

# Estimation of Body Tissue Gain of Entire and Castrated Male Pigs at Two Feeding Levels and Three Body Weights, Using Energy/Nitrogen Balance and Comparative Slaughter Techniques

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## Abstract

*Rates of tissue gain and body composition of 18 entire (E) and 18 castrated (C) male pigs, fed at one of two levels of feeding (high (H) or low (L)), were investigated in a 2x2 factorial experiment. Calorimetric, energy and nitrogen balances were carried out on each animal at 30, 60 and 90 kg live weight. The animals were slaughtered at 95 kg and their body composition was determined. The higher feeding level resulted in greater ( $P < 0.001$ ) rates of body weight gain, protein and fat deposition in all treatment combinations. Castration was associated with decreased and increased potential for protein and fat deposition, respectively. Mean values of shoulder fat thickness, loin fat and subcutaneous fat (P2) were greater ( $P < 0.01$ ) for the animals fed at the high compared with those fed at the low level and these fat measurements were greater in the castrated than the entire male pigs. Relative to the slaughter method, the balance method overestimated and underestimated the rates of protein and fat deposition by 0.16 and 0.10, respectively.*

**Key words:** Tissue gain, calorimetric, balance, slaughter, pigs

## Introduction

Changes in intakes of protein and/or energy can affect both the rate and composition of live weight gain in growing pigs. The magnitude of this effect depends largely upon the relationship between protein and energy intake and protein deposition, a subject, which has been reviewed by Campbell (1988). Castration is reported to reduce the rate of protein deposition by 0.30 and the slope of the linear portion of the relationship between energy intake and protein deposition by a similar amount (Campbell and Taverner, 1988). Live weight of the animal has been shown to influence both the rate and composition of gain. At lower body weights the rates of protein deposition are high and fat deposition are minimal, whereas, at higher body weights the reverse occurs (Black et al., 1986).

The present experiment is part of a study designed to evaluate the influence of lean tissue growth potential on the partition of nutrients and the efficiency of energy utilisation in growing pigs. The assumption made here is that variations in the potential rates of protein deposition have similar effects on energy expenditure regardless of the manner in which these variations were achieved. Therefore, in this paper, we report on rates and composition of body weight gain as influenced by castration, body weight and feed intake, in a modern genotype of pig with a high potential for lean growth. A comparison of the values obtained for the rates of tissue retention by the balance and comparative slaughter procedures is also made. The energy partition and efficiency of energy utilisation in the same animals will be given in a subsequent paper.

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## Material and Methods

### Experimental design and treatments

The trial was a 2 x 2 factorial design, involving pigs of two "sexes", entire (E) and castrated (C) male pigs, fed at one of two feeding levels: low (L) or high (H), making four treatments, that is EH, CH, EL and CL. Nine pigs were allocated to each of the four treatments. Calorimetric, energy and nitrogen balances were carried out when pigs had attained bodyweights of 30, 60 and 90 kg.

### Experimental animals and housing

The pigs were bred from the improved herd of sows maintained at the Institute of Grassland and Environmental Research (IGER), Shinfield, United Kingdom. They were free from enzootic pneumonia and the herd was continuously being improved by the annual purchase of selected pure-bred Landrace gilts and Large White boars from several of the major breeding companies within the country. Each batch of pigs was selected within two to three days of age, when half were castrated. The piglets were weaned at 21 days of age and transferred into environmentally controlled flat-deck weaner accommodation. On attaining an average bodyweight of 22 kg, they were randomly allocated to the experimental treatments. They were placed in individual pens (2.0 X 1.3 m) (home pens) in a pig house maintained at  $20 \pm 1^\circ\text{C}$ . Each pen was fitted with a trough specially adapted to prevent spillage, an automatic water drinker and rubber mats in the lying area. During nutrient balance periods, pigs were moved to the calorimeter building and housed in mobile metabolism crates designed for separate collection of urine and faeces.

