Effects of Castration, Level of Feeding and Body Weight on Energy Partition and Efficiency of Energy Utilisation in Growing Pigs

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Abstract

Efects of castration, feeding level and body weight on energy partition and efficiency of energy utilisation in growing pigs were studied. Eighteen entire and 18 castrated males, fed on either high (3.34 x maintenance) or low (2.25 x maintenance) level of feeding in a 2x2 factorial design, with 9 pigs per treatment were used. Energy/nitrogen balance and calorimetry were recorded at 30, 60 and 90 kg body weight. Increased feeding level resulted into increasing rates of energy (ER), protein energy (Pe) and fat energy (Fe) retention by 0.45, 0.29 and 0.62, respectively. Castration increased ER and Fe by 0.16 and 0.42, respectively but decreased protein energy retention by 0.13. Energy requirement for maintenance (ME_m) was 0.10 higher in the entire than castrated males and tended to increase with increased protein energy retention. Net energetic efficiencies for protein (k_p) and fat retention (k_f) were higher for the entire (0.61 and 0.98) than for castrated males (0.56 and 0.92). The results indicate that an increase in the rates of energy expenditure with increased lean tissue growth potential may be attributed to increased energy requirement for maintenance.

Keywords: Body composition, pigs, energy metabolism, energetic efficiency.

Introduction

The reduced voluntary feed intake observed in the modern genotype of pigs (Smith *et al.* 1991; Laswai *et al.*, 1991) compared with those recommended by the ARC (1981) suggests that there may be considerable differences in the partition of nutrients between maintenance, protein and fat accretion in improved animals. The efficiency of energy utilisation may also have changed since Campbell and Taverner (1988), Rao and McCracken (1990), Noblet *et al.* (1999) and Milgen *et al.* (2000) suggested that animals of high potential for protein deposition have higher rates of energy expenditure compared with those of low potential. In addition, McCracken and Rao (1989) and Noblet *et al.* (1989) observed significantly higher rates of heat production from pigs with a greater potential rates of protein deposition than those of lower potential. The findings suggest that energy expenditure may be strongly associated with protein accretion in growing pigs (Milgen *et al.*, 2000). However, there is little evidence to support this claim. The present study was an attempt to study the energy partition and expenditure in pigs at different rates of protein retention. This was achieved by measuring the energy requirements for maintenance, protein and fat deposition and net efficiencies of energy utilisation for protein and fat retention in entire and castrated male pigs at three different body weights.

Material and Methods

Experimental design and treatments

A 2x2 factorial experiment was carried out using 18 entire (E) and 18 castrated (C) male pigs randomly allocated to two feeding regimes, that is, low (L) and high (H), with 9 pigs per treatment. Calorimetric, energy and nitrogen balances were carried out on each animal at three

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body weights (30. 60 and 90 kg). The experiment was conducted in three batches each with 12 pigs and run over an experimental period of 12 months.

Experimental animals and management

The pigs were bred from improved herd of sows maintained and continuously being improved by the annual purchase of selected pure-bred Landrace gilts and Large White boars from several of the major breeding companies in the United Kingdom. The experimental pigs were therefore crosses of Landrace x Large White. They were randomly allocated to experimental treatments when weighed 22±1.8 kg live weight. They were penned individually in a pig house maintained at 20±1C. During energy and nitrogen 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. Its composition (g/kg as fed) was as follows: barley 81, wheat 420, wheat feed 150, soybean meal 210. fishmeal 60, fat (BP50) 50. lysine-HCl 1.0, limestone 10.5, di-calcium phosphate 5.0 and vitamin and mineral mixture 12.5. The estimated crude protein (g/kg DM) and digestible energy (MJ/kg) contents of the diet were 250 and 14, respectively. The high (H) feeding regime was 3.4 times the maintenance energy requirement (ME_m) of the animal (calculated as the thermoneutral maintenance requirement of 719 kJ ME/kg $W^{0.63}d^{-1}$; ARC, 1981). The low (L) level was 2.25 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. Daily feed intake of each pig was recorded. Any feed spilled or refused by each animal was collected, weighed, sampled and stored in a cold room until analysed for dry matter. 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, 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.

