Genetic analysis of feeding pattern traits in pigs

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Introduction

It is common practice in commercial piggeries to house growing pigs in groups. The desire to record feed intake of individual pigs in such an environment has led to the development of electronic feeders. In Australia, one electronic feeder system has been developed by QAF Meat Industries (formerly Bunge Meat Industries).

With the introduction of electronic feeders, the study of feeding patterns and feeding behaviours of livestock animals has become much easier. The volume of individual feed intake data that is generated from electronic feeders allows for quantitative genetic analysis of feeding patterns of livestock animals. This extra information on feeding pattern traits may be useful to enhance selection for economically important traits such as feed intake, growth rate and carcase composition.

It is the aim of this paper to summarise the main results of the Masters thesis by Jodine McSweeny on the genetic analysis of feeding pattern traits in group-housed pigs (McSweeny, 2002).

The QAF electronic feeders

The electronic feeder system developed by QAF Meat Industries has been described during the last workshop (McSweeny, et al. 2001 for more detail). Briefly, a number of unique features are listed.

Unique to the electronic feeders:

- There are three electronic feeders per pen, allowing for up to 30 animals per pen.
- Feed is automatically dispensed at a set rate of feeding.
- Rate of feeding on each feeder is set manually. This reduces the amount of feed wastage and allows the pigs no control over how fast they eat, generally a trait that is pig specific.

Unique to the experimental design:

- Animals are tested under a restricted feeding regime. Allowances are allocated for each individual animal based on their starting weight. The feeding allowance is allocated each day at midnight. Animals are allowed to ‘credit’ any feed not eaten in a day to the next day.

- Feed is credited for no longer than a week because the daily feeding allowance is increased each week by 100 grams per day to allow for increasing maintenance requirements of the growing pig. At this point all existing credit is cancelled.

Every feeding event in which a pig was able to receive food was recorded. However, any time a pig entered the feeder and was not able to obtain feed because it had exceeded its allocation was not stored. Each feeding event record comprised the pen number (pen), feeder number (feeder), date of feeding event (date), time of feeding event (time, 24 hhmmss), the electronic identification of the animal (eid), the duration of the feeding event (feedtime, seconds), the weight of the feed eaten during the feeding event (feed, grams) and the weight of the animal (weight, kilograms). Table 1 gives examples of individual feed intake records in the raw data set.

Table 1 Examples of individual feeding event records

Pen	feeder	date	time	eid	feedtime	feed	weight
11	31	23/02/00	9:00:14	18212046	310	474	58
11	32	23/02/00	9:08:24	18403075	122	129	0
11	33	23/02/00	9:16:40	17285144	37	46	0

Description of data

Boars representing three terminal sire lines developed at QAF Meat Industries (QAF) were housed in groups of approximately 30 animals with 24-hour access to electronic feeders for a seven-week test period. On average boars started test at 71 kg liveweight. Feeding events were recorded using the QAF electronic feeders between February and October 2001. The raw data set consisted of 617,215 feeding records, which were used to derive a number of feeding pattern traits.

Feeding pattern traits

Feeding pattern traits were defined on a feeding event and daily basis. Feeding event traits were average feed eaten per visit (FIV, kg) and average time spent feeding per visit (FTV, hrs). Of the actual feed intake per visit measures, approximately 40% were less than 0.1 kg with the overall distribution being highly skewed towards low intake per visit (Figure 1).

The daily feeding pattern traits calculated were average daily feed intake (DFI, kg), average time spent feeding per day (DFT, hrs) and the average number of visits per day (NVD). The distribution of the actual daily feed intake records shows a normal distribution with a large range from less than one kg up to 6 kg per day (Figure 2).

