Improving efficiency in pig production

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The relative importance of different components of efficiency depends on whether one's interest is biological or economic. A study of the elements of biological efficiency shows that the choice of slaughter mass has a profound effect, and that in relative terms reproductive characteristics are comparatively unimportant. The production of lean meat is shown to be improved significantly by adopting different strategies for meat production by such means as using once-bred gilts, boars rather than castrates, and very early weaning. Dietary factors are important in optimizing efficiency, particularly in establishing the nutrient requirements of very young pigs which are shown to have lysine requirements of about 1 g/MJ of digestible energy. The importance of feeding pigs as close to appetite as possible is stressed. The effect on very good and moderate genotypes by increasing feed intake is examined and in both cases shown to improve the efficiency of lean meat production. The importance of flexibility in production and in the processing industry is discussed in relation to improved efficiency.
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Biologiese of ekonomiese belange bepaal die relatiewe belangrikheid van die verskillende komponente van doeltreffendheid. 'n Ondersoek van die elemente van biologiese doeltreffendheid toon dat die keuse van massa tydens slag 'n diepgaande effek het en dat reproduktiewe eienskappe in relatiewe terme betreklik onbelangrik is. Die produksie van maer vleis is betekenisvol verbeter deur die aanwending van verskillende strategieë vir vleisproduksie, soos die gebruik van jong sôe, bere eerder as burge en baie vroeë speen. Rantsoenfaktore is belangrik by die optimisering van doeltreffendheid, veral by die vasstelling van voedingsvereistes van baie jong varke wat 'n lisienvereiste van ongeveer 1 g/MJ verteerbare energie het. Die feit dat varke nie oorvoer moet word nie, word beklemtoon. Die effek van die verhoging van voerinname op baie goeie en gemiddelde genotipes is ondersoek en het in albei gevalle die doeltreffendheid van produksie van maer vleis verbeter. Die belangrikheid van buigbaarheid in produksie en in die verwerkingsindustrie word bespreek ten opsigte van die verbetering van doeltreffendheid.
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Introduction

Pig production has been transformed over recent years from an interesting agrarian pursuit to a highly capitalized industry. The change has brought about a major awareness of the different indices of efficiency. What constitutes the most interesting of these indices, depends on one's viewpoint. If one is interested in the biology of pig production, then biological efficiency and its constituent elements are important. Alternatively, the farmer who already has a major investment in buildings and stock has a major interest in the ratio of feed costs to returns and in the speed of throughput. A third viewpoint is that of prospectively evaluating the options for a new production unit. A wide range of factors must then enter the calculation of efficiency, including comparative costs of buildings for different systems, home mixing versus purchased feeds, health status of the purchased stock, and breeding policy. Since this list is only a sample of the elements contributing to efficiency it is clear that only selected aspects can be considered within the scope of this article. The first part is a consideration of some general biological and economic factors and their effect on efficiency, and the second part relates to some specific nutritional considerations.

The relative importance of factors which contribute to biological efficiency

It is instructive to adopt the technique of assessing the effect on efficiency of an incremental change in one of the constituent parts of that efficiency. This is often difficult to do because of intercorrelations between the factors, but it does serve to highlight those elements to which efficiency is responsive. My approach has been to consider efficiency in terms comparable to those used by the working party of the Agricultural Research Council (ARC, 1981) of which I was a member. The factors considered are the costs of tissue synthesis for both protein and lipid, the maintenance cost, the partition between protein and fat, the effect of sow productivity and sow size, and the effect of slaughter mass. The index of efficiency was MJ of metabolizable energy (ME) (feed) needed to produce 1 kg of dissected lean tissue. The changes induced in this ratio associated with a 10% change in a favourable direction of each factor are shown in Table 1.