Daily food intakes were measured and total outputs of faeces, acid-preserved (25% H_2SO_4 w/v) urine and pen washings from the four pigs were collected for seven days. During the collection period, faeces, urine and washings were stored at 2°C. 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. The four pigs were then returned to their home pens, whereupon they continued with their respective treatments. Similar protocol was followed for all pigs at the different body weights.

Chemical analyses and derived parameters

Dry matter, gross energy and nitrogen contents of the feed, faeces and urine samples were estimated using A.O.A.C (1990) procedures. Daily digestible energy (DE), metabolisable energy (ME) and digestible nitrogen intakes (IDN), nitrogen retention (NR), protein energy (Pe) and fat energy (Fe) retention were derived according to ARC (1981).

The estimates of the maintenance energy requirement (ME_m) were obtained using two approaches. The first approach was by extrapolating ME intake to zero energy retention (ER) using simple linear regression analysis. The corresponding slope was the net energetic efficiency for utilisation of ME for growth (k_g). The second aproach was by using multiple regression model relating ME intake to the rates of protein energy (Pe) and fat energy (Fe) accretion (MJ ME/kg $W^{0.61}d^{-1}$) and extrapolating the ME intake where both the rates of protein and fat retention were zero. The reciprocal of the slopes for the later model provided estimates of the net energetic efficiency of ME utilisation for protein (k_p) and fat (k_f) accretion.

Data analysis

The recorded and most of the derived values were analysed according to Mead and Curnow (1986) and means were compared using Student t-test.

Results

Energy intake and metabolism by the animals

Effects of sex and feeding level on the energy intake and partition of ME intake into heat loss and energy retention at the different body weights are shown in Table 1. The DE and ME intakes in MJ/d increased with increasing feeding level and body weight in all treatments. Although there was no significant sex influence on the energy intake, the interaction between sex and feeding level was significant ($P<0.05$) at 90 kg body weight.

Table1: The main effects of sex and feedinglevel (FL) on the intakes of degestible energy(DE) and metabolizable energy(ME) and energy partition into heat loss (H), energy retention (ER), protein energy(Pe)and fat energy (Fe) accretion(MJ/d) at different body weights.

Compo Nent	Body weight	Feeding level		Significant[1]	Sex		Signi	SED	sign
		High	Low		Entire	Castrate			
DE									
	30	21.49	13.85	***	17.88	17.47	NS	0.60	NS
	60	29.70	21.02	***	25.45	25.27	NS	0.98	NS
	90	37 59	27.08	***	26.79	32.88	NS	1.02	**
ME									
	30	19.84	12.97	***	16.56	16.25	NS	0.643	NS
	60	27.48	19.77	***	23.58	23.67	NS	1.088	NS
	90	34.80	25.51	***	29.38	30.93	NS	0.924	***
H									
	30	12.72	9.69	***	11.41	11.00	NS	0.380	NS
	60	17.24	14.02	***	16.14	15.15	NS	0.573	NS
	90	21.21	17.77	***	20.19	18.79	NS	0.801	NS
ER									
	30	7.12	3.28	***	5.15	5.25	NS	0.735	NS
	60	10.20	5.76	***	7.44	8.52	NS	0.938	NS
	90	13.59	7.73	***	9.19	12.14	*	1.143	NS
Fe									
	30	2.55	0.25	***	1.21	1.59	NS	0.665	NS
	60	5.01	2.42	***	2.80	4.64	**	0.789	NS
	90	8.62	3.84	***	4.27	8.19	***	1.039	NS

[1] significant, *($P<0.5$), **$P<0.01$),***$P<0.001$)and NS not significant ($P<0.05$). SED, Standard error of the mean difference

