Determination of responses of growing pigs to dietary energy concentration

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The responses in growing pigs to balanced diets at different dietary energy levels are estimated from published data after recalculation of digestible energy (DE) levels using standard tables. Although responses in live weight gain (ADG), food intake (FI), digestible energy intake (DEI) and food conversion effciency (FCE) are calculated it was not the purpose of this paper to quantify the absolute relationship between these variables and dietary energy levels but rather to apply the general responses to formulate feeds to optimize profit margins. Linear regressions of ADG, FI, DEI and FCE on DE accounted for 82, 97, 97 and 93%, respectively, of the variation amongst the 15 estimates of the responses. Most of this variation was accounted for by difference amongst the constant term of the various experiments, which implies small differences amongst the slopes. The genotype of pig and live weight were found to be important in influencing the rate of response in some characteristics. The optimum nutrient density of the feed chosen will depend upon the efficiency of feed utilization, the cost of the feed and the income derived from the end product. The energy level at which margin over feed costs are maximised will be the optimum nutrient density.

Keywords: energy, nutrient density, pigs, profits

Introduction

It has been shown that the response of *ad libitum* fed growing pigs to dietary energy concentration is mainly in food or energy consumption, which has consequences for the efficiency of food utilisation and carcass quality (Owen & Ridgman, 1968; Campbell & Taverner, 1986; Kyriazakis & Emmans, 1995). Rate of body weight gain is affected to a much lesser extent. To choose an optimal dietary energy concentration, one first needs to define the biological responses of pigs offered diets formulated to various energy levels add then combine the results with the costs of formulation and the value of the outputs, all of which vary with time and locality. Fisher & Wilson (1974) conducted a survey of data for chickens and so determined their response to dietary energy and what factors would affect that response. In this paper a similar investigation is conducted in growing pigs from 10 to 90 kg live weight. To quantify the nature of the responses of the growing pig to dietary energy concentration data from publications that meet certain criteria were acquired and analysed before applying monetary values to the feed costs and animal outputs.

The objective of this paper was not to relate absolute levels of ADG, FI, DEI and FCE to dietary energy concentrations but rather to apply the general response trends to practical formulation of diets to optimize profit margins.

Method

Firstly it was necessary to determine what criteria would be used to select data. Once the data from suitable experiments had been obtained they were used to quantify the responses to dietary energy levels and to what extent factors like genotype, live weight, sex and housing would affect the response. Lastly economic responses were derived, from which optimum dietary energy concentrations could be determined for application in the formulation of practical pig diets.

Selection of data

The following criteria were used to select the appropriate experiments:

1. Nutrient and ingredient composition of the diets must be provided with sufficient detail to allow recalculation of dietary energy levels.
2. Diets must have a constant energy : protein or energy : amino acid ratio.
3. Animals must have had free and continuous access to feed.
4. Growth and feed intake results must be available in a form that allows additional calculations to be made.

To ensure more accurate estimates of dietary energy levels it was necessary to recalculate the energy concentrations from the ingredient composition of the diets. The publications used in this paper are shown in Table 1. Results from 10 experiments were included to provide a total of 17 response lines (or curves) with the number of digestible energy (DE) levels tested in each trial varying from 2 to 6 giving a total of 66 observations per response variable. The 66 observations were derived from the number of responses × DE levels over all experiments (Table 1). Other data sets were rejected because animals were not fed *ad libitum* (Lodge *et al*., 1972; Lawrence, 1977; Pike *et al*., 1984) or because energy : protein ratios were not constant across diets (Baird *et al*., 1 975).