The calculation is self-consistent in that as far as possible allowances were made for the correlated effects of any change. For example, the increase in the mature mass of the sow was taken to have consequences for the growth rate of the offspring and for the cost of keeping the sow (Fowler, 1980). It can be seen that increasing lean growth has a very

Table 1 Changes in the ME required (MJ/kg) to produce lean tissue associated with a 10% change in a favourable direction of factors contributing to the efficiency of pigs slaughtered at 90 kg live mass

Factors	ME per kg lean tissue (MJ)
Initial cost	90
Heat lost during lipid accretion	89
Heat lost during protein accretion	89
Increase in sow mature mass	89
Pigs per sow per year (20–22)	88
Maintenance requirement	87
Rate of lipid accretion reduced	87
Slaughter mass reduced	87
Growth rate of lean increased	81
Reduction of killing mass to 60 kg	73

considerable effect as does reducing the slaughter mass below 90 kg.

Rather surprisingly, increasing litter size has a relatively small effect at this level of production although it is not necessarily unimportant. The costs of tissue synthesis appear to be the least-important factors.

The effect of live mass at slaughter on efficiency is controversial. Commercially, it depends on the relative strengths of the pork and bacon markets and on the method of feeding. An example of how it affects biological efficiency is shown in Table 2.

Table 2 The overall cost of metabolizable energy (ME) of producing lean tissue in the carcass of the growing pig

Live mass (kg)	Cumulative ME intake (MJ)	Mass of lean tissue (kg)	ME cost per kg lean tissue (MJ)
30	1026	11,1	92
40	1289	15,6	83
50	1574	20,5	77
60	1893	25,8	73
70	2258	28,8	78
80	2645	31,2	85
90	3067	34,2	90

Data obtained from growing pigs (Fowler & Livingstone, 1972) were used to compute the efficiency of lean-tissue production in terms of ME.

To simplify the calculations, it was assumed that the feed cost of rearing the mother could be disregarded since at the end of her reproductive life the sow is also usually sold for meat. Annual production from the sow was set at 20 live pigs weaned and her feed consumption at 1 000 kg/year. Early growth appears inefficient owing to the high overhead cost of feeding the dam, whilst later on, growth becomes inefficient because of the increasing increment of fatty tissue and maintenance expenditure associated with each unit of lean-tissue gain. In terms of this calculation the optimum occurred at 60 kg live mass.

Not all the elements for potential change can be evaluated in the manner discussed above. For example, the discussion of a change from castrates to boars is meaningless in terms of a 10% change. For interest, rather than on an absolute scientific basis, I have calculated the economic effects of a number of possible changes in the strategy of producing pigs. The economic conditions used are those prevailing in the North of Scotland at the time of writing and refer to production costs rather than potential prices paid. The assumptions made, are that each system is 100% efficient, and that the levels of production have at least been achieved in some of the experimental work. No allowance has been made for any penalty which the processor may apply to the carcass, the assumption being entirely that the objective is to produce lean meat independently of associated fat. The results are given in Table 3, with an indication of the potential for application in the short or the longer term.

Table 3 Effect on economic costs of changing from traditional systems of production for bacon pigs at 90 kg

Change	Reduction in costs of lean meat production (%)
Restricted 80% to *ad lib.*	7,0[a]
Once-bred gilts rather than sows	3,7[a]
Boars rather than castrates	3,5[a]
Sows weaned at birth (from 4-weeks)	2,0[b]
Gilts weaned at birth (from 4-weeks)	1,8[b]
Lighter slaughter mass (70 rather than 90 kg)	1,8[a]

[a]Applicable in the short term
[b]Potentially applicable in the longer term

The simultaneous application of all the short-term options could increase the economic efficiency of lean-meat production by over 10%.

Efficiency and level of feeding

There is some dispute over the exact response of pigs to changes in the level of feeding. Fowler, Ross & Wilkinson (1980), discussed some of the conflicting theories. Much of the early thinking in this field was distorted by the assumption that when fed at a maintenance intake the body composition remained stable. As shown, however, in the review of ARC (1981) protein is deposited at energy equilibrium whilst fat is depleted. It is therefore quite possible for pigs to have a linear response in tissue growth to increments of feed, and this approach was used by the ARC to illustrate how the responses could be modelled. The contrary view is that there is a limit to daily lean deposition and when this is reached, additional food is merely deposited as fat. Whittemore & Fawcett (1976) used this concept in a model of pig growth.

