure 2). Similar to the first parity, differences in stayability between subsequent feeding classes were not significant. Overall, these results correspond to the reduced lifetime performance of sows with very low feed intake in the first and second parity outlined by Hermesch and Jones (2007) for these sows. They also indicate a threshold for the effect of feed intake on subsequent performance. This threshold might differ between sows and depend on nutrient requirements of the sow as well her body reserves available at farrowing.

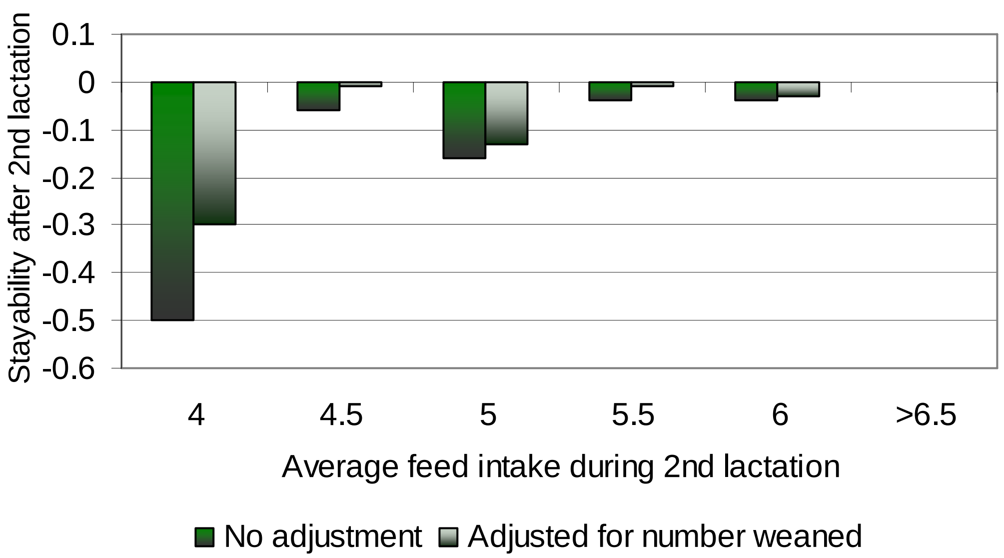

Figure 2. Solutions for stayability after the second parity for different lactation feed intake classes expressed relative to the highest lactation feed intake class

Gilts eating less than 3.5 kg per day had a reduced litter size of about one piglet in the subsequent parity in comparison to gilts eating above this threshold. Due to the low number of records available this effect was statistically not significant (P=0.10), however, the magnitude of the effect is of biological importance. Feed intake during the first or second lactation did not affect the subsequent weaning to conception interval. This trait was only available for sows that had a subsequent litter and no effect of lactation feed intake remained for this subset of sows.

4. Lactation feed intake and grower performance

Lactation feed intake had a high genetic correlation of 0.80(±0.11) with lifetime growth rate of the grower pig (Table 7). Genetic correlations between weekly measures of feed intake during lactation and growth rate were slightly lower with estimates of 0.55(±0.10) and 0.66(±0.10). In addition, growth rate had significant genetic relationships with litter size (-0.19±0.07)), average piglet weight at birth (0.49±0.12), number of piglets weaned (0.65±0.19) and pre-weaning mortalities (-0.27±0.13). These genetic correlations were unfavourable for litter size and favourable for the other reproductive traits, which is consistent with genetic correlations between them.

Table 7. Genetic and phenotypic correlations between lifetime growth rate and backfat with sow reproductive traits

Trait	Lifetime growth rate		Backfat	
	Genetic	Phenotypic	Genetic	Phenotypic
AFI	0.80(0.11)	0.16(0.02)	-0.02(0.12)	0.00(0.03)
AWK1	0.55(0.10)	0.13(0.02)	0.05(0.11)	0.01(0.03)
AWK2	0.66(0.10)	0.16(0.02)	0.01(0.11)	0.00(0.03)
FI20	0.35(0.17)	0.14(0.04)	-0.35(0.17)	0.01(0.04)
NBA	-0.19(0.07)	-0.04(0.03)	-0.02(0.07)	0.02(0.03)
ABW	0.49(0.12)	0.16(0.04)	0.09(0.13)	-0.03(0.07)
NW	0.65(0.19)	0.08(0.02)	-0.01(0.19)	0.02(0.04)
SB	0.01(0.12)	0.01(0.04)	0.00(0.12)	-0.05(0.04)
MORT	-0.27(0.13)	-0.03(0.04)	-0.07(0.13)	-0.03(0.04)

Abbreviations: **AFI**: Average lactation feed intake (kg/day); **AWK1**: Average feed intake during the 1st week after day 4 of lactation (kg/day); **AWK2**: Average feed intake during the 2nd week after day 4 of lactation (kg/day); **FI20**: Feed intake of litter at day 20 (score); **NBA**: Number of piglets born alive (piglets); **ABW**: Average piglet weight at birth (kg/piglet/litter); **NW**: Number of piglets weaned (piglets); **SB**: Number of still born piglets (piglets); **MORT**: Number of pre-weaning mortalities (piglets)

Backfat of the finisher pig had no significant genetic relationships with sow reproductive traits. Only feed intake of the litter had a significant negative genetic relationship with backfat (-0.35±0.17). This may indicate that pigs need to eat more if the dam has less body reserves available.