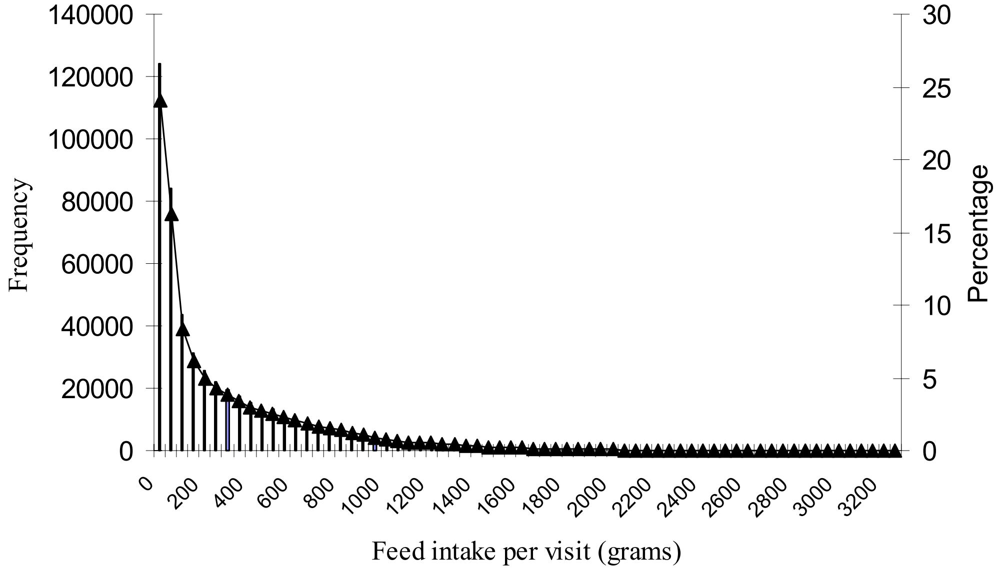

Figure 1 Distribution of feed intake per visits

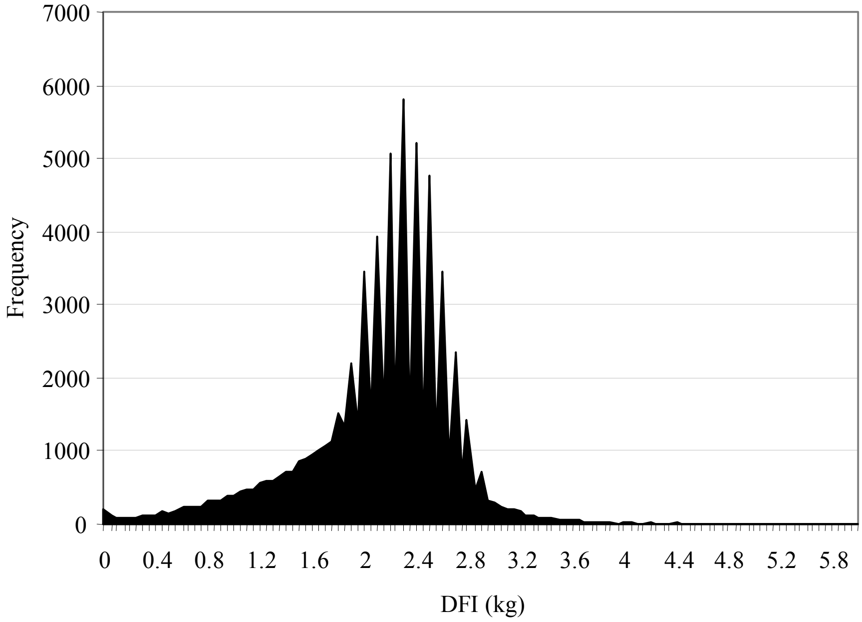

Figure 2 Distribution of daily feed intake (DFI – rounded to 0.5 kg)

The three daily feeding pattern traits were expressed as the total feed eaten, time spent feeding and number of visits **per hour per day as a proportion** of the total feed eaten, time spent feeding and number of visits **per day** (Figure 3). The feeding pattern described shows a diurnal feeding pattern with two peak feeding times, the first at 10.00 h and the second between 16.00 h and 17.00 h. Between 10.00 h and 18.00 h the proportion of visits is higher than the feed eaten. In contrast, the proportion of visits is lower than feed eaten from midnight to 9am. The interesting aspect of this feeding pattern of all animals is the difference between the percentage eaten from 23.00 h to midnight (< 1%) and the percentage eaten from midnight to 01.00 h (~ 5%). This observation led to the description of the trait %6am, which was defined as the percentage of the daily feed consumption eaten before 06.00h (%6am).