Table 1 Summary of the response information used from the literature

Reference	Number of responses	Energy levels per response
Ball & Aherne (1987)	1	2
Campbell *et al.* (1975) Expt 1	1	4
Expt 2	1	5
Campbell & Taverner (1986)	1	5
Kyriazakis & Emmans (1995)	1	5
O'Grady (1978)	1	2
O'Grady & Bowland (1972)	2	4
Owen & Ridgman (1967)	3	6
Owen & Ridgman (1968)	5	3
Patterson (1985)	1	2

Determination of biological responses

The four production variables considered were average daily live weight gains (ADG), feed intake (FI), digestible energy intake (DEI) and feed conversion efficiency (FCE). Data for these variables were obtained from the published results. To determine the effects of each trial separately and the effects of descriptive factors a linear regression model using 'dummy' variables was fitted using the Least Squares method in Minitab (1994). Dummy variables were used to determine whether there was a common intercept and/or slope between experiments and various descriptive factors were applicable. The following model was used to fit the data:

$$Y = a_0 + b_0X_0 + a_I + b_IX_I + ... + a_i + b_iX_i + e \quad (1)$$

where

Y= response variable

a_0 = constant or intercept term for the "first" experiment

b_0 = slope value for the 'first' experiment

X_0 = Digestible Energy concentration of 'first' experiment

$a_{I...i}$ = effect of an additional experiment or descriptive factor ($X_{I...i}$) on a_0 (intercept)

$b_{I...i}$ = effect of an additional experiment or descriptive factor ($X_{I...i}$) on b_0 (slope)

$X_{I...i}$ = Digestible Energy concentration of additional experiment or, either 0 or 1 for a descriptive factor

e = residual error

Factors that had some commonality between experiments were breed type, live weight, sex and housing arrangements. When considering whether these factors had any significant effect on the various responses, regression coefficients were compared by *t*-test. Because there has been a marked improvement, owing to genetic selection, in growth rate and carcass quality it was appropriate to divide breed type into two categories according to year of publication. Results obtained prior to 1980 reflected a slower growing, fatter type of pig (Fat) while after 1980 it was assumed that the pigs grew faster and were leaner (Lean). There were insufficient data to justify more than two categories. In terms of live weight, five levels were defined: 10–30 kg, 30–60 kg, 60–90 kg, > 90 kg and between 10 and 90 kg. Unfortunately there was only sufficient replication in the available data in the first three weight categories and therefore only these were considered separately in the analyses. The sex variable comprised of males only and males and females together: there were no suitable data for females only. Housing defined the effects of individual *versus* group pens.

After initially including the data from the two experiments of Campbell *et al.* (1975) it was found that these data had a strong negative influence on the regression responses such that their inclusion substantially reduced the goodness of fit of the model. The reason for the negative effect lay in the young age (3 to 8 weeks) and low live weight range (5.4 to 20 kg) from which the data were obtained with the result that values for ADG, FI and DEI were considerably lower than any of the other data used in this paper. In an attempt to remove as much error variation as possible both the experiments of Campbell *et al.* (1975) were excluded from further analyses.

Determination of economic responses

To apply the responses in FI, ADG and FCE to energy concentrations it is necessary to attach monetary values to both input costs and prices obtained for the end product. From the estimates of biological responses to DE it is possible to determine the economic response expressed in terms of margin over feed costs. This step requires estimates of energy and amino acid requirements over various stages of growth and fattening in order to formulate feeds and obtain a cost per feed. For simplicity and comparability with the literature the growth phase of the pig was divided into three weight categories (10–30 kg, 30–60 kg and 60–90 kg live weight) each with their own nutrient requirements. Diets were formulated on the basis that lysine was the most limiting amino acid with the remaining essential amino acids balanced according to the ideal ratio of Wang & Fuller (1989). Lysine : energy ratios for the three phases of 0.75, 0.65 and 0.55 g lysine/ MJ DE respectively, were used in the formulation of rations. These ratios were based on current practice in South Africa.

However, to compare with what is more appropriate to achieve maximum potential lean tissue growth during the respective live weight ranges of current genotypes (Whittemore,1993), an additional set of ratios of 0.80, 0.75 and 0.70 g lysine/ MJ DE were also tested. Table 2 provides details of the cost of the respective diets.