Overall, information about genetic parameters between feed intake of lactating sows and performance of the grower pig is sparse. Genetic correlations between lactation feed intake and performance traits were positive for feed intake (0.33 to 0.59) and growth rate (0.44 to 0.60) (Bunter, 2008; unpublished results). Genetic correlations between lactation feed intake and backfat were lowly negative and mostly not significant (-0.24 to -0.8). This work is continuing and genetic parameters will be re-estimated once all data are available.

Lactation performance in Large White gilts were compared between lines that had been divergently selected for daily food intake (DFI), lean food conversion ratio (LFC) and lean meat growth under *ad libitum* (LGA) and restricted feeding (LGS) (Cameron *et al*., 2002). Food intake during lactation was significantly higher in the high LGA line than the low LGA line. This was accompanied by a lower live weight loss during lactation of the high LGA line sows than the low LGA line sows. There were no significant differences between divergent selection lines of the other selection strategies, which may be unexpected for the divergent DFI selection lines.

Selection for high lean meat growth under *ad libitum* feeding resulted in higher feed intake during lactation and a high genetic correlation was found in this study between growth rate and lactation feed intake. The high LGA line was 13 kg heavier at farrowing than the low LGA line in contrast to no significant differences in sow live weight for the divergent DFI lines (Cameron *et al*., 2002). It should be investigated to what extent the higher feed intake during lactation can be attributed to larger body size of the sow and therefore her capacity to eat large amounts of feed.

Summary

Lactation feed intake and 5-day measures of feed intake had heritabilities ranging from 0.14 to 0.17. Repeatability estimates were 0.32 and 0.33. The three measures of lactation feed intake were genetically the same trait indicating that for selection purposes it is sufficient to record lactation feed intake over a 5-day period recorded after day four of lactation.

Feed intake during lactation had no significant genetic relationships with litter size, average piglet weight at birth, still born, pre-weaning mortalities and number weaned. However, the direction of the moderate genetic correlations was favourable for average piglet weight at birth, still born and number weaned.

Lactation feed intake had very high genetic correlations with the number of piglets and parities of the sow achieved over her lifetime. A number of reproductive traits contribute to good lifetime performance of sows and lactation feed intake may be a selection criterion for sow longevity that captures the joint contributions of reproductive traits of the sow towards improved lifetime performance.

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References

Ball, R.O., R.S. Samuel and S. Moehn (2008). “Nutrient requirements of prolific sows.” *Advances in Pork Production*, **19**: 223-236.

Bergsma, R., E. Kanis, M. W. A. Verstegen and E. F. Knol (2008). **“**Genetic parameters and predicted selection results for maternal traits related to lactation efficiency in sows.” *J. of Anim. Sci*. **86**: 1067-1080.

Bunter, K L**;** Luxford, B G and Hermesch, S (2007). “Associations between feed intake of growing gilts, lactating sows and other reproductive or performance traits.” Proceedings of the 17th Conference of the Association for the Advancement of Animal Breeding and Genetics. Armidale, Australia. September 24-26. pp.57-60.

Bunter, K.L., Smits, R., Hermesch, S., B.G. Luxford (2008). Sow body composition and its associations with reproductive and litter growth performance of the primiparous sow. AGBU Pig Genetics Workshop notes, pp 67-83.

Cameron N.D., J.C. Kerr, G.B. Garth, R. Fenty and A. Peacock (2002). Genetic and nutritional effects on lactational performance of gilts selected for components of efficient lean meat growth. *Animal Science* **74**: 25-38.

Gilmour, A.R., B.J. Gogle, B.R. Cullis and R. Thompson (2006). ASReml User Guide Release 2.0 VSN International Ltd, Hemel Hempstead, HP1, 1ES, UK.

Hermesch, S. (2006). “From genetic to phenotypic trends.” AGBU Pig Genetics Workshop Notes, pp 59 – 65.

Hermesch, S (2007). “Genetic analysis of lactation feed intake in lactating sows.” Proceedings of the 17th Conference of the Association for the Advancement of Animal Breeding and Genetics. Armidale, Australia. September 24-26. pp.61-64.

Hermesch, S and Jones, R M (2007). “Association between lactation, feed intake and lifetime reproductive performance of sows.” Proceedings of the 11th Biennial Conference of the Australasian Pig Science Association. Brisbane, Australia, November 25-28. p.196.

Hermesch, S.; Luxford, B.G. and Graser, H.-U. (2001). "Genetic parameters for piglet mortality, within litter variation of birth weight, litter size and litter birth weight." In Proceedings of the 14th Conference of the Association for the Advancement of Animal Breeding and Genetics. Queenstown, NZ, pp.227-230.

Mullan, B.P. and I.H. Williams (1989). “The effect of body reserves at farrowing on the reproductive performance of first litter sows.” *Anim. Prod*. **48**: 449-457.

National Research Council (NRC) (1998). “Nutrient requirements in swine.” 10th ed. Washington, D.C., National Academy Press.

SAS (1999). Enterprise Miner, Release 9.1. SAS Institute Inc., Cary, NC.

Suárez, M; Hermesch, S; Braun, J A and Graser, H-U (2005). "Estimates of genetic parameters for reproductive traits at different parities in Australian hyperprolific Large White sows." In Proceedings of the 16th Conference of the Association for the Advancement of Animal Breeding and Genetics. Noosa, Australia. September 25-28. pp.145-148.