Genetics of efficient lean meat growth under ad libitum and restricted feeding

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Introduction

The potential benefits of selection for efficient lean meat growth under restricted feeding have been indicated by selection experiments by McPhee et al. (1988) and Cameron and Curran (1995). The earlier selection experiment by McPhee et al. (1988) showed that scale feeding better exposed the genetic variation in partitioning of food into lean and fat deposition indicating that it might be the preferred method of selection for efficient lean meat growth. These results were confirmed by Cameron and Curran (1995) who showed that Large White pigs selected for high growth rate under restricted feeding grew significantly faster than pigs selected for high growth rate performance recorded under ad libitum feeding. Both studies tested pigs during their earlier growth stage. In addition, both selection experiments were undertaken in research herds. The manual labour required to restrict pigs is not feasible in commercial conditions. An alternative might be to use electronic feeders which also allow pigs to be restrictively fed. In addition, pigs can be group penned representing commercial conditions much more closely than single pens. Pigs are less efficient during their later part of the growth period and with the shift to heavier carcases it becomes more important to maintain high protein deposition rates in heavier carcasses. A PRDC funded project (UNE23P) was initiated to estimate genetic parameters for performance traits recorded under ad libitum and restricted feeding in boars and gilts. Results from this project obtained after approximately half of the animals have been performance recorded are summarised within this paper.

Design of project

This joint project between AGBU and Bunge Meat Industry started in February 1996 when the first animals were performance recorded. The data presented here includes records until December 1997 when 5850 animals had completed the test. The data includes boars and gilts (Large White and Landrace) which were performance recorded from 70 or 80 kg live weight at the start of performance test to an end weight of approximately 110 kg. The testing period comprised six weeks which, for parts of the data, included an adaptation time of one week at the beginning of test. Animals were penned in groups of 25 to 30 animals with three feeders being installed in each group. The aim of a balanced design of animals over feeding regime by sex classes has been achieved (Table 1) given practical limitations. The number of observations within each class is similar across feeding regime by sex classes. In addition, for a genetic analysis it is best that offspring of sires are evenly distributed over all feeding regime by sex classes. Although not shown explicitly, this goal has also been achieved.

Table 1: Number of pigs within each sex by feeding regime group (after editing)

	Ad libitum feeding	Restricted feeding	Total
Boars	1377	1164	2541
Gilts	1362	1334	2696
Total	2739	2498	5237

Description of data

Two changes in data recording occurred over time. Firstly, later animals were recorded at a higher live weight which reflects the shift to heavier carcasses in Australia. Secondly, based on preliminary analysis, it was decided to allow for one week of adaptation time before pigs would enter the test. These changes occurred in August 1996 and February 1997 and the whole data set can therefore be subdivided into three subdata sets. These three subdata sets are also characterised by different levels of restriction of feed intake (Figure 1). The first data set is characterised by lower means in all performance traits and higher level of restriction in feed intake. Subsequently, this data set was excluded from the analysis. Results presented in this paper include only animals performance recorded after August 1996.

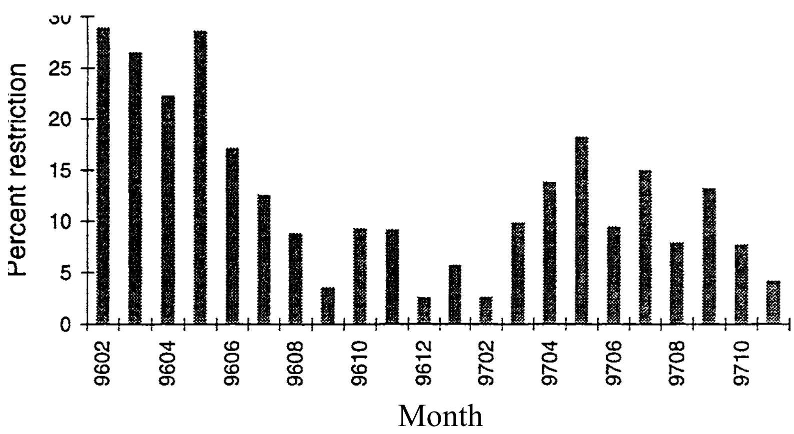

Figure 1: Level of restriction (in percent) over time (year-month)