Table 2 The cost of rations (R/ton) based on different dietary energy concentrations and nutrient densities (lysine : digestible energy)

	g Lysine/ MJ DE				
DE (MJ/kg)	0.55	0.65	0.70	0.75	0.80
10.0	676	717	736	767	796
10.5	700	740	765	790	825
11.0	732	776	799	831	860
11.5	772	821	845	869	907
12.0	822	871	897	924	963
12.5	875	924	958	997	1035
13.0	929	983	1021	1069	1109
13.5	985	1050	1102	1135	1173
14.0	1046	1122	1180	1206	1256
14.5	1130	1195	1265	1288	1339

Income was derived from the marketing of pigs at 90 kg live weight or 67 kg slaughter weight assuming a 74% dressing percentage. An average carcass price of 750 c/kg was used, which is close to the average price/kg for the third quarter of 1997 of 765 c/kg (Livestock and Meat Statistics, 1997).

Margin over feed costs was used to determine the optimum nutrient density and results were expressed as a proportion of the margin over feed costs at 10 MJ/kg DE. The optimum nutrient density is determined from the maximum margin over feed costs per batch of pigs. This would be the concentration of dietary energy and amino acids that would provide the maximum economic returns rather than maximum biological performance.

Factors that were found to significantly affect the responses to DE would also be incorporated into the determination of the optimum nutrient density by separating their effects on the response to DE.

Results and Discussion

To check whether the growth responses to DE were linear, a quadratic term was added to the linear model described in Equation 1. The results showed only the linear responses were significant ($p < 0.05$) with no significant quadratic effects ($p > 0.05$). It is assumed in this paper, therefore, that the growth responses to DE are linear.

Fitting data to the model defined in Equation 1 accounted for 82–90% of the variation in all responses to DE with the constant terms for trials accounting for most of the variation between experiments. Although there were no significant differences in slopes between experiments the inclusion of other factors did result in significantly different slopes. When considering the effects of

Table 3 A summary of the regression slopes (b_1) and their standard errors (s.e.) for feed intake (FI) (kg/d), DE intake (DEI) (MJ/d), average daily live weight gains (ADG) (kg/d) and feed efficiency (FCE) (g gain/kg food) regressed on DE (MJ/kg) and the level of significance (*p*) and variation accounted for by the linear model (r^2) before considering the effects of live weight and genotype

Response	b_1	s.e.	*p*	r^2
FI	-0.0567	0.0184	**	96.9
DEI	1.687	0.204	***	97.1
ADG	0.0375	0.0066	***	81.7
FCE	29.687	4.625	***	92.6

For *p*: ** = < 0.01; *** = < 0.001

live weight, sex, genotype and housing on the responses to DE after fitting constants for the different experiments, only live weight and genotype were found to have any significant effect. Therefore the remainder of the discussion will be confined to the effects of these two variables. The influence of genotype and live weight will be discussed separately in each of the respective responses. As this paper is only concerned with the nature of the responses and not absolute values for each response variable, and as responses by definition involve a rate of change, particular attention will be given to the regression coefficients and not the constant terms. Tables 3 and 4 provide summaries of the regression coefficients

Table 4 A summary of the regression slopes (b_1) and their standard errors (s.e.) for feed intake (FI) (kg/d), DE intake (DEI) (MJ/d), average daily live weight gains (ADG) (kg/d) and feed efficiency (FCE) (g gain/kg food) regressed on DE (MJ/kg) and the level of significance (*p*) and variation accounted for by the linear model (r^2) after considering the effects of live weight and genotype

