When pigs fly; what does it mean?

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Introduction

There is some evidence in pigs that reducing animal stress levels could improve pork quality through a reduction in the incidence of both pale soft exudative and dark firm dry pork (Guardia *et al*. 2005). A classic example of the link between stress and meat quality is the halothane or porcine stress syndrome gene. Animals carrying the gene are susceptible to acute stress prior to slaughter, resulting in an increased incidence of pale soft exudative pork (Hambrecht *et al*. 2005). In addition, the selection for calmer, less stressed pigs could be beneficial to animal welfare and ease stock handling, lowering staff occupational health and safety risks. To successfully select for calmer pigs with lower stress levels, it is important that a method of selection meeting several criteria be developed. These include; the development of an objective, cost effective, on farm measure of a temperament trait that is related to stress, evidence that the temperament trait is under genetic control, the development of an appropriate statistical model to estimate additive and residual variances for the trait and an understanding of how it is correlated with production and meat quality measures.

In beef cattle an objective measure of temperament called flight time (time to cover a set distance when exiting a form of restraint) that meets the above criteria has been developed. It is thought that this trait is related to an animal’s fearfulness and as such is a proxy measure of stress (Petherick *et al*. 2002). In cattle, flight time has been found to be both heritable and genetically correlated with tenderness. The study by Kadel *et al.* (2006) showed that longer cattle flight time (animals that moved slower) was genetically correlated (0.33) with more tender meat which is a prime determinant of beef quality. In a similar study Reverter *et al.* (2003) reported that cattle flight times were positively genetically correlated (0.37) with consumer assessed tenderness, negatively genetically correlated with shear force (-0.48) and also lowly genetically correlated (0.09) with higher finishing growth rates and fat depth measured at the p8 site (0.18). The aims of this investigation were to asses if a similar measure of flight time was heritable in pigs, and to estimate genetic correlations between flight time and the important production traits backfat and average daily gain.

Materials

Data originating from Belmont, a farrow to finish commercial piggery located in Queensland Australia, were recorded between April 2004 and November 2007. Pigs were measured for backfat at the P2 site using ultrasound, weighed and flight time tested by six different piggery staff. The flight time measurement of pigs is analogous to the method used in beef cattle, with several small modifications (Crump 2004). In pigs, flight time is the time taken for a pig to clear a one meter distance between light sensitive start and stop diodes set 0.25 and 1.25 meters from the weigh scale exit (Figure 1). Occasionally pigs were reluctant to exit the weigh scales and were encouraged to do so by the measuring staff. Pigs were subjectively scored between one and five by the measuring staff based upon the amount of encouragement required to move it past the stop diode. A score of 5 required the most encouragement.

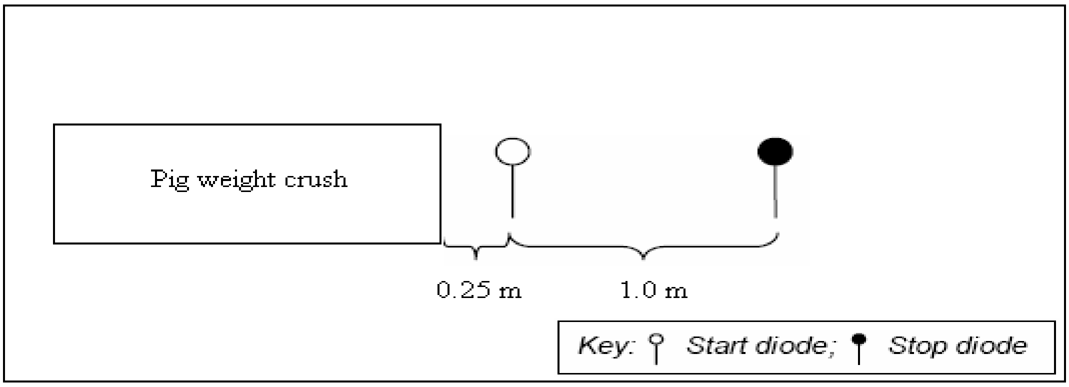

Figure 1. Flight time measuring system in pigs modified from Crump (2004)

The order of pigs within a group tested for flight time was recorded and ranged between 1 and 37. Pig number 1 was for example the first pig tested from a grower pen on a given date. Pigs were grown in individual pens (16 levels) and were tested on 128 different dates. Grower groups were reconstructed from these data where animals tested from the same pen within 15 days were combined into single grower groups. Post editing grower group size ranged from 22 to 37 pigs (Table 1).