1. Comparison of means for performance traits across feeding regimes

A number of performance traits were recorded on these animals. Means and phenotypic standard deviations were set to 100 for performance traits of the ad libitum fed group of pigs. This allows the comparison of the effect of feeding regime on raw means and phenotypic variations (Table 2). The traits recorded before test should not systematically be influenced by feeding regime and difference in means and phenotypic variation are due to sampling of animals. For these traits differences in means between feeding groups are small and can be ignored. However, age at test and consequently growth rate, as well as backfat, have a higher phenotypic variation in the group of animals which are fed restrictively.

Traits recorded during test are expected to be influenced by feeding regime. Daily feed intake was restricted to 88% on average in comparison to the ad libitum fed group. This reduction in feed intake has reduced the variation in daily feed intake to 46% of the variation in this trait observed for the ad libitum group. Therefore, animals still vary in their feed intake in the restricted feeding group which is also demonstrated by a coefficient of variation of 7% for this group in comparison to 14% for the ad libitum feeding group.

The question now arises how this restriction in feed intake has influenced means and phenotypic variation of further performance traits. This 12% reduction in feed intake has reduced growth rate during test by 8%, feed conversion ratio by 3% and backfat by 7%. Phenotypic variances in these traits were less affected by this restriction in feed intake and were reduced by 6% for growth rate and by 1% for feed conversion ratio and backfat.

Table 2: Means and phenotypic standard deviations for performance traits recorded under restricted feeding in comparison to traits recorded under ad libitum feeding (variables under ad libitum feeding = 100)

Trait	**mean**	**Variation**
Traits independent of feeding regime		
Weight at test begin	99	97
Age at test begin	99	139
Growth rate before test	100	109
Backfat at test begin	100	111
Traits influenced by feeding regime		
Daily feed intake	88	46
Growth rate during test	92	94
Feed conversion ratio	97	99
Backfat at P2	93	99

Model

A number of fixed effects influencing performance traits were analysed for each feeding regime. The main fixed effects were week of recording and sex of the animal. In addition, the interaction between these two fixed effects was significant. However, these fixed effects are also represented by the group of the animal. Therefore, a group effect equivalent to sex by week was included in the model. Further fixed effects fitted were breed of the animal and animal weight at test begin and at slaughter. The only random effect fitted in the model was the additive genetic effect.

Heritability estimates

Heritability estimates are presented for performance traits in Table 3 for ad libitum feeding and in Table 4 for restricted feeding. The heritability estimate for feed intake is 0.27 for the ad libitum group. This estimate is in agreement with results from UNE17P (Hermesch, 1996). The restriction of feed intake in the second feeding regime group leads to a decrease in variance components, both environmental variations as well as additive genetic variation. In addition the heritability estimate is also decreased (h^2: 0.08). Feed intake under restricted feeding is still heritable which indicates that not all pigs were actually restricted in their feed intake capacity.

Growth rate measured during the test period of five weeks is characterised by a large environmental variation. Consequently, the heritability estimate is also low with an estimate of 0.11 for the ad libitum group. In comparison, the heritability estimate is even lower for the restrictedly fed group of pigs (h^2: 0.08). These low heritability estimates for growth rate during the test period are lower than the estimate obtained in UNE17P. The heritability for growth rate during test was 0.18 applying the same model which does not include litter effect (Hermesch, 1996). The short test period is one cause of this low heritability estimate. Any random differences in weight measurements due to differences in gut fill have a larger effect on growth rate recorded during a short test period with a smaller total gain than on average daily gain recorded during a longer test. For example, the average gain during test is 30 kg under ad libitum feeding and 27 kg under restricted feeding. The total gain is smaller under restricted feeding and therefore these random differences in gut fill have a proportionally larger effect which is reflected in lower heritability estimates for test station growth rate under restricted feeding. In contrast, McPhee et al. (1988) found a tendency of a higher heritability for growth rate under restricted feeding (h^2: 0.41; se:0.15) in comparison to the heritability estimate obtained for growth rate recorded under ad libitum feeding (h^2: 0.28; se:0.19).

