Some aspects of energy utilization for the production of lean tissue in the pig

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The biological efficiency of a complex process such as pig production can be expressed in a variety of ways. Hopefully, by examining the more relevant biological indices one arrives at conclusions which bear on the economic situation. The objective in this paper is to examine the factors which relate to one particular index of efficiency, namely the conversion of a major input, food, to a major product, lean tissue. The choice of lean tissue as the index of output complicates, to some extent, the development of exact relationships because it is neither a chemical entity nor is it easily measured, since the physical separation of tissues involves a rather arbitrary technique. It is, however, a component of meat which correlates closely with the concept of quality and can be defined anatomically as the skeletal muscle.

Pig production is usually analysed in separate phases, for example as sow productivity or as the performance of the growing pig. In this paper the utilization of dietary energy will be considered first in the growing animal and secondly in terms of the over-all energy cost of producing a unit amount of lean tissue in the slaughtered animal.

Utilization of dietary energy for lean tissue production by the growing animal

A helpful and quantitative approach to this subject is that developed by Kielanowski (1972), in which the intake of metabolizable energy (ME) is regarded as the sum of the energy for maintenance and of the energy costs of protein and lipid deposition during a specific period of time. The values obtained by such an approach are illustrated for a pig of 60 kg live weight in Table 1 using data from Kielanowski (1972).

Protein is usually taken to be closely related to the lean tissue of the animal but one-third of retained protein is not, in fact, in the muscle tissue. Inspection of Table 1 shows that about 9% of the dietary ME is retained as protein, so that one may conclude that only about 6% is effectively retained as muscle protein in the favoured edible part of the animal.

A physical breakdown of the gross energy content of different parts of the animal is given in Table 2. The data were taken from a growth experiment in which pigs were slaughtered at various live weights between 20 and 90 kg (Fowler & Livingstone, 1972).

https://doi.org/10.1079/PNS19760012 Published online by Cambridge University Press

Table 1. *Partition of daily intake of metabolizable energy by a* 60 *kg pig (after Kielanowski,* 1972)

	Protein deposition (100 g)	Lipid deposition (200 g)	Maintenance	Total	Percentage of intake
Retention (MJ)	2·3	8·0	—	10·3	38
Associated heat loss (MJ)	4·3	2·9	9·2	16·5	62
Total (MJ)	6·7	10·9	9·2	26·8	100

Table 2. *The gross energy content of different components of gain in pigs growing from* 25 *to* 90 *kg live weight*

Component	Weight gain of tissue (kg)	Energy content of tissue gain (MJ)	Percentage of total retained energy
Lean tissue (skeletal muscle)	21·5	253	22·8
Fatty tissue (subcutaneous, perinephric and intermuscular fat)	19·2	640	57·8
Skeletal tissue (including hocks)	5·4	48	4·3
Non-carcass (head, viscera etc.)	12·0	167	15·1
Total empty-body gain	58·1	1108	100·0

The inclusion of intramuscular fat in the lean tissue increases the energy content relative to the energy of the protein alone but despite this, the proportion of energy in the highly desirable part of the carcass is really quite small. If the information in Tables 1 and 2 is now combined, using an efficiency of retention of energy in the whole animal of 38% (Kielanowski, 1972) and the proportion of this retained as lean tissue, 22·8%, then the value for efficiency of retention of dietary ME in the lean tissue of the growing pig is 8·7%.

In the units of animal husbandry, the efficiency of lean tissue production can be measured in terms of kg food intake/kg weight gain. This index of response to treatments has been used in only a few experiments but an indication of its value is given by referring to the experiment of Blair, Dent, English & Raeburn (1969). In this work, female and castrated male pigs were killed at four live weights and nutritional treatments involving four levels each of daily food intake, protein concentration, and lysine concentration were imposed. The sensitivity of lean-tissue food conversion to these factors is indicated in Table 3. The ranges are to some extent a reflection of the low number of pigs on each individual treatment but reference to the original paper shows that the nutritional factors studied affected profoundly this index of performance. The data for the different slaughter weights suggest a trend for the efficiency of conversion of food to lean tissue to be lower at the higher weights.

https://doi.org/10.1079/PNS19760012 Published online by Cambridge University Press

Table 3. *Lean-tissue food conversion ratios (kg food intake/kg lean tissue gain) for pigs on different dietary regimens* and killed at different weights (from Blair, Dent, English & Raeburn, 1969)*

Growth range (kg)	Sex		Effect of varying the dietary regimen*	
	Castrate	Female	Lowest	Highest
23–45	8·8	8·7	6·3	12·1
23–68	8·8	8·3	6·5	12·0
23–91	9·3	9·0	7·5	12·4
23–114	10·1	9·9	8·2	13·3

*Total food intake, dietary protein concentration and dietary lysine concentration were varied (see text).