These data were merged with Belmont production records for the same animals to obtain information on pig breeds (63% Large White, 29% Landrace, 8% Duroc), sex and date of birth. From these data pig ages at testing and lifetime average daily gain were derived. A pedigree file consisting of 35,582 animals and extending back to January 1995 was available.

Table 1. Mean, standard deviation (SD), minimum (min) and maximum (max) values for characteristics of the Belmont flight time data set

	n	mean	SD	min	max
weight (kg)	9429	103	9.27	75	131
average daily gain (g/d)	9429	671	67.8	467	870
backfat (mm)	9429	11.4	2.12	7.0	18.0
age (days)	9429	154	8.28	130	190
flight time (sec)	9275	2.09	1.14	0.08	9.4
flight time group size (n)	516	18.1	9.72	1.00	37
grower group size (n)	353	28.4	3.78	22	37

Statistical Methods

Preliminary investigation of flight time records revealed a slightly positively skewed distribution with a spike of animals attaining a flight time record of eight seconds. This spike represented an equipment failure and animals with a flight time of exactly eight seconds were removed. Animals exceeding ten seconds for flight time were also removed from the data as were animals that encountered some form of difficulty in travelling the one meter interval. Animals exceeding three standard deviations from the mean for weight, age, average daily gain and backfat were similarly removed from the data. Fixed effect models used to generate genetic parameters and least squares means were derived using a 0.05 significance level in the SAS (1999) GLM procedure. Fixed effects modelled for flight time were breed, date of test, pig number and staff score (the amount of encouragement required to move the pig). Fixed effects modelled for average daily gain and backfat were breed, test date, and sex. The backfat model also included end weight as a linear covariate.

Estimates of heritabilities, common litter effects and group effects for flight time, average daily gain and backfat were obtained by fitting univariate animal models using ASReml (Gilmour *et al.* 2006). A Log Likelihood ratio test was used to evaluate the significance of individual random effects. Estimates of genetic correlations between traits were generated from a series of bivariate analyses fitting all the random effects.

Comparative studies

Several comparative studies have been carried out on flight time in pigs and cattle, the basic statistics of which are summarised in Table 2. The study conducted by Hansson *et al.* (2005) using 3,567 records had a similar mean and standard deviation to this study which differed notably from that used by Bunter (2005). Reasons for this marked difference could include different operator techniques of encouraging pigs from their crates, a different testing set up and/or an underlying difference in fearfulness in the pig populations.

Table 2. Comparison of flight time means and variations from different studies

	Mean	Standard deviation	Coefficient of variation (%)
Current	2.09	1.14	55
Hansson *et al.* (2005)	2.03	1.27	63
Bunter (2005)	1.09	0.30	27
Reverter *et al.** (2003)	1.23	0.53	43
Kadel *et al.** (2006)	1.42	0.60	42

* Study conducted on beef cattle

Heritabilities

Flight time was heritable in this study (0.16 to 0.18) (Table 3), which is in accordance with results from two previous studies of this trait, conducted upon two different Australian pig populations. Hansson *et al.* (2005) estimated a flight time heritability of 0.20±0.04 while Bunter (2005) using a smaller sample of pigs (n=963) also obtained a heritability estimate of 0.20±0.07.

Flight time heritability estimates dropped from 0.18±0.02 to 0.16±0.02 with the inclusion of permanent environment of the litter random effect and remained unchanged when the additional random effect grower group was included. Log Likelihood ratio tests indicated that the model using three random effects was a better fit than the two random effects (animal and permanent litter) or the one random effect (animal) models for flight time. The flight time heritability estimates indicate that genetic progress can be achieved if flight time was used as a selection criterion.