### Diet and feeding

A single, pelleted diet was used throughout the experiment. The composition of the diet (g/kg as fed) was as follows: barley 81, wheat 420, wheat feed 150, soybean meal 210, fish-meal 60, fat (BP50) 50, lysine-HCl 1.0, limestone 10.5, dicalciumphosphate 5.0 and vitamin

and mineral mixture 12.5. The calculated crude protein (g/kg DM) and digestible energy (MJ/kg) contents of the diet were 219 and 13.8, respectively. The diet was provided at two feeding levels high (H) or low (L), the feeding scales being based on the body weight of the animal. Level H was 3.4 times the maintenance energy requirement ( $\text{ME}_m$ ) of the animal, (calculated as the thermoneutral maintenance requirement of  $719 \text{ kJ ME/kg}^{0.63} \cdot \text{d}$ , ARC, 1981) which had been established as being the *ad libitum* level of energy intake for this type of pig (Laswai, *et al.*, 1991). The L level was 2.25  $\text{ME}_m$ , which represented approximately 0.66 the *ad libitum* intake level. The feed allowance for each pig was adjusted weekly, following weighing. The daily ration for each pig was given in two equal meals at 0900 and 1600h. Feed refusals were collected and weighed each morning and daily feed intakes of each pig were recorded. Water was available *ad libitum*.

### Calorimetric, energy and nitrogen balance

Heat production, energy and nitrogen balances were performed simultaneously on each pig when it had attained 30, 60 and 90 kg body weight. This procedure was followed so as to enable partition of metabolisable energy into heat output, energy retention, protein and fat energy retention. Four animals were selected for measurement of heat output, energy and nitrogen balance each week. For the seven days prior to taking measurements, the pigs were adapted to the conditions within the calorimeters and to the experimental protocol, whereupon the animals were weighed and each animal placed in a fresh mobile metabolism crate. Two pigs in crates were placed in two calorimeters and the remaining two pigs in crates were put into the habituation room to start their nutrient balance measurements. The two calorimeters were used simultaneously. Their internal dimensions were 2.03 x 1.12 x 1.22 m and they were kept in temperature-controlled rooms in a purpose-built calorimetry building. The calorimeter operated on the heat sink principle and each animal's heat output was recorded continuously (Verstegen *et al.* 1973). The metabolism crates were changed for thorough cleaning

thrice weekly and this process was carried out as swiftly as possible to avoid interference with air exchange in the calorimeter.

Daily food intakes were measured and total outputs of faeces, acid-preserved urine and pen washings from the four pigs were collected for seven days. At the end of the balance period, thoroughly mixed sub-samples of the total 7-day output of faeces (3 x 250 g) or mixed urine and washings (2 x 500 ml) for each pig were taken and stored at -20°C until required for analysis. After a three or four day period in the calorimeter, the pigs were exchanged for those in the habituation pens. After the 7-day nutrient balance period, the four pigs were returned to their home pens, whereupon they continued with their respective treatments.

## Slaughter procedures

Twenty four animals, twelve from each 'sex' were slaughtered two to three days after they had completed their final balance period. Eight other pigs, four castrates and four entire males (average 30 kg live weight) from the same herd were slaughtered to serve as a baseline for the estimation of initial body composition. The pigs were given free access to water but were deprived of feed for the 16 hours prior to slaughter. They were then weighed and slaughtered. The blood and internal organs were weighed both before and after washing. The carcasses were split into two symmetrical halves along the vertebral column. Physical carcass measurements, that is, carcass length, backfat thickness and P<sub>2</sub> were recorded and fat softness was assessed using a penetrometer. The carcass, including the head was then cut into small portions (approximately 12 kg). These portions were frozen together with the blood and the empty digestive tract and then minced thoroughly through a Feed Tec KF 320 mincer. A sample of the mixture was stored at -20°C until subsequent analyses.

## Chemical and data analyses

Dry matter, gross energy and nitrogen contents of the feed, faeces, urine and carcass samples were estimated using A.O.A.C (1990) procedures. The daily digestible energy (DE), metabolisable energy (ME) and digestible nitro-

gen intakes (IDN), nitrogen retention (NR), protein and fat retention were derived according to ARC (1981). The recorded and most of the derived values were tested according to Mead and Curnow (1986).

## Results

### Nutritive value of the diet

The determined DE and ME contents of the diet used in the present study was  $14.4 \pm 0.20$  and  $13.4 \pm 0.23$  MJ/kg DM, respectively. There was no indication of any effect of sex on the metabolisability of dietary energy within the range of body weights studied (Table 1). Feeding level and sex interactions were not significant ( $P > 0.05$ ).

