SELECTION FOR GROWTH RATE IN PIGS ON RESTRICTED FEEDING. GENETIC PARAMETERS AND CORRELATED RESPONSES IN RESIDUAL FEED INTAKE.

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SUMMARY

Residual Feed Intake (RFI) represents the deviation of the actual *ad libitum* food consumption of each animal from that predicted on the basis of its growth rate alone or combined growth rate and backfat. After four years of selection of a line for high and one for low post weaning growth rate on restricted feeding, the high line exhibited a significant reduction in residual feed intake relative to the low line. This indicated a lower energy requirement for maintenance in the high than the low line, possibly due to reduced physical activity of the animals. Estimates of genetic parameters showed that RFI was moderately heritable. Genetic correlations of RFI with backfat and food conversion ratio were moderately to highly positive, suggesting that selection for low RFI would improve carcass lean content and efficiency of food utilisation.

Key words: heritability, selection, *ad libitum*, restricted feeding

INTRODUCTION

Selection for production traits, especially for high efficiency of lean production, may lead to correlated genetic changes in maintenance energy requirement (ME_m) of the animal because lean body mass directly influences the thermal capacity and the rate of heat loss; and indirectly affects the basal metabolic heat production and maintenance requirement (Kolstad and Vangen, 1996). Knowledge in this area is presently incomplete. Generally, the literature appears to show that selection for high efficiency of lean production is associated with high metabolic heat production and maintenance requirements in pigs (Stundstol et al., 1979). Selection for high lean growth rate on restricted feeding may however result in a reduced maintenance requirement. Vangen (1980) demonstrated that pigs selected for increased lean growth on semi-restricted feeding were able to maintain heavier body weights than fat pigs on the same amount of feed, even though lean pigs had 6% less fat, and it costs less energy to maintain fat than protein. The results of McPhee et al. (2000) showed that sows selected for high lean growth on restricted feeding exhibited more placid behaviour around farrowing, possibly resulting in a reduced energy requirement for activity driven maintenance. This has been found to account for as much as 8- 10% of total metabolisable energy intake in pigs (Henken et al., 1991).

Due to the high cost of testing facilities there has been little development of direct measurements of ME_m. Genetic differences in ME_m have been estimated by feeding animals restricted rations to maintain constant live weight for a fixed period (Taylor and Young, 1967). Recently, residual feed intake (RFI), that is, the amount of feed consumed over that accounted for in tissue deposition, has been proposed not only as an alternative measure of feed efficiency but also as an indicator of ME_m for cattle (Krover, 1988) and poultry (Luiting et al., 1990).

The current study reports correlated responses in RFI, its heritability estimate, and genetic correlations with production traits in Large White pigs selected for high and low body weight gain on restricted feeding, when performance tested on *ad libitum* individual feeding.

MATERIALS AND STATISTICAL METHODS

Animals and performance testing procedures. On 33 occasions, 12 pigs of each sex were sampled across litters from the high and the low lines, placed in individual pens at 50 kg and fed *ad libitum* over a 6 week period. All animals were fed a diet containing 14 MJ DE, 0.65g/MJ available lysine. Live weights were recorded at the start and end of the test, and used to calculate average daily gain (ADG). Daily food intake (DFI) was calculated by subtraction of the total amount of food refused from the total amount of food offered during the test period and dividing by the number of days on test. The food conversion ratio (FCR) was the ratio of DFI over ADG. Measurement was made of ultrasonic P2 backfat thickness (BF) at the end of the test.

Data characteristics. The pedigree and data structures of the individually housed pigs are given in Table 1.

Table 1: data structure and characteristics

Years	Animals	Sires	Dam
Base	118	16	61
1997	168	27	82
1998	141	30	77
1999	206	35	106
2000	119	19	69
Total	**752**	**88**	**266**

Estimation of residual feed intake. Residual feed intake (RFI) was computed as the difference between the observed daily feed intake (DFI) and the predicted feed intake (pDFI). The observed daily feed intake was corrected for effects of batch and sex and their interactions using the following model:

$$DFI_{ijk} = \mu + B_i + S_j + B \text{ x } S_{ij} + e_{ijk}$$

Where:

DFI is the observed daily feed intake of the individual k
μ is adjusted mean
B_i is the effect of batch (i = 1, 2, 3, …33)
S_j is the effect of sex (j = 1, 2)
B_{ij} X S is the interaction of batch and sex
e_{ijk} is the random error term

The predicted feed intake was estimated from different regression models that included 1) growth rate (RFI_1) and 2) growth rate and backfat (RFI_2) after adjustment for the fixed effects of batch (33 classes) and sex (male and female). The general model is as the following:

$$pDFI = = \mu + B_i + S_j + B \text{ x } S_{ij} + b_1GR_{ijk} + b_2FT_{ijk}$$

Where:

pDFI is the predicted daily feed intake.
b_1 and b_2 are partial regression coefficients.
GR is the growth rate (g/d).
FT is P2 backfat thickness (mm).