		10–30 kg		30–60 kg		60–90 kg		> 90 kg		10–90 kg		
Response	Genotype	b_1	*p*	b_1	*p*	b_1	*p*	b_1	*p*	b_1	*p*	r^2
FI	Fat	-0.051	NS	0.032	NS	-0.089	NS	-0.170	**	-0.064	NS	97.8
	s.e.	0.106		0.075		0.071		0.077		0.079		
	Lean	0.009	NS	-0.043	NS	nd		nd		nd		
	s.e.	0.077		0.064								
DEI	Fat	0.557	NS	2.361	**	1.901	*	1.251	NS	1.955	*	97.5
	s.e.	1.297		0.916		0.875		0.942		0.974		
	Lean	1.048	NS	1.547	‡	nd		nd		nd		
	s.e.	0.942		0.784								
ADG	Fat	0.0169	NS	0.0356	NS	0.0255	NS	0.0066	NS	0.0229	NS	88.9
	s.e.	0.0348		0.0246		0.0235		0.0253		0.0261		
	Lean	0.0941	***	0.0728	***	nd		nd		nd		
	s.e.	0.0253		0.0210								
FCE	Fat	34.95	**	12.41	NS	16.17	‡	14.74	NS	14.66	NS	98.7
	s.e.	12.99		9.17		8.76		9.43		9.75		
	Lean	94.98	***	43.23	***	nd		nd		nd		
	s.e.	9.43		7.85								

p: NS = Not significant; ‡ = < 0.10; * = < 0 05; ** = < 0.01; *** = < 0.001

nd = no data available

and their significance before and after, including the effect of genotype and live weight. Because of the low number of degrees of freedom a significance level of $p < 0.10$ was considered as noteworthy and given as a significant response (‡).

Classification of the responses into the various genotype and live weight categories was not equal. In the Fat strain of pig there were 2, 3, 3, 2 and 1 responses for the 10–30 kg, 30–60 kg, 60–90 kg, >90 kg and 10–90 kg subgroups respectively, and for the Lean strain there were only 3 and 1 responses for the 10–30 kg and 30–60 kg groups respectively.

The initial analyses of the 61 observations from 15 responses (excluding Campbell *et al.*, 1975) based on Equation 1 accounted for most of the variation through fitting different constants and a single slope for the different experiments. Further slight improvements in the models for DEI, ADG and FCE could be made by adjusting the slope value to take into account the effects of genotype and live weight (Table 4). From an economic point of view the response in FCE was of greatest importance as it allowed for the estimation of feed costs without requiring an estimate of days to market.

Response in food consumption to DE

Without considering the effect of genotype, live weight or anything else most of the variation was accounted for after fitting the constant term for the different experiments (r^2 = 96.9%) . There were no significant differences in slopes between experiments and therefore it can be assumed that the responses in FI to DE share a single slope value (-0.0567 kg d^{-1} /MJ DE kg^{-1}). The regression coefficient was significantly different ($p < 0.01$) from zero.

Figure 1 illustrates the relationship between FI and DE. Genotype and live weight had no effect in improving the accuracy of the response within the weight categories 10–30, 30–60 and 60–90 kg.