Heat output (MJ/d) increased with body weight and level of feeding for all treatment combinations (Table 1). Although heat production tended to be higher in the entire males throughout the growing/finishing period, the effect of sex differences was not significant ($P>0.05$). Total energy retained (ER, MJ/d) increased with body weight and feeding level (Table 1). Castrates tended to retain more energy than the entire males and the difference was significant ($P<0.05$) at 90 kg body weight. There was no significant interaction between sex x feeding level on energy retention at any of the body weight studied. The main effects of feeding level and sex on the energy retained as protein (Pe) and fat (Fe) are also given in Table 1. Values of protein energy were higher ($P<0.001$) in the high-fed animals than in low-fed ones and entire males retained significantly ($P<0.05$) more protein energy than castrated males at all three body weights studied. The rates of fat energy accretion in both the low- and the high-fed animals increased with increasing body weight. Increased ME intake resulted in increased rates of fat energy accretion in both entire and castrated male animals. Sex differences in Fe retention were significant and increased with body weight. Entire males accreted proportionately 0.24, 0.41 and 0.50 less Fe than castrated males at 30, 60 and 90 kg body weight, respectively. The feeding level x sex interaction on both protein and fat energy retention was; however not significant. The relationship between ER and ME (MJ/kg $W^{0.61}d^{-1}$) intake for the different treatment combinations was significantly ($P<0.001$) correlated with an overall correlation value of 0.89.

Energetic efficiencies of growth

The estimates of partial energetic efficiency for growth (k_g) and energy requirement for maintenance (ME_m) are presented in Table 2. At any given body weight, ME_m was higher in the entire than the castrated males with mean values of 0.959 and 0.871 MJ ME/kg $W^{0.61}d^{-1}$, respectively. In general, values of ME_m tended to decrease slightly with increasing body weight, with the decrease being greater for castrates than entire males.

Table 2: The linear regression equations relating ER and ME (MJ/kg $W^{0.61}d^{-1}$) intake and estimates of maintenance energy requirement (ME_m) and partial energetic efficiency for growth (k_g) in different sexes at different body weights

Sex	Body Weight (kg)	C	SE[1]	k_g	SE[1]	ME_m (MJ/kg $W^{0.61}d^{-1}$)	r
Entire males							
	30	- 0.656	0.18	0.669	0.10	0.981	0.87
	60	- 0.625	0.14	0.651	0.07	0.960	0.91
	90	- 0.594	0.17	0.640	0.09	0.928	0.87
	30-90	- 0.628	0.09	0.655	0.05	0.959	0.89
Castrated males							
	30	- 0.597	0.13	0.650	0.07	0.919	0.91
	60	- 0.528	0.15	0.634	0.07	0.833	0.90
	90	- 0.507	0.16	0.649	0.08	0.780	0.90
	30-90	- 0.575	0.08	0.661	0.04	0.871	0.90
Combined sexes							
	30	- 0.623	0.11	0.658	0.06	0.948	0.89
	60	- 0.591	0.10	0.650	0.05	0.909	0.90
	90	- 0.624	0.12	0.684	0.06	0.913	0.89
	30-90	- 0.621	0.06	0.668	0.03	0.929	0.89

[1]Standard error of the estimate

Variations in ME intake were highly correlated to the rates of both protein energy and fat energy retention in all treatment combinations, with the overall correlation value of 0.91 (P<0.001). The values of ME_m obtained by the multiple regression analyses varied with body weight without any clear defined trend (Table 3). Values tended to be higher in the entire than in castrated males, with the overall mean values of 1.023 and 0.870 MJ ME/kg $W^{0.61}d^{-1}$, respectively. The overall ME_m for the combined group was 0.946 MJ ME/kg $W^{0.61}d^{-1}$.

The estimates of the energetic efficiency of ME utilisation for protein (k_p) and fat (k_f) accretion are also presented in Table 3. The mean values varied with body weight and tended to be higher in the entire than castrated males.