The truth may lie somewhere between these extremes although it is probable that both may apply to different stages of growth. In terms of pigs slaughtered at 87 kg live mass the tests of the Meat and Livestock Commission (MLC, 1982) for Commercial Product Evaluation provide an interesting data base.

The efficiency of pigs fed restrictedly and to appetite on the eighth test are compared, first with an index of biological efficiency (feed cost per kilogram lean) and secondly with an index of economic efficiency. The units of this second index are British pence (p) but these can readily be converted to other currencies by considering them equivalent to the cost of 1 MJ of balanced meal.

The assumptions in the economic index are that lean meat is worth 200 p/kg independently of the type of carcass with which it is associated, that the cost of each pig place is the same on restricted or *ad libitum* feeding, and that all interest charges, depreciation on building and running costs are included in the daily cost per pig place. The biological and economic indices are given in Tables 4 and 5. It is clear that although the biological index very slightly favours restricted feeding, the economic index gives more weight throughout, and favours feeding to appetite. This illustration suggests that the judgement of optimal levels of feeding is complex and relies more on individual circumstances than on a basic scientific truth, particularly when the choice lies between two levels which are close to *ad libitum.*

There is clearly a need for a continuing supply of data on pigs of up-to-date genotype fed on modern balanced diets to allow accurate calculations of the optimal strategy to be made.

Efficiency and dietary protein

Because raising the effective protein of a diet is costly, it is expensive to supply an excess and inefficient to reduce the growth of lean tissue by providing too little. Although awareness of the recommendations for the nutrient requirements of pigs leads one to the conclusion that the younger the pig the greater its requirement. It is not clear from the reviews of, for example, ARC (1981) how the need changes.

There are several reasons for this. First, the reviewers were reluctant to have a recommendation on a factorial model preferring rather to divide the empirical data into three live-mass groups and recommend accordingly. Secondly, there are considerable difficulties in obtaining data for the efficiency of utilization of ingested protein even when its amino-acid composition is known. Thirdly, the exact specification of the protein requirements depends on the energy level with which the protein is fed.

The danger of this understandable caution is that few are made aware of the general shape of the requirement even when one of the variables is removed and pigs are fed to appetite.

The purpose of the next part is to illustrate the implications of the ARC factors for pigs fed to appetite from 10 to 100 kg. Intakes were calculated as MJ digestible energy (DE) per day from the ARC equation:

$$DE = A(1 - e^{-0,0204W})$$

where DE = daily intake of DE (MJ); A = 50 — the asymptote of intake; and W = live mass.

The growth rates are those which are typical of pigs fed to appetite at the Rowett Institute, and the factor for converting daily live-mass gain to daily protein gain was 0,165 based on the data of Kotarbinska (1969) and results obtained by ourselves. It is worth noting that after 10 kg live mass the proportion of protein in the body remains surprisingly constant because the reduction in water associated with protein tends to be almost perfectly offset by increase in lipid.

The obligatory protein losses (OL) were calculated as

$$OL = 0,15 \times 6,25/\text{kg}W^{0,75}$$

after the values proposed by Carr, Boorman & Cole (1977).

The efficiency of utilization of ideal protein in the diet is affected by the ileal digestibility of protein and particularly lysine and the utilization after absorption. The value was taken as 0,5 since this is close to the average which can be derived from equations given by ARC and is consistent with the slopes of Figures 1, 2 and 3 (from ARC, 1981), if the protein deposition is taken as 0,165 of the daily gain. The final step is to estimate the requirement for the most limiting amino acid taking it as 0,07 of ideal protein.