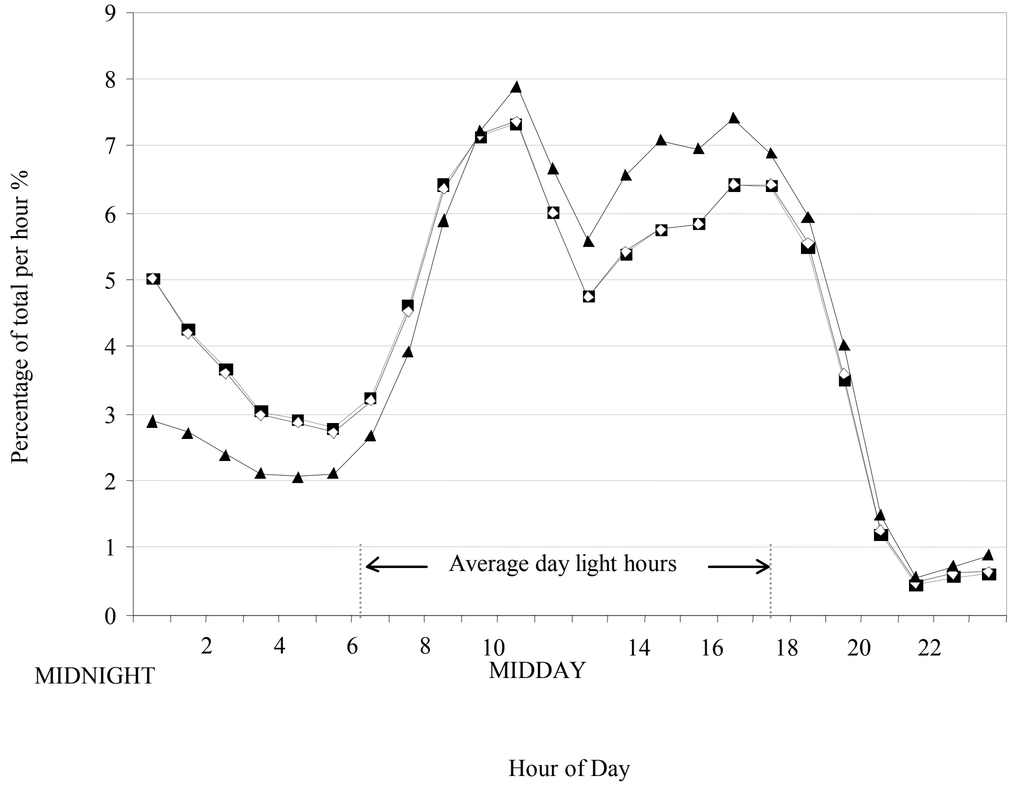

Figure 3 Average feed eaten per hour (■), average time spent feeding per hour (◊) and average number of visits per hour (▲) as a percentage of the total feed eaten, time spent feeding and total number of visits per day, respectively.

The trait %6am is indicative of a specific feeding pattern of the animal, which potentially has an influence on the way an animal grows and consequently the performance traits. Approximately 15% of animals ate more than 50% of their allowance before 06.00 h (Figure 4).

Under *ad libitum* feeding it is expected that the percentage of feed eaten between 23.00 h and midnight is similar to the percentage of feed eaten in the next hour. However, the daily feed allowance was allocated at midnight and feeding patterns differed before and after midnight. The discrepancy between the percentage of food eaten either side of midnight indicates that there are hungry animals waiting to be fed, as a result of the restricted feeding regime. The variation in the amount of feed eaten prior to 06.00 h indicates that some animals may have been hungrier in the early morning, and by implication more restricted, than others. Additional support for this could come from the recording of unsuccessful feeder visits, where an animal attempted to obtain feed but had no more allocation. However, this information was not available.