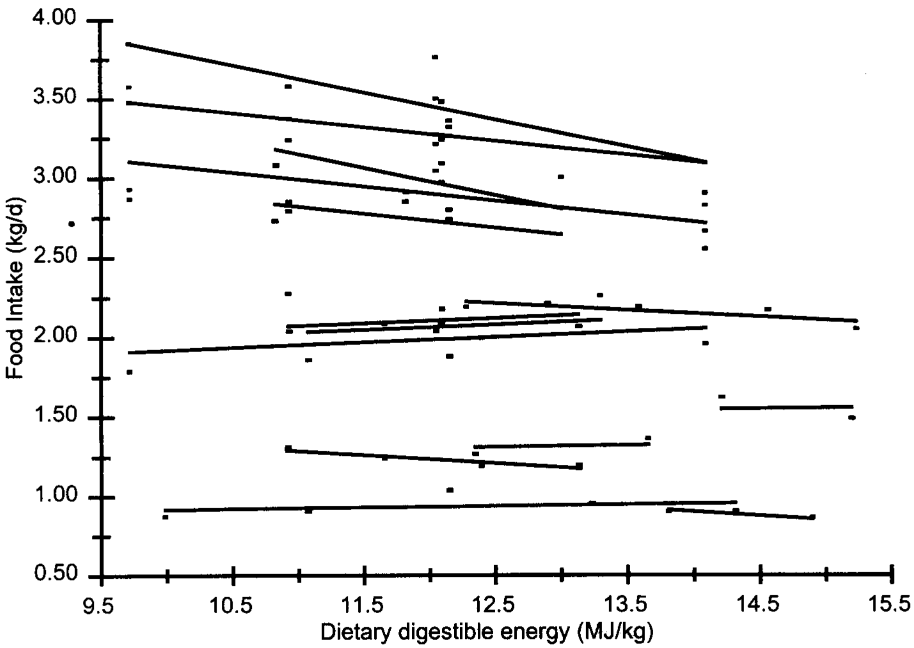

Figure 1 Relationship between daily food intake and dietary digestible energy. (—)Fitted values from regression model incorporating live weight and genotype effects; (■) published data.

Response in energy intake to DE

Energy intake increased with increasing DE content at a rate of 1.687 MJ/d per MJ DE /kg (Figure 2). This rate was significantly different from zero and therefore of practical importance when formulating feeds because it allows for the optimum balance to be attained between feed costs and energy intake. However, the response in energy intake was affected by live weight and genotype such that for Fat pigs greater than 30 kg live weight the rate at which energy intake increases with increasing dietary DE level is greater than for Lean type pigs (Table 4).

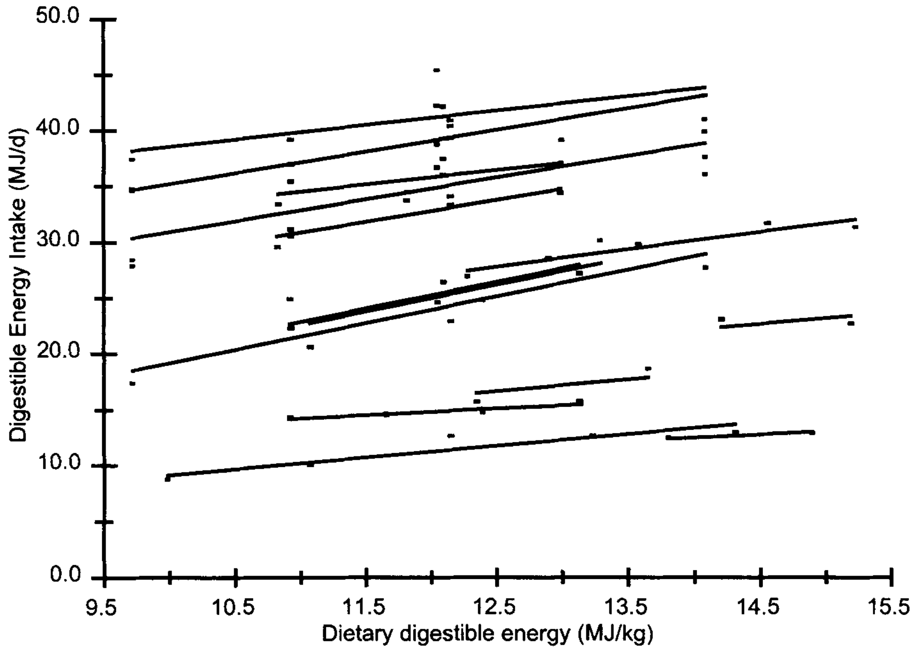

Figure 2 Relationship between digestible energy intake and digestible energy. (—) Fitted values from regression model incorporating live weight and genotype effects; (■) published data.

Response in live weight gain to DE

The responses in ADG (Figure 3) were more variable (r^2 = 81.7%) than those of FI, DEI and FCE. Between experiments the constant terms were significantly different but the rates of ADG change were the same. On average ADG increased 37.5 g/d for every unit increase in DE which was a significant rate of change ($p < 0.001$). However this response was affected by both genotype and live weight (Table 4) with noticeable increases in the rate of change for Lean type pigs in both the 10–30 kg and 30–60 kg weight categories but no apparent differences in the rate of response in Fat genotypes across all weight categories. The inclusion of the effects of genotype and live weight increased the amount of variation accounted for to 88.9%.