The results are shown in Table 6. Clearly the ratio of lysine per MJ falls throughout the growing period. It is tempting to conclude that the requirements can only be met without waste by having a series of diets throughout growth. This is perhaps an example of where there must be a compromise between the scientific ideal and what is practical on the farm. It does not, however, seem impossible to achieve a better match of requirements if the microchip revolution makes programmed feeding a reality.

It should be pointed out that in high-energy diets for young pigs and particularly those containing fat, it is not unreasonable to consider inclusion rates for lysine (as an index of ideal protein) of up to 16 g/kg.

Early weaning and once-bred gilts

Sow productivity is correlated with early weaning. In terms of improving biological efficiency the response to shortening the lactation is impressive (see Table 7).

The ultimate extrapolation, weaning at birth, has proved to be technically extremely difficult (Fowler & Varley, 1982). The limitation on the farm is set more by the problem of

Table 4 Response to *ad lib.* feeding (data from Meat and Livestock Commission, 1982)

	Feed/day (kg)	Gain/day (g)	Lean/day (g)	Feed to lean (g/g)
Restricted	1,87	654	253	7,3
Ad lib.	2,37	825	310	7,6
Percentage increase with *ad lib.*	26,7	26,1	22,5	–

Table 5 Economics of feed level, using data from Table 4

	Feed/day (kg)	Cost of feed/day (p)	Cost of pig place/day (p)	Total cost/day (p)	Return value of lean/day (p)	Margin/pig place/day (p)
Restricted	1,87	33,7	10	43,7	50,6	6,9
Ad lib.	2,37	41,5	10	51,5	62,0	10,5

Table 6 Calculated lysine requirement per MJ of digestible energy in diets of growing pigs fed to appetite

Live mass (kg)	Daily[a] DE (MJ)	Daily[b] live gain (g)	Daily[c] deposition protein (g)	Daily[d] obligatory protein losses (g)	Total daily protein (g)	Ideal[e] protein daily (g)	Dietary[f] lysine daily (g)	Lysine per MJ DE (g/MJ)
10	9,23	380	62,7	5,3	68,0	136	9,5	1,03
20	16,75	570	94,1	8,9	103,0	206	14,4	0,86
30	22,89	710	117,2	12,0	129,2	258	18,1	0,79
40	27,89	875	144,4	14,9	159,2	318	22,3	0,80
50	31,97	900	148,5	17,6	166,1	332	23,2	0,72
60	35,30	900	148,5	20,2	168,7	337	23,6	0,67
70	38,01	900	148,5	22,7	171,2	344	23,9	0,63
80	40,22	900	148,5	25,1	173,6	353	24,7	0,61
90	42,03	900	148,5	27,4	175,9	352	24,6	0,59
100	43,50	850	140,3	29,7	170,0	340	23,8	0,55

[a]From DE = 50 (1 − $e^{-0,0204W}$) (ARC, 1981); [b]Data from Rowett Institute; [c]Assuming 0,165 of daily gain to be protein (ARC, 1981); [d](ARC, 1981); [e]Assuming gross efficiency of utilization of ideal protein 0,5 (ARC, 1981); [f]Assuming lysine in ideal protein = 0,07

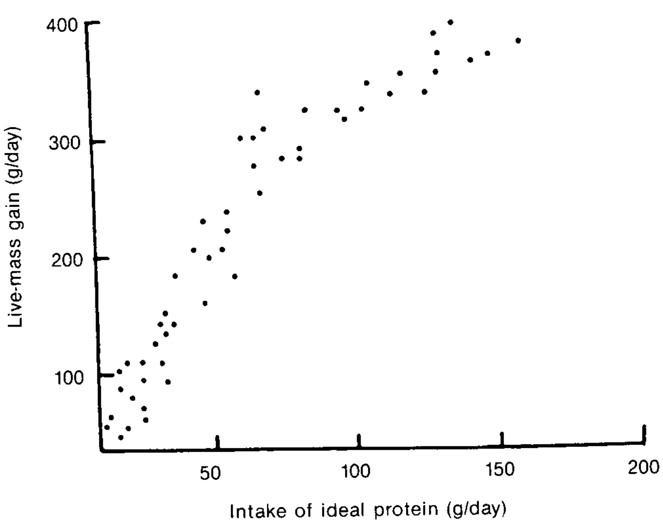

Figure 1 Relationship between protein intake and the daily gain of pigs 0–3 weeks of age