The RFIs were calculated per pig using the following models:
$RFI_1 = DFI – (\mu + B_i + S_j + B \text{ x } S_{ij} + 0.598 \text{ x } GR_{ijk})$
$RFI_2 = DFI – (\mu + B_i + S_j + B \text{ x } S_{ij} + 0.545 \text{ x } GR_{ijk} + 0.780 \text{ x } FT_{ijk})$

Genetic (co) variance components. Genetic and environmental variance components for all traits were estimated with the animal model- restricted maximum likelihood method using the average information algorithm of Gilmour et al. (1999) (ASREML). The model included fixed effects of batch and sex and the random effect of the individual animal. Final body weight was fitted as a linear covariate for P2 fat depth.

RESULTS AND DISCUSSION

Correlated response. The correlated responses of residual feed intake to selection for high growth rate on restricted feeding are given in Tables 2 and 3. The high line exhibited lower residual feed intake, indicating a lower energy requirement for maintenance than the low line. This reduced maintenance energy may have been due to reduced physical activity even though this has not been measured in these lines. In a different study, McPhee et al. (2000) found that sows in a line selected for high lean growth on restricted feeding displayed reduced physical activity.

Table 2: Correlated response in residual feed intake (RFI) of pigs on *ad libitum* individual feeding throughout four years of selection for high and low growth rate.

Criteria /Years	RFI_1 (g/d)		RFI_2 (g/d)	
	High	Low	High	Low
1997	-0.15	3.58	2.61	0.81
1998	-10.66	26.45	-1.69	28.87
1999	-15.60	17.33	-20.61	2.21
2000	-10.40	52.96	-15.63	40.00
Standard Error of Difference	24.63		24.58	

Table 3: Overall correlated response in RFI of pigs on *ad libitum* individual feeding throughout four years of selection for high and low growth rate.

Criteria	High line	Low line	Standard Error of Difference
RFI_1 (g/d)	-11.63	13.87	7.95
RFI_2 (g/d)	-10.51	7.19	7.92

Genetic parameters. The current estimates of heritabilities for RFI_1 and RFI_2 (Table 4) fall within the range of the literature results recently reported in pigs, which are from 0.2 to 0.47 (Table 5). De Haer and de Vries (1993), and Labroue (1995) reported somewhat higher estimates than the published average (0.45 in Dutch pigs, and 0.46 in French Large White and 0.47 in Landrace breeds, respectively). The heritability for RFI_2 estimated from the model including backfat and growth rate is somewhat lower than that for RFI_1 estimated from growth rate alone. This is consistent with the findings of Johnson et al. (1999). Genetic correlations of RFI with BF and FCR were all positive, suggesting that selection for reduced RFI would decrease BF and improve efficiency of food utilisation.

Table 4: Heritabilities (x 100), and genetic correlations (x 100) of RFI with performance traits

Traits	H^2	ADG	P2- fat	FCR
RFI_1 (g/d)	24 ± 8	*	13 (22)	50 (15)
RFI_2 (g/d)	20 ± 8	*	20 (22)	29 (18)

***Failed to converge**

Variation between studies in the estimates of RFI using phenotypic regression as in this study is difficult to interpret at genetic level. This variation may be explained by differences in models fitted to estimate residual food intake. Residual feed intakes were mostly derived from DFI regressed on ADG and BF (Foster et al. 1983; and Von Fele et al. 1996) or ADG and lean growth or content (De Haer et al. 1993; Mrode and Kennedy, 1993; Labroue 1995) by multiple regression analysis. Johnson et al. (1999) also incorporated initial test age and weight, and loin eye area to estimate four different measures of residual food intake. They found that measures of RFI that included backfat had lower estimates of heritability than those without backfat. Furthermore, variation in RFI comprises numerous intrinsic factors such as variation in food digestibility, in energy efficiency partitioning for maintenance and production or variation in maintenance energy requirements for physical activity, body thermo-regulation, maintenance of body tissues and basal metabolic rate (De Haer et al. 1993).

Table 5: Estimates of heritability and the genetic correlations of RFI with performance test traits

References	h^2	ADG	BF	Loin Eye Area
Foster et al. (1983)	0.30			
De Haer and de Vries (1993)	0.45			
Mrode and Kennedy (1993)	0.34	0.24	0.37	
Labroue (1995)	0.47			
Von Felde et al. (1996)	0.18	0.03	0.00	
Johnson et al. (1999)	0.13	0.15	0.44	-0.29

Estimates were pooled across models or breeds

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