The observed feeding pattern of animals in this study is in agreement with a study by (Ramaekers 1996) that compared feeding behaviours of animals fed under *ad libitum* and restricted feeding regimes. Feed was allocated to the animals at midnight each day and they too observed the restricted animals eating shortly after the daily feed allowance was allocated. Unsuccessful visits were recorded in the study and they found that the number of visits to the feeders was greater for the restricted animals than the *ad libitum* fed animals, observed as an increase in the number of unsuccessful visits. This observation supports the assumption that some pigs are eating during early morning hours because they are hungry and are restricted by their feed allocation.

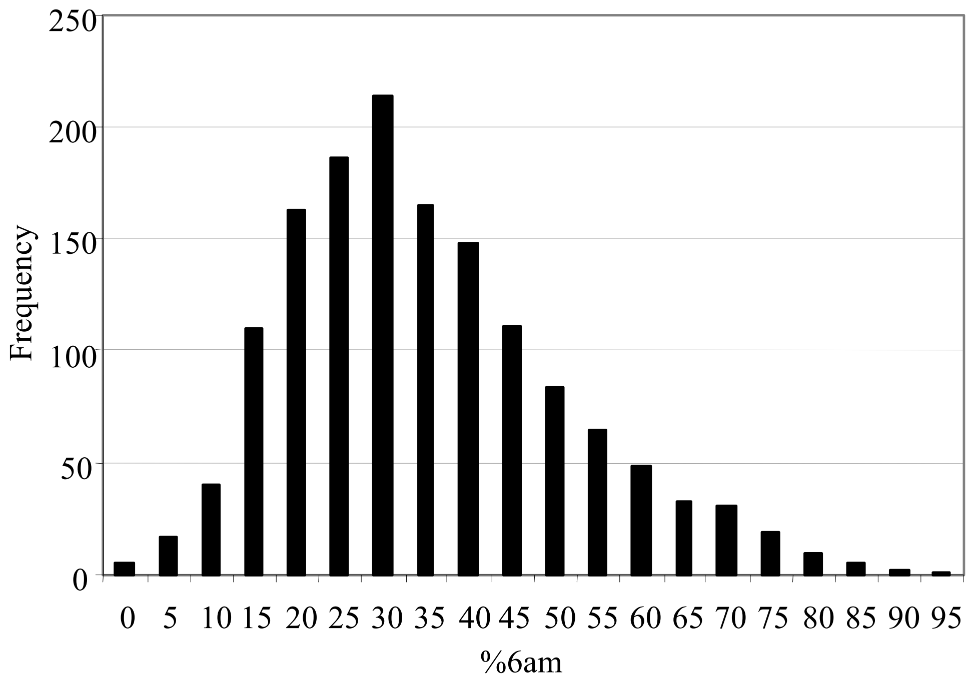

Figure 4 Distribution of feed eaten before 06.00 h as percentage of total (%6am – rounded to nearest 5%)

On average, pigs ate 360 grams of feed per visit, had seven visits per day and ate 35% of their feed early in the morning (Table 2). The four feeding pattern traits (FIV, FTV, NVD, %6AM) have a large variation as shown by the respective coefficient of variation (defined as 100 times the standard deviation divided by the mean). The coefficients of variation were all above 45% in comparison to 10.8 for daily feed intake and 14% for daily feeding time.

Table 2 Mean (x), standard deviation (Std), minimum (Min), maximum (Max) and coefficient of variation (CV) for all feeding pattern traits[A].

Trait	N	Units	x	Std	Min	Max	CV
FIV	1459	kg	0.36	0.17	0.04	1.19	47.2
FTV	1459	hrs	0.13	0.06	0.02	0.43	47.4
DFI	1459	kg	2.10	0.27	1.25	3.19	10.8
DFT	1459	hrs	0.80	0.11	0.46	1.29	14.0
NVD	1459	visits	7	4	2	31	49.3
%6am	1456	%	35	16	0.04	93	46.0

[A] FIV – feed intake per visit; FTV – feed time per visit; DFI – daily feed intake; DFT – daily feed time; NVD – number of visits per day; %6am – percentage of feed eaten before 06.00 h;