Response in feed conversion efficiency to DE

Although the linear model in Equation 1 accounted for most of the variation between experiments (r^2 = 92.6%) without considering the effects of genotype and live weight there was an improvement

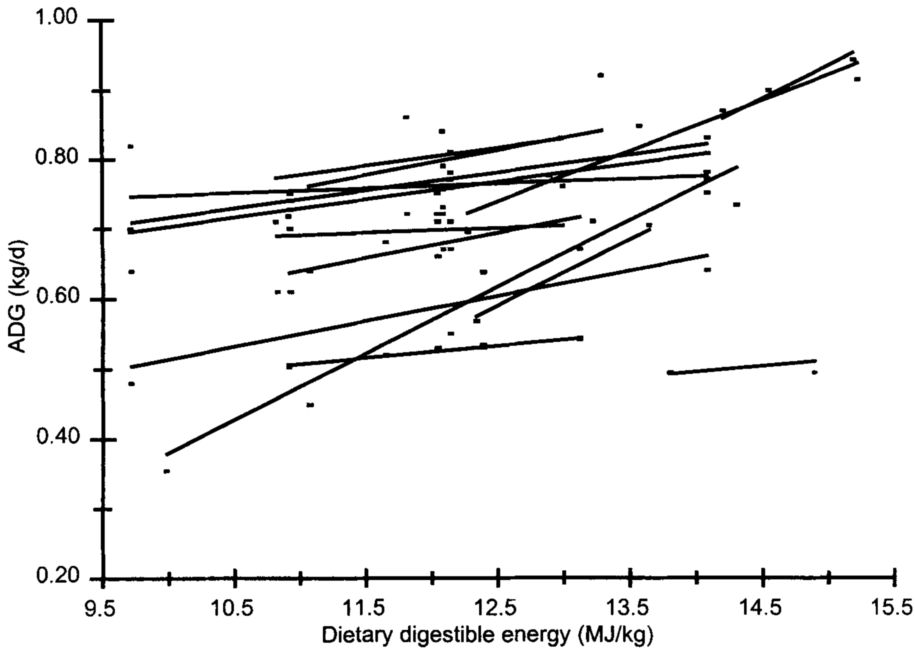

Figure 3 Relationship between average daily live weight gain (ADG) and dietary digestible energy. (—) Fitted values from regression model incorporating live weight and genotype effects; (■) published data.

in response with the inclusion of these two variables (r^2 = 98.7). Most of the variation was accounted for by fitting different constant terms for trials with a common slope. The mean slope of FCE on DE was 29.69 g/kg per MJ /kg DE but the slope was higher for lighter pigs (10–30 kg) and also for Lean pigs in the 30–60 kg live weight range.

Determination of optimum nutrient density

To determine the optimum returns over feed costs and hence the optimum dietary energy concentrations, the levels of production and the rate of response must be defined. The corollary to this is that optimum energy levels are a consequence of both the level of production and the rate of response in production with dietary energy. In the case of pork production the marketing of pigs is at a fixed live weight, irrespective of age, and therefore with a known change in live weight the response to FCE becomes important. In this exercise the level of performance is defined as a live weight change of 20, 30 and 30 kg over the 10–30 kg, 30–60 kg and 60–90 kg periods, respectively and combined with response data for FCE the total feed consumed and feed costs for each weight interval were determined. For a given carcass price/kg it was then possible to calculate the margin over feed costs per pig. From these calculations the energy levels which will maximise the margin over feed costs per batch of pigs were estimated for a number of different production scenarios including different types of pigs, different fixed costs and different lysine : energy ratios.