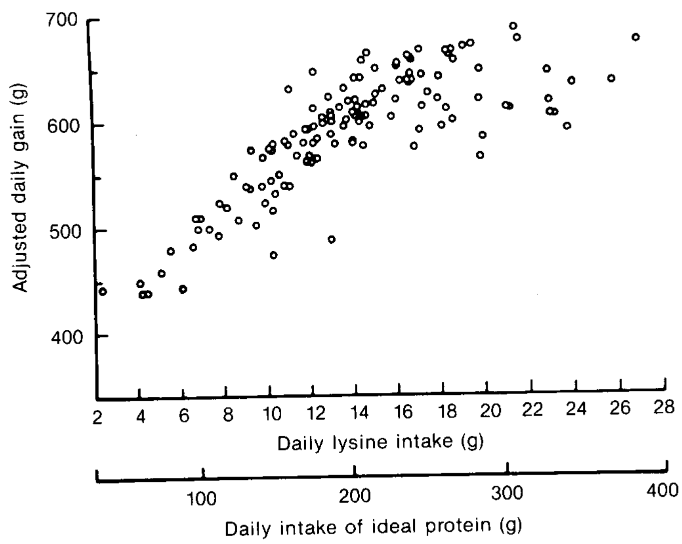

Figure 3 Relationship between daily gain and daily intake of ideal protein for pigs of 15–20 kg. Daily gains are adjusted to remove differences between experiments in mean daily gain

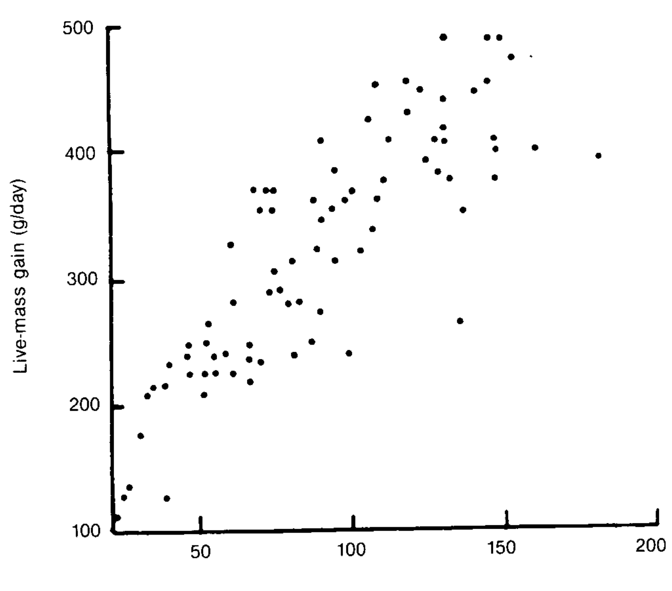

Figure 2 Relationship between protein intake and the daily gain of pigs 3–8 weeks of age

Table 7 Age of weaning, litters per year, pigs reared per sow per year and piglet mortality for the top third of MLC-recorded herds and the potential for piglets weaned at 0–2 days

	Age at weaning (days)					
	40–56	33–39	26–32	19–25	14–18	0–2
Litters/sow/year	2,15	2,27	2,34	2,42	2,48	2,8
Pigs reared/sow/year	21,3	22,4	22,6	23,4	24,4	30,0
Mortality	10,3	10,8	9,4	10,0	9,2	<5,0

providing a suitable diet than by any other single factor. It has been shown (Fowler & Varley 1982) that weaning at any age should in nutritional terms be a process rather than an event. It has also been shown by Miller, Newby, Strokes & Bourne (1984) that adaptation to new proteins, particularly soya-bean protein, is crucial if scour is to be prevented.