Table 3: The maintenance energy requirement (Mem, Mj/kg $W^{0.61}d^{-1}$) and net energetic efficiecy of protern (k_p) and fat (k_f) deposition for entire and castrated male pigs at different body weights.

Sex	Body weight (kg)	ME_m	k_p	k_f
Entire males				
	30	0.882	0.52	1.25
	60	0.824	0.41	1.52
	90	1.059	0.65	0.93
	30-90	1.023	0.61	0.98
Castrated males				
	30	0.371	0.31	1.49
	60	0.867	0.47	0.98
	90	0.750	0.36	0.98
	30-90	0.870	0.52	0.37
Combined sexes				
	30	0.700	0.42	1.25
	60	0.876	0.46	1.05
	90	0.892	0.47	0.95
	30-90	0.946	0.56	0.92

Discussion

The observed increase in heat output with feeding level accords with the findings of several other workers (Close *et al.*, 1985; Noblet *et al.*, 1999) and arises from the higher heat increment associated with the higher level of feeding. The higher heat loss in the entire males relative to the castrated males, although insignificant ($P>0.05$), was consistent with other findings reported on animals which differed in their rates of protein accretion (Noblet *et al.*, 1989; McCracken and Rao, 1989; Noblet *et al.*, 1999; Milgen *et al.*, 2000). Noblet *et al.* (1989), however, obtained significant differences in heat loss between two strains of pigs, which differed in their rates of protein deposition only after adjusting for similar metabolic body weight and protein and fat retention. This adjustment may be useful in the elimination of errors due to strain differences in body weight and in rates of protein and fat retention. In the current study, however, an attempt was made to adjust heat loss only to a metabolic body weight and not for the rates of protein or fat retained.

The significant increase in total energy retention with feeding level was inevitable and resulted from the increasing amounts of both protein and fat retained (Quiniou *et al.*, 1996; Milgen et al., 2000). The higher ER for the castrated compared with the entire males at higher body weights was partly attributed to their significantly higher feed intake and hence more ME intake than their counterpart (Fuller *et al.*, 1995; Quiniou *et al.*, 1996). Other possible reason is that, castration is associated with reduction of testicular steroids; such as testosterone, which have a profound role on gene-regulated enzymes that regulate metabolic processes (Lobley, 1998; Buttery *et al.*, 2000). In addition, other receptors, such as insulin growth factor I (IGF-I) mRNA are known to be stimulated by steroid hormones (Brandstetter *et al.*, 2000) and are involved in spearhead the metabolic pathways that are responsible in the energy partition in the body (Lobley, 1998; Buttery *et al.*, 2000). Since castrates had relatively reduction in the capacity of muscle retention attributed to the reduction of testicular hormones (Brandstetter *et al.*, 2000) much of the energy intake could have been diverted to fat retention and hence higher ER than the entire males. It is interesting to note that the net energetic efficiency of ME utilisation for growth (k_g) was not different between the entire and castrated males (Table 2). The mean value of k_g of 0.66 agrees with that of 0.69 given by ARC (1981) and other estimates made on growing pigs (Close *et al.*, 1983).

The estimates of maintenance energy requirement (ME_m) obtained by the simple linear regression model relating ER to ME intake were lower than those obtained by the multiple regression model, which relates ME intake to the rates of protein and fat energy retention. The reason for this trend is not clear, though it can be explained by the limitations underlying both models in the estimation of the energetic efficiencies and ME_m as explained by other workers (Tess *et al.* 1984). The overall mean value of ME_m for the entire males (0.959 MJ/kg $W^{0.61}d^{-1}$) obtained by the simple linear regression model was considerably higher than the value of 0.719 MJ/kg $W^{0.63}d^{-1}$ reported by ARC (1981) for unimproved genotypes of pigs. However, this value was slightly lower than some other estimates made on improved genotypes of pigs (Campbell and Taverner, 1988; Noblet *et al.*, 1989; Rao and McCracken, 1990). Noblet *et al.* (1999) for example reported values of ME_m for improved pig genotype fed *ad libitum* to range from 0.940 to 1.120 MJ/kg $W^{0.60}d^{-1}$. On the other hand, the mean value of 1.023 MJ/kg $W^{0.61}d^{-1}$ obtained by the multiple linear regression model accords with the values reported by Campbell and Taverner (1988) and Noblet *et al.* (1989; 1999) for improved genotypes of pigs. This implies that estimates of ME_m are dependent on the model used for its calculation as pointed out by Milgen *et al.* (2000). Regardless of the model, these findings support the suggestion of Campbell and Taverner (1988) and McCracken and Rao (1989) that improved genotypes of pigs have relatively high maintenance energy requirement.