Table 3. Heritabilities (h^2) permanent environment of the litter effects (c^2) and grower group effects (g^2) and phenotypic variations ($\sigma^2 p$) from the three random effect models for average daily gain, backfat and flight time and their standard errors

Model	Trait	h^2	c^2	g^2	$\sigma^2 p$
A*	average daily gain	0.35±0.03			3505±77
A+Pe**	average daily gain	0.23±0.03	0.09±0.01		3380±71
A+Pe+G***	average daily gain	0.20±0.03	0.07±0.01	0.15±0.02	3611±89
A	backfat	0.45±0.03			3.51±0.09
A + Pe	backfat	0.40±0.04	0.04±0.01		3.44±0.09
A + Pe + G	backfat	0.40±0.04	0.04±0.01	0.03±0.01	3.48±0.04
A	flight time	0.18±0.02			1.22±0.02
A + Pe	flight time	0.16±0.02	0.03±0.01		1.21±0.02
A + Pe + G	flight time	0.16±0.02	0.02±0.01	0.02±0.01	1.22±0.02

*A = Animal **Pe = Permanent environment of the litter *** Permanent environment of the group

The inclusion of the third random effect grower group had no effect on the heritability estimate for backfat but it did reduce the heritability estimate for average daily gain (Table 3). The Log Likelihood ratio tests however indicated that the more appropriate model to estimate average daily gain or backfat heritabilities included the grower group as an additional random effect.

The 0.15±0.02 estimate of the random effect grower group for average daily gain is significant (Table 3). Arango *et al*. (2005) also found, on the basis of a Log Likelihood ratio test, that the inclusion of a third random effect for grower group was significantly better for estimating variance components than a model using either one or two random effects. Similarly, a study conducted by Bergsma *et al*. (2008) found that social effects influenced additive variance for average daily gain but not for backfat. Taken together these results indicate that elements within a group have a substantial influence on growth but are not as influential upon backfat or flight time.

Genetic correlations

In this study, flight time had no significant genetic correlation with average daily gain (Table 4). Hansson *et al*. (2005) also reported a non significant genetic correlation between flight time and average daily gain of 0.21±0.16. Conversely Bunter (2005) did find a significant genetic correlation of 0.34±0.16, however, the flight time mean and standard deviation (Table 2) used by Bunter (2005) differed considerably from those used in this study or that of Hansson *et al*. (2005) (Table 2). In summary, these results show that selection for flight time would have little to no genetic effect upon average daily gain.

Flight time was, however, genetically correlated with backfat (Table 4). There was a negative correlation (-0.46±0.18) between flight time and backfat due to the permanent environment of the litter effect. Genetic correlations between flight time and backfat were 0.26±0.11 and 0.14±0.16 respectively in the other two Australian studies by

Hannson (2005) and Bunter (2005). Overall, the genetic correlation between flight time and backfat suggests that the direction of this correlation is unfavourable and that selection for reduced backfat may result in animals with a reduced flight time.

The phenotypic correlations between flight time and average daily gain or backfat were not significantly different to zero. This is consistent with the phenotypic correlation estimations reported by both Hansson *et al.* (2005) and Bunter (2005).

Table 4. Genetic, litter and group correlations (ra, rpe_litter, rpe_group respectively), (above diagonal) and environmental (re) and phenotypic correlations (rp) (below diagonal) for models using the random effects animal, permanent litter and group

		average daily gain	backfat	flight time	
average daily gain			0.15±0.09	-0.05±0.11	ra
			0.22±0.10	0.08±0.14	rpe_litter
			-0.08±0.11	-0.05±0.12	rpe_group
backfat	re	0.09±0.03		0.24±0.10	ra
	rp	0.10±0.02		-0.46±0.18	rpe_litter
				0.15±0.15	rpe_group
flight time	re	-0.03±0.02	-0.01±0.02		
	rp	-0.03±0.02	0.04±0.02		