The nitrogen content (Diet-N, g/kg DM) of the diet remained constant at an average of 40.2 g/kg DM in all of the treatment combinations (Table 1). The intakes of total nitrogen (NI) and apparently digestible nitrogen (IDN) increased with both feeding level and body weight. There was no significant difference between sexes in either NI or IDN at body weights of 30 and 60 kg. However, at 90 kg body weight entire males had significantly lower IDN than castrated males.

### Experimental pig performance

Feed intake increased as body weight increased for all the treatment combinations (Table 2). The sex differences in feed intake were not significant ( $P > 0.05$ ) at 30 and 60 kg body weight, but significant ( $P < 0.05$ ) at 90 kg. The sex x feeding level interaction effect on feed intake was significant ( $P < 0.01$ ) and specific only at 90 kg body weight. The rates of body weight gain were higher for high- than low-fed animals for all treatment combinations (Table 2). The rates of gain in the high-fed animals increased from 30 to 60 kg and remain constant at 60 and 90 kg body weight. However, for the low energy-fed animals, the rates increased with the increase in body weight throughout the experimental period. The entire males gained weight faster than the castrated males (Table 2).

Feed conversion ratios were not significantly different between high- and low-fed ani-

**Table 1: The average main effects of sex and feeding level (FL) on the estimates of energy and nitrogen intake and utilisation at the different body weights**

	Body weight	Feeding level		Significant	Sex		SED
		High	Low		Entire	Castrate	
<b>DE</b>							
	30	13.84	14.61	**	14.33	14.12	0.30
	60	14.15	14.74	***	14.47	14.42	0.16
	90	14.37	14.63	NS	14.62	14.38	0.23
<b>ME</b>							
	30	12.77	13.68	**	13.30	13.15	0.35
	60	13.08	13.87	***	13.44	13.51	0.26
	90	13.30	13.78	*	13.54	13.54	0.23
<b>ME/DE</b>							
	30	0.92	0.94	*	0.93	0.93	0.01
	60	0.92	0.94	*	0.93	0.94	0.01
	90	0.93	0.94	NS	0.93	0.94	0.01
<b>Dietary nitrogen (g/kg DM)</b>							
<b>Diet-N</b>							
	30	40.37	40.62	NS	40.49	40.59	0.47
	60	40.37	40.19	NS	40.33	40.23	0.33
	90	39.11	39.93	NS	40.07	39.96	0.27
<b>Digestible - N</b>							
	30	32.37	34.59	***	33.47	33.28	0.62
	60	32.99	33.75	*	33.32	33.42	0.33
	90	32.00	34.17	***	33.04	33.13	0.38
<b>Nitrogen intake (g/d) and digestibility</b>							
<b>NI</b>							
	30	62.74	38.55	***	50.91	50.38	1.82
	60	84.78	55.91	***	70.65	70.04	2.09
	90	102.40	73.88	****	86.10	90.18	2.84
<b>IDN</b>							
	30	49.97	32.85	***	41.74	41.09	1.64
	60	69.35	48.14	***	59.02	58.47	1.99
	90	83.79	62.23	***	71.84	75.18	2.18
<b>IDN:NI</b>							
	30	0.80	0.85	***	0.83	0.82	0.01
	60	0.82	0.86	***	0.84	0.84	0.01
	90	0.82	0.85	***	0.84	0.84	0.01

<sup>1</sup>Sex effects were not significant in all parameters except IDN at 0.05 and feedingxsex interaction was not observed except for NI and IDN (P<0.01)

mals at 30 kg live weight. For all of the treatment combinations, the ratios increased with the increase in body weight and they were higher in the high-fed than the low-fed pigs. Castrated males had significantly poorer feed efficiency values compared with the entire males and the differences increased with increase in body weight.