Table 8 The deviation of the constants *a* and *b* in the equation $y = a + bx$, where y = lean gain (g/d), x = daily intake of feed (MJ DE), for pigs slaughtered at 87 kg live mass from the Commercial product evaluation trial of the MLC (1980)

	Feeding level	Daily intake (MJ DE/ day)	Daily gain of lean (g)	Slope *b*	Intercept *a*
Best three companies	Restricted	24,6	264	9,81	+23
	Ad libitum	30,0	317		
Worst three companies	Restricted	24,9	232	8,26	+26
	Ad libitum	32,4	294		

Table 9 Costs of producing lean gain in pigs slaughtered at 89 kg. Calculated using slopes given in Table 8

	Multiples of maintenance	DE (MJ/day)	Cost (MJ ≡)	Lean gain (g/day)	g of lean per MJ DE	g of lean per MJ ≡
Best three companies	2,5	24,2	34,2	260	10,8	7,6
	3,0	29,0	39,0	308	10,6	7,9
	3,5	33,8	43,8	355	10,5	8,1
Worst three companies	2,5	24,2	34,2	226	9,3	6,6
	3,0	29,0	39,0	266	9,2	6,8
	3,5	33,8	43,8	306	9,0	7,0

Genes and efficiency

Pig breeding has made enormous strides in the last 50 years, but there is still considerable scope for improvement. It is very attractive to consider the consequences for efficiency of incorporating some of the features of the highly prolific Chinese breeds such as those found round Lake Taihu with Western pigs (Cheng, 1983).

Since it will take the breeders some time to disentangle the attractive and unattractive features of such pigs, it is appropriate to consider the trends in the modern breeds of pigs which we have.

There has been concern in recent years in the UK about the problems associated with pigs which are said to be too lean for the trade. It is in one sense, the inevitable consequence of selection against fat.

The point to make here is that when the population of pigs becomes optimally lean for the market, the main route for genetic improvement is to increase the rate at which pigs grow lean tissue and fat. This can only be done by increasing intake. This reversal of present genetic trends, presents us with the interesting prospect of trying to restore the appetite of pigs which was one of their major attributes in the first place. Our understanding of the physiology of intake in pigs is limited, and in Europe at any rate it is becoming increasingly difficult to find ethical ways of influencing growth other than by nutrition or genetics.

The potential for increasing efficiency in animals of different genetic potential is shown in Tables 8 and 9.

Results of the three best and three worst companies on the CPE test of MLC (1980) for pigs slaughtered at 89 kg are shown. The restricted and *ad libitum* feeding regimes were used to calculate a within-group regression of intake on daily lean gain. The slope was then used to calculate the effect of rate of feeding on biological efficiency (g of lean/MJ DE) and economic efficiency (including fixed costs) g of lean per unit of money equal to 1 MJ. In the UK at this time this equalled 1 pence. The results show that even within a genotype group, greater feed intake gives a greater efficiency in economic terms.

Conclusions

Pigs are the most efficient of large animal species in converting digested energy to lean. They are not as efficient as they could be, partly because we have not yet exploited their existing attributes and partly because we have not yet developed the animal genetically to its full potential.

One barrier to achieving the last steps in efficiency is lack of flexibility. This occurs both in our strategies for husbandry and feeding but perhaps most importantly, in the processing industry. The flexibility to slaughter boars, once-bred gilts, fat but efficient pigs, and lighter pigs open up new opportunities for the farmer and processor alike. It would be a pity if the imagination of scientists was totally frustrated by the politics and traditions of marketing and inertia on the part of the producer. It would be an even greater pity if the only route to innovation was a reaction to the painful process of economic decline.

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