Heritability estimates for feed conversion ratio were 0.07 under ad libitum feeding and 0.08 under restricted feeding. Feed conversion ratio is a component trait of feed intake and growth rate. Component traits are more strongly influenced by the individual trait with the larger variation (Simm et al., 1987). In this case, growth rate has the larger variation and heritability estimates of feed conversion ratio are therefore more closely related to growth rate than to feed intake. However, by reducing the variation of feed intake under restricted feeding heritability estimates for feed conversion ratio is increased which is mostly due to a decrease in environmental variation.

Table 3. Number of records (N), heritability estimates (h^2) with standard errors (s.e.) and additive genetic (σ^2_a), environmental (σ^2_e) and phenotypic variances (σ^2_p) for performance traits recorded under ad libitum feeding

Trait	N	h^2	s.e, of h^2	σ^2_a	σ^2_e	σ^2_p
FDINT*	1971	0.27	0.04	0.026	0.071	0.097
ADG	1971	0.11	0.03	1821	15171	16992
FCR	1969	0.07	0.03	0.016	0.194	0.210
LP2	1970	0.36	0.04	2.14	3.8	5.94

* Abbreviations:

FDINT: Daily feed intake during test
ADG: Average daily gain during test
FCR: Feed conversion ratio
LP2: Backfat at P2 recorded with real time ultrasound on the live animal

Variance components are reduced by restricted feeding for all backfat measurements. However, heritability estimates are not significantly different between feeding regimes. In comparison, McPhee et al. (1988) found higher variance components but lower heritability estimates of backfat measurements under ad libitum feeding.

Table 4. Number of records (N), heritability estimates (h^2) with standard errors (s.e.) and additive genetic (σ^2_a), environmental (σ^2_e) and phenotypic variances (σ^2_p) for performance traits recorded under restricted feeding

Trait	N	h^2	s.e, of h^2	σ^2_a	σ^2_e	σ^2_p
FDINT*	1856	0.08	0.02	0.001	0.014	0.015
ADG	1856	0.08	0.02	1018	11669	12687
FCR	1855	0.09	0.03	0.017	0.161	0.178
LP2	1856	0.38	0.05	1.75	2.82	4.57

* for Abbreviations see Table 3

Genetic correlations between performance traits

1. Comparison of genetic correlations between performance traits -within feeding regimes

Feed intake under ad libitum feeding is highly correlated with growth rate (rg: 0.82) and feed conversion ratio (rg: 0.7; Table 5). In contrast, under restricted feeding these genetic correlations are smaller (0.36 for ADG and 0.03 for FCR). Feed conversion ratio has a lower genetic correlation with growth rate under ad libitum feeding (rg: -0.18) but a strong genetic correlation of-0.94 under restricted feeding. Selection for a lower feed conversion ratio under ad libitum feeding leads more to a decrease in feed intake than an increase in growth rate. In contrast, selection for lower feed conversion ratio under restricted feeding corresponds to an increase in growth rate with little change in feed intake.

Genetic correlation between backfat and feed intake is higher under restricted feeding (rg: 0.57) than under ad libitum feeding (rg: 0.38). This might be an indication that the pigs which were not restricted yet under the restricted feeding regime are the very lean pigs with a low feed intake capacity. However, given the standard errors of these genetic correlations these differences are not significant and need to be confirmed in the final analysis.

Restricting feed intake in pigs leads to a more favourable genetic correlation between growth rate and backfat. These two traits have no genetic relationship under ad libitum feeding (rg: 0.00) but have a negative, and therefore favourable, genetic correlation under restricted feeding (rg: -0.26). McPhee et al. (1988) found a genetic correlation of 0.35 between these two traits under ad libitum feeding and a negative genetic correlation of -0.22 between these two traits under restricted feeding. The shift in genetic correlations can be explained by the linear-plateau model previously described within these workshop notes. Feed intake under restricted feeding is below the optimal feed intake within the linear part of the model which is characterised by an increase in protein deposition together with a minimum amount of lipid deposition determined by the marginal ratio with an increase in feed intake. Therefore, a higher growth rate is associated with a higher lean meat growth. In contrast, a positive genetic correlation between growth rate and backfat under ad libitum feeding implies that feed intake is higher than the optimal feed intake (plateau part of the model). Any increase in growth is accompanied by an increase in fat growth.