## Nitrogen and tissue retention

Nitrogen retention (NR) was significantly higher for the high-fed than the low-fed pigs (Table 2). NR for the high-fed pigs tended to increase from 30 to 60 kg with a slight decrease at 90 kg body weight. NR was significantly higher in the entire than castrated males and the difference between "sex" increased with body

**Table 2: The average main effects of sex and feeding level (FL) on the nitrogen retention and general performance of the pigs**

	Body weight	Feeding level		Significant	Sex		Significant	SED
		High	Low		Entire	Castrate		
<b>Food intake (g/d)</b>								
	30	1554	948	***	1258	1248	NS	0.05
	60	2098	1426	***	1766	1757	NS	0.05
	90	2618	1850	***	2179	2289	*	0.07
<b>Weight gain (g/d)</b>								
	30	984	614	***	838	759	**	35.40
	60	1090	819	***	1073	836	***	56.50
	90	1097	894	***	1068	922	**	62.90
<b>Food:gain</b>								
	30	1.595	1.573	NS	1.518	1.650	*	0.08
	60	1.986	1.792	*	1.675	2.104	***	0.12
	90	2.412	2.138	*	2.043	2.506	***	0.14
<b>NR (g/d)</b>								
	30	30.89	20.45	***	26.63	24.71	*	1.44
	60	35.03	22.54	***	31.36	26.21	*	2.23
	90	33.57	26.28	***	33.24	26.62	***	1.94
<b>Protein (g/d)</b>								
	30	193.1	127.8	***	166.5	154.4	NS	9.03
	60	218.9	140.9	***	196.0	163.8	**	13.91
	90	209.8	164.1	***	207.7	166.4	***	12.13
<b>Fat (g/d)</b>								
	30	6.80	0.76	***	3.28	4.29	NS	1.70
	60	10.1	4.80	***	5.56	9.34	**	1.59
	90	13.6	6.06	***	6.57	13.13	***	1.59
<b>NR/NI</b>								
	30	0.49	0.53	*	0.53	0.50	NS	0.02
	60	0.42	0.40	NS	0.44	0.38	***	0.02
	90	0.33	0.36	NS	0.39	0.30	***	0.02
<b>NR/IDN</b>								
	30	0.62	0.63	NS	0.64	0.60	NS	0.03
	60	0.51	0.47	*	0.53	0.45	***	0.03
	90	0.41	0.42	NS	0.47	0.36	***	0.03

<sup>1</sup>Feeding x sex interaction was not significant except for food intake at 90 kg body weight ( $P < 0.01$ )

weight. The efficiency of utilisation of dietary nitrogen was similar for both "sexes" at 30 kg. However, at 60 and 90 kg body weight, entires were significantly ( $P < 0.001$ ) more efficient at utilising dietary N than their castrated counterparts (Table 2). The rates of protein (P; NR x 6.25) and fat (F) deposition (g/d) as influenced by feeding level and sex at the different body weights are shown in Table 2. The estimated rates of fat deposition (g/d) were greater in the

high-fed animals compared with those, which received the low level of feeding, and lower in the entire than in the castrated males.

### Slaughter characteristics and carcass composition

The average slaughter weight and empty body weight were not significantly different between feeding levels, but were higher for the

**Table 3: The main effects of sex and feeding level (FL) on the carcass characteristics and body components of pigs slaughtered at 95 kg body weight**

Component	Feeding level		Significant	Sex		Significant	SED
	High	Low		Entire	Castrate		
<b>Slaughter weight</b>							
(SWT kg)	96.38	94.50	NS	98.50	92.38	**	2.48
<b>Empty body weight</b>							
(EBW kg)	92.93	90.83	NS	94.89	88.87	**	2.06
<b>Carcass measurements (mm)</b>							
Length	820.00	817.72	NS	823.22	814.50	NS	12.22
Shoulder fat	29.17	24.06	**	24.33	28.89	**	2.01
Loin fat	17.39	7.94	***	10.94	14.39	*	1.95
P <sub>2</sub>	15.30	9.94	***	12.00	13.28	NS	1.44
Fat firmness	613.75	690.39	NS	602.47	706.67	*	52.33
<b>Chemical composition (g/kg)</b>							
Water	630.70	654.07	**	664.07	620.69	***	10.70
Protein (Nx6.25)	179.92	197.17	***	193.00	184.10	*	4.77
Fat	148.62	101.83	***	99.24	151.21	***	13.38
Ash	35.28	35.98	NS	34.64	36.62	NS	2.40
Gross energy (MJ/kg DM)	26.20	24.15	***	24.26	26.08	***	1.53
<b>Body contents (kg)</b>							
Water	58.79	59.45	NS	63.09	55.15	***	1.53
Protein	16.73	17.90	***	18.32	16.32	***	0.38
Lean <sup>1</sup>	75.52	77.36	NS	81.41	71.47	***	1.76
Fat	13.71	9.23	***	9.48	13.46	***	1.32
Ash	3.28	3.26	NS	3.29	3.26	NS	0.23
<b>Tissue retention (g/kg)</b>							
Protein	165.1	127.3	***	162.4	130.80	***	8.44
Fat	151.8	60.7	***	84.1	128.50	**	15.35