Analyses

Testing of fixed effects for all feeding pattern traits was carried out using PROC GLM in (SAS, 1988). The fixed effects tested for each feeding pattern trait were contemporary group (CG), which was the group of animals tested at the same time in each pen, the breed of the animal (BREED), the feeding level the animal was assigned to (LEVEL) and the number of days the animal was on test (NDT, 42-49 days). The numbers of animals representing each breed were 527, 517 and 415 for breeds 1, 2 and 3 respectively. For each feeding pattern trait the weight at the start of test (WTIN, with a mean of 71kg, a standard deviation of 9kg and ranging from 49 to 106 kg) was fitted as a covariate nested within the feeding level (WTIN(LEVEL)).

All analyses to estimate variance components were performed using ASREML (Gilmour, Cullis et al. 1999). An individual animal model, with two generations of pedigree information (parents and grandparents), was used to estimate genetic parameters. Litter was considered as a random permanent environmental effect for all traits.

Initially, single trait analyses were carried out with and without the litter effect being fitted. A likelihood ratio test was used to test whether the model including litter as a random effect provided a better fit than the model without litter. However, litter was not included as a random effect in the two-trait analyses because litter was often confounded with the contemporary group effects, which resulted in numerous convergence problems.

Heritabilities for feeding pattern traits

Heritabilities were high for feed intake per visit and feeding time per visit (0.42 and 0.43; Table 3.). Other heritabilities ranged from 0.25 for percentage of feed eaten before 6am to 0.31 for daily feeding time. Heritabilities were reduced by 0.10 to 0.13 when litter was included in the model as a second random effect (see (McSweeny 2002) for details).

All estimates for the feeding pattern traits were within the range of current literature estimates (von Felde et al. 1996; Labroue et al., 1997; Guéblez et al. 1997; Hall, 1997) In contrast, the heritability estimate for feeding time per visit in this study was 0.43 (±0.08) compared to 0.27 (±0.16) (de Haer and Vries 1993) and 0.11 (±0.05) (Hall, 1997). The significant increase in heritability for FTV could be due to the set rate of feeding of the feeders. The constant rate of feeding forces animals to adjust their feeding time to achieve their desired meal size, in accordance with the adaptation principle described by Nielsen (1999). The heritabilities of feed intake per visit and feeding time per visit are very similar with a constant rate of feeding and adaptation of feeding time; feed intake per visit and feeding time per visit are equivalent traits. The trait %6am has not been investigated in any other known study, however, a moderate heritability estimate of 0.25 indicates that this trait would respond to selection.

Table 3 Heritability (h^2) (with standard errors in brackets) and phenotypic variance (V_p), for feeding pattern traits averaged over test – litter effect not fitted

Trait	h^2	V_p
Feed intake / visit (kg)	0.42 (0.08)	0.0218
Feeding time / visit (hrs)	0.43 (0.08)	0.00318
Daily feed intake (kg)	0.29 (0.07)	0.0347
Daily feeding time (kg)	0.31 (0.07)	0.00671
Number of visits / day (visits)	0.29 (0.07)	9.88
Percentage of feed eaten before 6am (%)	0.25 (0.07)	179

Correlations between feeding pattern traits

A number of traits were effectively the same trait, which was reflected through correlations that were at the end of the parameter space (close to 1). For example, it was not possible to estimate correlations between feed intake per visit and feeding time per visit (Table 4). Similarly, daily feed intake and daily feeding time were genetically the same trait (genetic correlation: 0.97). These high correlations can be explained by the set rate of feeding (amount of feed dispensed per second), which implied that feed intake per visit (or per day) was equivalent to feeding time per visit (or per day). Pigs with high feed intake per visit will have fewer visits per day. However, the number of visits per day has no significant genetic relationship with daily feed intake (or daily feeding time).

Table 4 Phenotypic correlations, first line above diagonal, environmental correlations, second line above diagonal and genetic correlations (in **bold**) (standard errors in brackets), below diagonal, between feeding pattern traits.