Table 5: Genetic correlations between feed intake (FDINT) growth rate (ADG), feed conversion ratio (FCR) and backfat at P2 site (LP2) recorded under ad libitum (above diagonal) and restricted feeding (below diagonal)

Trait	FDINT	ADG	FCR	LP2
FDINT		0.82 (0.08)	0.70 (0.13)	0.38 (0.08)
ADG	0.36 (0.18)		-0.18 (0.19)	0.00 (0.02)
FCR	0.03 (0.20)	-0.94 (0.03)		0.41 (0.12)
LP2	0.57 (0.11)	-0.26 (0.15)	0.58 (0.12)	

2. *Comparison of genetic correlations between performance traits across feeding regimes*

A genetic correlation of one between two traits implies that these two traits are genetically the same trait. For the four traits shown here only feed conversion ratio has a correlation significantly lower than one (Table 6). Feed conversion ratio under restricted feeding is therefore genetically a different trait than feed conversion ratio under ad libitum feeding. This is also reflected in different genetic correlations with growth rate and feed intake. Feed conversion ratio under ad libitum feeding is strongly correlated with feed intake under restricted feeding (rg: 0.81) and moderately correlated with growth rate under restricted feeding (rg: -0.48). In contrast, feed conversion ratio under restricted feeding has no genetic relationship with feed intake under ad libitum feeding (rg: 0.08) but is highly correlated with growth rate under ad libitum feeding (rg: -1.00). Pigs will still be fattened under ad libitum feeding but might be selected in the nucleus under restricted feeding. Therefore, these genetic correlations are favourable indicating that selection for feed conversion ratio under restricted feeding will not reduce feed intake under ad libitum feeding but increase growth rate. Other genetic correlations are not significantly different from each other between feeding regimes and are therefore not discussed explicitly.

Table 6: Genetic correlations across feeding regimes between feed intake (FDINT) growth rate (ADG), feed conversion ratio (FCR) and backfat at P2 site (LP2)

Trait		FDINT ad lib.	ADG ad lib.	FCR ad lib.	LP2 ad lib.
FDINT	**(restr.)**	1.00 (*)	0.32 (0.17)	**0.81 (0.18)**	0.42 (0.13)
ADG	**(restr.)**	0.20 (0.13)	1.00 (*)	**-0.48 (0.15)**	-0.12 (0.13)
FCR	**(restr.)**	**0.08 (0.13)**	**-1.00 (*)**	0.68 (0.14)	0.36 (0.13)
LP2	**(restr.)**	0.19 (0.10)	-0.29 (0.11)	0.59 (0.11)	0.99 (0.03)

* estimate at the border of the parameter space, standard error could not be obtained

Summary

A PRDC funded project was initiated to obtain genetic parameters for performance traits under ad libitum and restricted feeding. Records obtained from February 1996 to December 1997 were included in this analysis. The aim of a balanced design has been achieved with animals evenly distributed over all feeding regime by sex classes. On average, animals were restricted by 12% in comparison to the ad libitum feed intake. As a consequence of this reduction in feed intake performance in growth rate, feed conversion and backfat were reduced by 3 to 8%. The level of restriction did not eliminate all variation in feed intake. This trait still had a coefficient of variation of 7% under restricted feeding in comparison to a coefficient of variation of 14% under ad libitum feeding. The heritability for feed intake was moderate (h^2: 0.27) under ad libitum feeding and low under restricted feeding (h^2: 0.08). Heritability estimates did not differ between feeding regimes for growth rate, feed conversion ratio and backfat. However, variance components were reduced for all performance traits under restricted feeding. Feeding regime influenced genetic correlations between performance traits. Feed conversion ratio is genetically a different trait under both feeding regimes. Selection for feed conversion ratio under ad libitum feeding will mainly reduce feed intake and only moderately increase growth rate. In contrast, selection for feed conversion ratio under restricted feeding will not influence feed intake but will increase growth rate. These results indicate that selection under restricted feeding might be the preferred choice for selection of efficient lean meat growth. However, this needs to be investigated through index calculations.

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