The present results also indicate an effect of castration on the growing pig's energy requirement for maintenance. The higher ME_m value observed in the entire males relative to the castrated males is consistent with the findings of Campbell and Taverner (1988) and Noblet *et al.* (1999). Differences in the rates of lean tissue growth and hence protein turnover and lean body mass have been postulated to contribute to the observed variations in ME_m between strains, sexes and body weight (Campbell and Taverner, 1988; Rao and McCracken, 1990; Quiniou *et al.*, 1996; Noblet *et al.*, 1999).

The range of energetic efficiency of protein deposition (k_p) values (0.31 to 0.65) determined from the present study was lower than the range of 0.75 to 0.85 estimated theoretically by Millward *et al.* (1976). These discrepancies between hypothetical and derived values were noted by other workers (Fuller *et al.*, 1987). The overall k_p values of 0.61 and 0.52 for the entire and castrated males, respectively (Table 3), suggest that the entire male animals utilised less energy in depositing protein compared with castrates. The explanation for this trend could be that, testosterone, which is known to increase protein synthesis more than protein degradation leads to increased muscle mass via muscle hypertrophy, which is associated with less energy cost (Buttery *et al.*, 2000). The overall k_p-value of 0.56 compared well with the k_p-value of 0.54 estimated by ARC (1981) but higher than 0.49 and lower than 0.64. k_p-values reported by Quiniou *et al.* (1996) and Noblet *et al.* (1999), respectively. The values of energetic efficiency for fat deposition (k_f) obtained in the present study (0.92-1.52) were slightly higher than the values (0.80-0.85) estimated theoretically (Blaxter, 1989) and a value (0.74) recommended by ARC (1981). This is possibly due to the fact that the theoretical computations assume that glucose gives rise to acetyl coenzyme A via glycolysis (Reid *et al.*, 1980). However, other metabolic processes do take place and may lower the theoretical estimates of energetic efficiency of fat synthesis. The tendency of values being more than or nearly equal to a unity (Table 3) is mainly a consequence of statistical inter-correlation and can probably not be interpreted physiologically.

In general, the above estimates of the costs of protein and fat deposition indicate that entire males are energetically more efficient in depositing both protein and fat than castrated males due to the inherent bio-active substances produced by the testes. In a way, this seems to contradict the previous conclusion that castrated males are energetically more efficient than entire males (Noblet *et al.*, 1989). This further indicates that the observed difference in the energy expenditure between entire and castrated males may have resulted from the variation in the maintenance energy intake or energy equilibrium where in fast growing animals, protein is expected to be deposited on the expense of fat (Quiniou *et al.*, 1996). However, the difference may also be associated with the small range of ME intake, which was much less in the entire than castrated males and hence smaller ranges of protein and fat retention.

Conclusion

The observed higher energy requirement for maintenance for the entire males relative to castrates could be attributed to their differences in body composition inference by the rates of protein and fat energy retention. The net energetic efficiencies for protein and fat accretion were also higher for the entire males than castrated males. Thus, the differences in the energy expenditure between animals of different genetic potential for protein retention reported in some studies could be attributed to their variation in the maintenance energy requirement.

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