Trait	FIV	FTV	DFI	DFT	NVD	%6am
FIV		NE	.35 (.03)	.34 (.03)	-.74 (.01)	.57 (.02)
		NE	.29 (.07)	.18 (.07)	-.70 (.03)	.55 (.05)
FTV	NE		.35 (.03)	.39 (.03)	NE	.57 (.02)
			.28 (.07)	.26 (.07)	NE	.54 (.05)
DFI	**.48 (.13)**	**.50 (.13)**		.88 (.01)	-.13 (.03)	.43 (.02)
				.84 (.02)	-.12 (.06)	.33 (.05)
DFT	**.61 (.11)**	**.62 (.11)**	**.97 (.02)**		-.12 (.03)	.42 (.02)
					-.08 (.06)	.29 (.06)
NVD	**-.86 (.06)**	**NE**	**-.14 (.18)**	**-.21 (.17)**		-.41 (.02)
						-.44 (.05)
%6am	**.64 (.11)**	**.66 (.10)**	**.69 (.12)**	**.74 (.11)**	**-.33 (.17)**	

NE = Not estimable

Therefore, a constant rate of feeding has an effect on the description of the feeding pattern traits. This effect is due to the animals being forced to adapt to the set rate of feeding by staying in the feeders longer to obtain the desired feed intake, which may be longer in comparison to unconstrained feeding conditions. Previous literature estimates also showed a large genetic correlation between feed intake per visit and feeding time per visit and a positive correlation between daily feed intake and daily feeding time (0.93 and 0.31, respectively, (Hall, et al. 1999). In the study by Hall *et al.* (1999), the rate of feeding was not manually set and was determined by the individual animal. The differences in genetic correlations estimated between daily feed intake and daily feeding time for the two studies indicates that a constant rate of feeding has a larger influence on the daily feed intake than on the feed intake per visit.

The genetic association between feed intake per visit and feed eaten before 6am showed that the animals eating at this time were eating larger meals (rg: 0.64) and therefore making fewer visits (rg: -0.33), possibly because there were less animals feeding at this time and less chance of being interrupted while feeding. In addition, these animals may have been the more dominant ones and therefore did not accept interruptions.

Genetic correlations between feeding pattern and performance traits

Genetic parameters for performance traits have been presented before and will not be repeated here (see McSweeny, 2002 for further details). Genetic correlations between feeding pattern traits and lifetime growth rate (lADG), test daily gain (tADG), feed conversion ration (FCR) and backfat at the P2 site are shown (Table 5). Genetic correlations between daily feed intake and both growth rate traits as well as backfat were positive ranging from 0.45 for backfat to 0.78 for lifetime growth rate. The genetic correlation between daily feed intake and feed conversion ratio was zero, which was due to the restricted feeding regime.

Genetic correlations between feed intake per visit and growth rate traits were positive (0.22 and 0.52). However, this trait had no significant genetic correlation with backfat and feed conversion ratio. Genetic correlations between percentage of feed eaten before 6am were 0.32 and 0.57 for growth rate during test and lifetime average daily gain. The positive genetic correlation between percentage of feed eaten early in the morning and backfat shows that pigs that eat a larger amount of feed early in the day have a higher feed intake, a higher growth rate and a higher fat deposition.

The genetic correlations between number of visits and other performance traits were not significantly different from zero, based on standard errors. This implies that recording the number of visits in breeding programs using the QAF electronic feeders would not add information that could be used for the genetic improvement of performance traits. Previous studies that estimated genetic correlations between NVD and performance traits (see Von Felde *et al*., 1996; Labroue *et al*., 1997 and Hall *et al*., 1999) found significant correlations between number of visits and the performance traits. Hall *et al*. (1999) suggested that food intake and number of visits would be useful in a selection index. This is not the case in this study possibly because the number of visit are likely to be truncated for animals that are restricted in their feed intake. In addition, the number of unsuccessful visits was not included in the data, which may have made this trait less informative.

Table 5 Genetic correlations first line in **bold**, phenotypic correlations, second line in *italics* and environmental correlations, third line (standard errors in brackets) between performance traits and feeding pattern traits averaged over test.