A further example, taken from data obtained at the Rowett Institute, is given in Table 4 (R. A. Houseman & V. R. Fowler, unpublished results). In this experiment boars, castrates, and gilts were compared at three slaughter weights after receiving three different nutritional regimens. In each regimen, a conventional diet containing 165 g crude protein (nitrogen×6·25)/kg was fed and this was offered either *ad lib.*, or twice daily (as much as the pig could eat in 20 min), or to a scale of 130 g/kg body-weight$^{0.75}$ per d. These results show with considerable clarity the over-all superiority of the boar and a reduction of efficiency with increasing killing weight, and suggest interactions of feeding regimen with body-weight and sex.

Table 4. *Lean-tissue food conversion ratios (kg food intake/kg lean tissue gain) for boars, castrates and gilts fed on three different regimens**

(Mean values for four pigs/treatment)

Slaughter weight (kg)	Feeding regimen†	Boars	Castrates	Gilts
90	Restricted	10·3	10·7	9·5
	2×20 min	10·7	12·4	11·2
	Ad lib.	9·6	11·2	13·3
105	Restricted	8·4	12·6	10·2
	2×20 min	9·3	13·5	11·0
	Ad lib.	9·3	14·0	11·4
120	Restricted	9·8	13·8	11·7
	2×20 min	11·0	14·9	12·6
	Ad lib.	11·4	16·3	13·4

*From R. A. Houseman & V. R. Fowler (unpublished report to the Meat and Livestock Commission).

†Pigs were either given 130 g food/kg body-weight$^{0.75}$ per d (restricted), or given as much as they could eat in two 20 min periods/d (2×20 min), or fed *ad lib.*

The over-all efficiency of lean tissue production

It is clear that calculations of lean-tissue food conversion ratio are of considerable merit for exploring the significance of various factors during the growing phase. However, it may be argued that one cannot draw inferences about

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the most appropriate system of production from such studies since one is ignoring the energy cost of producing the weaner pig. The purpose in this section is to examine the over-all energy costs of lean tissue production and assess the relative importance of different means of minimizing the energy required per unit of lean tissue produced in the slaughter animal.

To simplify the calculation, the assumption was made that the economic cost of producing the breeding gilt is exactly offset by the sale of a sow at the end of its breeding life. The amount of food required by a breeding sow per year approximates closely to 1000 kg, and it has been assumed that the sow produces twenty piglets/year, each weighing 10 kg at weaning. To provide a sequential picture of the over-all energy cost of lean tissue production, data have been used from the experiment reported by Fowler & Livingstone (1972). In this instance, since carcass lean tissue is inevitably associated with carcass bone, the two have been combined to provide a value described as carcass bone+muscle.

The cost per kg, in terms of digestible energy, of live weight or carcass bone+muscle, including that attributable to the sow, was calculated for different live weights and the results are shown in Table 5.

Table 5. *The over-all cost in terms of digestible energy* (DE) *of producing live weight or carcass lean+bone in pigs*

Live wt (kg)	Cumulative DE intake (MJ)	Lean+bone content (% live wt)	DE cost (MJ) /kg live wt	DE cost (MJ) /kg lean+bone
30	1081	43	36	84
40	1357	45	34	75
50	1657	48	33	69
60	1993	50	33	66
70	2377	48	34	71
80	2785	46	35	76
90	3229	45	36	80

The maximal efficiency was achieved at about 60 kg live weight. It is tempting to speculate on the basis of such calculations why the average commercial killing weight is so much greater. Clearly an allowance must be made for the higher practical costs of housing a baby pig per unit of live-weight gain. Even so the results suggest that with this level of sow performance, a market which genuinely paid for lean meat would perhaps be most efficient if pigs were normally killed at lighter weights than 91 kg.

It is possible, using lean-tissue food conversion ratio as an index of biological efficiency, to explore the consequences of attempting by feeding, breeding or management to improve one particular facet of the pig's performance. In Table 6 the effects on lean-tissue food energy conversion of a 90 kg pig of changing some component of efficiency by 10% are shown.

One of the most important improvements appears to be related to increasing the rate of lean tissue deposition. This factor should clearly be a major target for improvement by management of the quality of the diet and by selective breeding.

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Table 6. *Changes in the digestible energy* (DE) *cost of producing carcass lean+bone (MJ/kg) resulting from a change in a component of the over-all efficiency of a pig of* 90 *kg live weight*

Initial value	80
10% reduction in cost of protein synthesis	79
10% increase in no. of pigs/sow	78
10% reduction in maintenance	77
10% reduction in lipid deposition	77
10% increase in lean deposition	75
10% reduction in killing weight	75
(Reduction of killing weight to 60 kg)	(66)

The other factor of importance is the question of optimal slaughter weight. It would, perhaps, be valuable to take into account more actively the very favourable lean-tissue food conversion of the pig of 60–70 kg live weight when husbandry and marketing practices are under review.

I should like to thank my colleagues Dr R. A. Houseman and Mr R. M. Livingstone for their help in preparing the data presented in Tables 2 and 4.

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Printed in Great Britain

https://doi.org/10.1079/PNS19760012 Published online by Cambridge University Press