<sup>1</sup>Calculated as Water + Protein (kg)

entire than castrated males (Table 3). Mean values of shoulder fat thickness and loin fat were higher ( $P < 0.01$ ) for the high-fed animals compared with the low-fed ones, and also higher in the castrated than the entire males. The average values of the subcutaneous fat ( $P_2$ ) were significantly higher in the high- than the low-fed pigs (Table 3). Although the mean values of  $P_2$  were higher in the castrates than the entire males the differences were not significant. The carcasses of the high-fed animals had proportionately 0.32 more fat than in those of low-fed animals. Castrated male pigs were much fatter at both low and high feeding levels than the entire males.

The proportion of protein in the carcass on the other hand, was lower ( $P < 0.001$ ) in the high energy-fed animals than in the low energy-fed pigs (Table 3). The mean protein content was higher ( $P < 0.05$ ) in the entire (193.0 g/kg) than the castrated males (184.1 g/kg). Carcass gross energy composition (MJ/kg DM) was significantly higher in the high energy-fed than in the low energy-fed and also higher for the castrates than the entire male pigs. Protein deposition estimated from the slaughter data was higher ( $P < 0.001$ ) in the high energy- than in the low energy-fed animals. It was also higher ( $P < 0.001$ ) in the entire compared with the castrated males. There were no significant

( $P > 0.05$ ) feeding level  $\times$  sex interaction influences on any of the parameters derived from the slaughter data.

## Discussion

The observed lack of "sex" effects on nutrient digestion suggests that the poorer feed conversion efficiency noted for the castrates compared with the entire males was probably due to differences in the composition of the gain. The greater deposition of fat in the castrates compared with the rapid accretion of lean in the entire males may account for this, as the deposition of fat utilises more energy than that of lean (Rao and McCracken, 1990). The interaction between feeding level and "sex" at 90 kg body weight was due to the lower appetite of the EH pigs, who refused some of their feed. As a consequence of their low dietary intakes at this weight, the EH pigs had reduced nitrogen intakes, but it is of note that their rates of nitrogen retention still remained greater than those of the CH animals, indicating that protein supply in these diets was not limiting. The decrease in the efficiency of nitrogen utilisation with increases in bodyweight presumably resulted from a decrease in the animal's demand for protein, the remaining energy being partitioned into fat.

The physical measurements of fat thickness obtained in the present study for the entire males are considerably lower than those reported by ARC (1981) and Ellis *et al.* (1983) for a control line of pigs. The values of shoulder fat thickness for the entire males compare well with those obtained in the selection line of pigs (Ellis *et al.*, 1983) and in boars of high genetic potential for lean growth (Rao and McCracken, 1990). The mean fat and protein values and hence fat to protein ratios were consistent with those obtained by Rao and McCracken (1990). The average values of protein accretion rates obtained by the slaughter method compare well with those reported by Campbell and Taverner (1988) and McCracken and Rao (1989). Increased protein retention was associated with reduced fat deposition, the rates of which were more rapid at 90 kg body weight.

Castration was associated with decreased potential protein deposition and increased fat retention. At any given body weight and feeding

level, protein deposition was higher and fat accretion lower in the entire animals than the castrated males. The maximal protein deposition in the entire males was proportionately 0.16 higher than in castrated males. These results accord those of Campbell and Taverner (1988). The effect of castration on rates of protein accretion tended to increase with body weight, except for unexpected results which were obtained in the high-fed animals at 90 kg body weight due to the reduced feed intake of EH animals.