Trait[A]	tADG	lADG	FCR	FATP2
FIV	**0.22 (0.15)**	**0.52 (0.11)**	**0.04 (0.16)**	**0.01 (0.13)**
	0.14 (0.03)	0.24 (0.03)	0.04 (0.07)	0.03 (0.03)
	0.09 (0.08)	-0.01 (0.10)	0.05 (0.03)	0.06 (0.10)
FTV	**0.22 (0.15)**	**0.51 (0.11)**	**0.05 (0.16)**	**0.002 (0.13)**
	0.13 (0.03)	0.23 (0.03)	0.05 (0.03)	0.04 (0.03)
	0.08 (0.08)	-0.02 (0.10)	0.05 (0.07)	0.08 (0.10)
DFI	**0.56 (0.12)**	**0.78 (0.07)**	**0.01 (0.18)**	**0.45 (0.13)**
	0.58 (0.02)	0.73 (0.02)	-0.08 (0.03)	0.27 (0.03)
	0.58 (0.05)	0.70 (0.04)	-0.11 (0.07)	0.16 (0.09)
DFT	**0.43 (0.14)**	**0.69 (0.08)**	**0.12 (0.18)**	**0.39 (0.13)**
	0.48 (0.02)	0.64 (0.02)	-0.04 (0.03)	0.24 (0.03)
	0.50 (0.05)	0.61 (0.05)	-0.11 (0.07)	0.13 (0.09)
NVD	**0.06 (0.18)**	**-0.22 (0.17)**	**-0.12 (0.18)**	**0.002 (0.15)**
	0.02 (0.03)	0.01 (0.03)	-0.10 (0.03)	-0.01 (0.03)
	0.01 (0.07)	0.15 (0.08)	-0.09 (0.07)	-0.02 (0.09)
%6am	**0.32 (0.17)**	**0.57 (0.12)**	**0.16 (0.19)**	**0.20 (0.16)**
	0.23 (0.03)	0.35 (0.03)	-0.002 (0.03)	0.13 (0.03)
	0.19 (0.06)	0.22 (0.07)	-0.06 (0.06)	0.11 (0.08)

[A] FIV – feed intake per visit; FTV – feed time per visit; DFI – daily feed intake; DFT – daily feed time; NVD – number of visits per day; %6am – percentage of feed eaten before 06.00 h; tADG – test daily gain; lADG – lifetime growth rate; FCR – feed conversion ratio; FATP2 – backfat at P2 site

Implications

Implications of these genetic parameters were evaluated through index calculations. A standard index using economic weights derived by Cameron and Crump (2001) for the Australian industry were used. The initial index was based on using information on lifetime growth rate, backfat and litter size. This index did not use any information on daily feed intake from the electronic feeders. The genetic gain was set to 100 for this basic index. The genetic gain increased by 11.4% when information on test daily gain and daily feed intake was used. Using extra information on feed intake per visit only increased economic gain by a further 1.3% to 112.7%. The economic gain increased to 116.8 % when information on percentage of feed eaten before 6am was also included in the index. This trait provides information for two traits in the breeding objective – lifetime growth rate and backfat.

Table 6 Summary of breeding objective traits (**bold**) and selection criteria for each index calculated along with economic gain (Index 1 = 100) and accuracy.

Trait	Index 1	Index 2	Index 3	Index 4
lADG	X	X	X	X
BF	X	X	X	X
FCR				
NBA	X	X	X	X
TADG		X	X	X
DFI		X	X	X
FIV			X	X
%6am				X
Economic gain in percentage	100	111.4	112.7	116.8
Accuracy	0.523	0.584	0.590	0.613

Conclusions

Any breeding company that records daily feed intake in group housed pigs with electronic feeders should use the extra information that is available from feeding pattern traits. However, feeding pattern traits may be quite different between feeder systems as well as feeding regime and have to be determined for each performance recording system. Furthermore, all available information should be recorded including unsuccessful visits of a pig to the electronic feeder.

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