Pork Quality

The two main quality defects in pork are pale soft exudative meat and dark firm dry meat. Both are related to stress and the pH of the carcass (Fernandez and Torenberg, 2007). Pale soft exudative meat results when a carcass pH drops to values below 6.0 within the first hour of slaughter and dark firm dry meat occurs when the final carcass pH remains above values of 6.0, 24 hours post slaughter (Guardia *et al.* 2005). Pale soft exudative meat is the result of animals suffering acute stress prior to slaughter while dark firm dry meat is the result of an animal depleting its glycogen reserves through chronic stress prior to slaughter (Guardia *et al.* 2005). Lactic acid build up through anaerobic metabolism of muscle glycogen post slaughter drops meat pH (Fernandez and Torenberg, 2007) which has beneficial effects upon meat tenderness provided that it does not occur too quickly (Thompson 2002). It should be important to producers of pork that incidences of dark firm dry meat be avoided as it adversely affects consumer satisfaction and is more conducive to bacterial growth leading to a reduced shelf life for the dark firm dry product (McCaw *et al.* 1997). Pork quality defects would reduce pork consumption as dissatisfied consumers would be averse to repeating bad experiences. This would adversely affect prices through a reduction in product demand. Theoretically the reverse of this should also be true and higher pork prices should result from increased demand if high quality pork can be consistently supplied.

Bunter (2005) reported a significant genetic correlation between flight time and meat pH recorded 24 hour post mortem of -0.53±0.21. This genetic correlation indicates that animals with faster flight times breed animals with higher final carcass pH values. Meat from carcasses with high ultimate pH values is tougher. Higher final pH meat is associated with dark firm dry pork and has a reduced shelf life. Therefore, selection based upon slower (higher) flight times should assist in improving overall pork quality through increased tenderness and a lowering of the incidence of dark firm dry pork.

Breed effects

After adjustment for fixed effects it was found that a significant difference in flight times existed between Large White and both Landrace and Duroc pig breeds (Table 5). Large White pigs moved faster from the weigh scales. Significant differences also existed between Large White pigs and the other two breeds for average daily gain and backfat. Both Cameron (1990) and Hermesch *et al.* (2000) reported that the meat and eating quality of pork is detrimentally affected by selection for lean meat content. The higher daily gain and lower backfat results for Large White pigs when compared to the other two breeds (Table 5) suggest that these pigs have experienced more selection pressure for reduced fat and increased daily gain, which is expected to affect their genetic potential for meat and eating quality and is associated with lower flight times.

Table 5. Least squares means (standard errors) for flight time, average daily gain and backfat by breed

	Flight time (seconds)	Average daily gain (g/day)	Backfat (mm)
Duroc	2.7(0.1)	655(2.7)	12.6(0.09)
Landrace	2.7(0.1)	665(1.4)	11.6(0.04)
Large White	2.3(0.1)	674(1.1)	11.5(0.04)

Conclusions

So just what does it mean when pigs fly? The flight time heritability estimate indicates that genetic progress is achievable if flight time was used as a selection criterion in pigs. When estimating the heritability of flight time, backfat or average daily gain the permanent environment of the litter and the grower group should be fitted as additional random effects. The genetic correlation between flight time and average daily gain signifies that selection for higher flight time should not have a significant negative effect upon growth. However, the genetic correlation between backfat and flight time indicates that selection for higher flight time would detrimentally affect progeny fat levels.

Genetic relationship between faster pigs and higher carcass pH values was found by Bunter (2005), which support genetic correlations found in beef between flight time and tenderness (Reverter *et al.*, 2003; Kadel *et al.*, 2006). Therefore it is likely that selection based upon a pig’s ability to fly (or more precisely inability to fly) could be used as a proxy selection method for improving pork quality through increased tenderness and a reduction of dark firm dry pork. However, a study connecting pork eating quality and flight time is required to determine this genetic relationship.

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