The two methods, that is, calorimetry and balance and comparative slaughter, used to estimate the rates of protein and fat deposition and hence body composition of the pigs in the present study gave closely related results. The prediction equations comparing estimates from the slaughter values with the balance method for the different treatments gave correlation values ranging from 0.85 to 0.92. There were, however, some discrepancies between the two methods. The balance method overestimated the rate of protein retention relative to the slaughter method and the differences increased with level of feed intake. For the high-fed animals protein retention determined by nitrogen balance was greater by 0.20 and for the low-fed animals by 0.11 (Tables 2 and 3). Other workers have also found the nitrogen balance procedure to overestimate protein deposition in comparison with the slaughter technique (Just *et al.* 1982); Rao and McCracken, 1990). This overestimation of nitrogen retention might have occurred because of losses of volatile nitrogen forms, which might have escaped mainly via excreta. In their review, Just *et al.* (1982) pointed out the possible causes and ways of minimising these discrepancies and the methodology of collection, storage and preparation of faeces and urine samples for chemical analysis were emphasised. The mean fat retention was underestimated by 0.10 (95.2 versus 106.0 g/d) in both the high- and the low-fed animals when the balance method was used instead of the slaughter method. Since in energy/nitrogen balance technique, fat energy retention is obtained as the difference between the total energy retention and protein energy retention, overestimation of protein retention will lead to an underestimation of fat retention.

## Conclusions

The study revealed that body composition could successfully be manipulated by changing levels of feeding, castration and variations in body weight. Changing levels of feeding results in changes in rates of protein and fat retention, and hence body composition. Increasing body weight is characterised with decreasing and increasing proportions of body protein and fat, respectively. At any given body weight and feeding level, the rate of protein deposition is lower and of fat accretion higher in the castrated relative to the entire males.

In addition, balance and slaughter techniques for estimating body composition produce closely related results. Although the former relative to the later technique, tend to overestimate protein retention and hence underestimate fat retention, it is useful in providing information on the same animal at different body weights.

## References

- A.O.A.C. 1990. Official Methods of Analysis. 15th ed. The Association of Official Analytical Chemists, Washington, DC.
- ARC 1981. The Nutrient Requirements of Pigs. Agricultural Research Council. Commonwealth Agricultural Bureaux (CAB).
- Black, J. L., Campbell, R. G., Williams, I. H., James, K. J. and Davies, G. T. 1986. Stimulation of energy and amino acid utilisation in the pig. *Research Development Agriculture* 3: 121-126.
- Campbell, R. G. 1988. Nutritional constraints to lean tissue accretion in farm animals. *Nutritional Research and Reviews* 1: 233-253.
- Campbell, R. G. and Taverner, M. R. 1988. Genotype and sex effects on the relationship between energy intake and protein deposition in growing pigs. *Journal of Animal Science* 66: 676-686.
- Campbell, R. G., Taverner, M. R. and Curic, D. M. 1988. The effects of sex and live weight on the growing pigs response to dietary protein. *Animal Production* 46: 123-130.
- Ellis, M., Smith, W. C., Henderson, R., Whittemore, C. T. and Laird, R. 1983. Comparative performance and body composition of control and selection line Large White pigs. 2. Feeding to appetite for a fixed time. *Animal Production* 36: 407-413.
- Just, A. Fernandez, J. A. and Jørgensen, H. 1982. Nitrogen balance studies and nitrogen retention. In *Digestive Physiology in the Pig*. (Ed. J. P. Laplace, T. Corring and A. Rerat). INRA, France; Paris.
- Laswai, G. H., Close, W. H. and Keal, H. D. 1991. The voluntary food intake of modern pig genotype. *Animal Production* 52:601.
- McCracken, K. J. and Rao, S. D. 1989. Protein:energy interactions in boars of high lean deposition potential. In *Energy Metabolism of Farm Animals*. (Eds Y. Van der Honing and W. H. Close). pp. 13-16. Pudoc, Wageningen.
- Mead, R. and Curnow, R. N. 1986. *Statistical Methods in Agriculture and Experimental Biology*. Chapman and Hall, London.
- Rao, D. S. and McCracken, K. J. 1990. Effect of protein intake on energy and nitrogen balance and chemical composition of gain in growing boars of high genetic potential. *Animal Production* 51: 389-397.
- Verstegen, M. W. A., Mount, L. E. and Close, W. H. 1973. The optimum duration of metabolic balance experiments with groups of pigs. *Proceeding of The Nutrition Society* 32: 72A.