So as to follow commercial practice, market related feed prices were used to formulate a series of diets differing in nutrient densities. The costs of these feeds are shown in Table 2. After considering the various response data and knowing the change in live weight, the response of FCE to DE was used to determine feed costs. This eliminated the need to estimate the number of days pigs would be

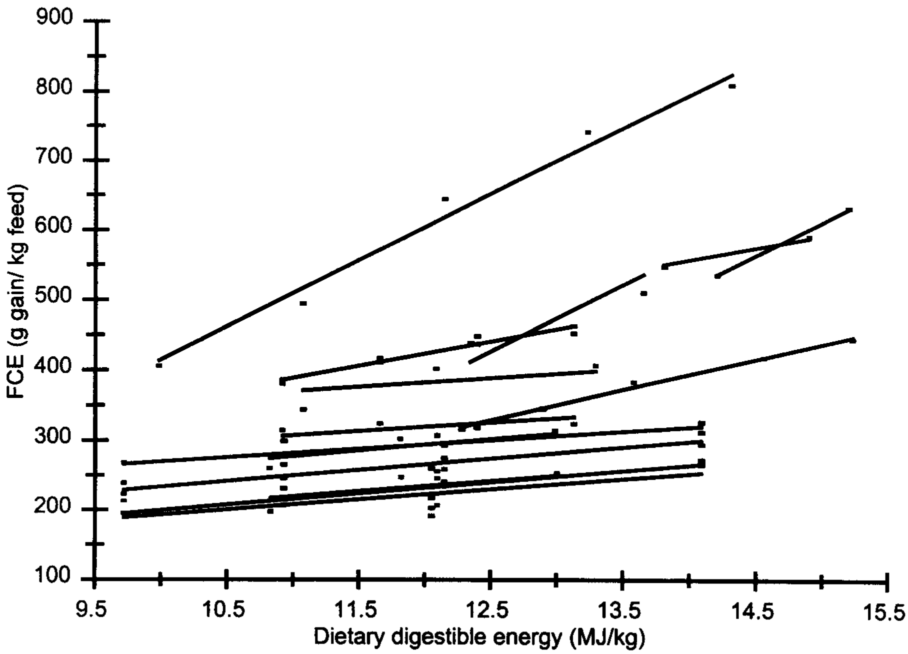

Figure 4 Relationship between efficiency of feed conversion (FCE) and dietary digestible energy. (—) Fitted values from regression model incorporating live weight and genotype effects; (■) published data.

on a certain feed in order to calculate total feed costs over the growing period from 10 to 90 kg.

The lack of data over the 60–90 kg live weight range for the more recent genotype (Lean) required the assumption that the efficiency of feed utilization was approximately 85% that of the previous weight range (30–60 kg). This assumption was based on the work done by Campbell *et al* (1985a,b) and others (SCA, 1987) who estimated the range in FCE over the 30–60 kg and 60–90 kg categories to be 0.46 to 0.38 and 0.38 to 0.34, respectively. To accommodate this reduction in efficiency it was assumed that the rate of change in FCE was 0.85 the slope value of the previous weight range.

Effect of live weight

As there were significant differences in the response of FCE to DE between the various live weight ranges (Table 4) it was necessary to incorporate these changes by predicting the feed costs for each weight range separately. Over the live weight ranges 10–30 kg, 30–60 kg and 60–90 kg, it was assumed that for each energy level the lysine :energy ratio would change from 0.75, 0.65 and 0.55 g/MJ respectively. Figure 5 shows the differences in margin over feed costs when using the average constant term and single slope value over all experiments to calculate the food intake and hence feed costs *versus* dividing the growth period of both the Fat and Lean genotypes into the three different weight groups and using their respective FCE responses to DE. The former response to DE does not consider the effects of live weight on FCE and tends to overestimate FCE particularly at higher live weights. Unless specifically stated all discussion refers to responses based on dividing the growing period into the three live weight periods and using the appropriate lysine:energy ratios for all energy levels.

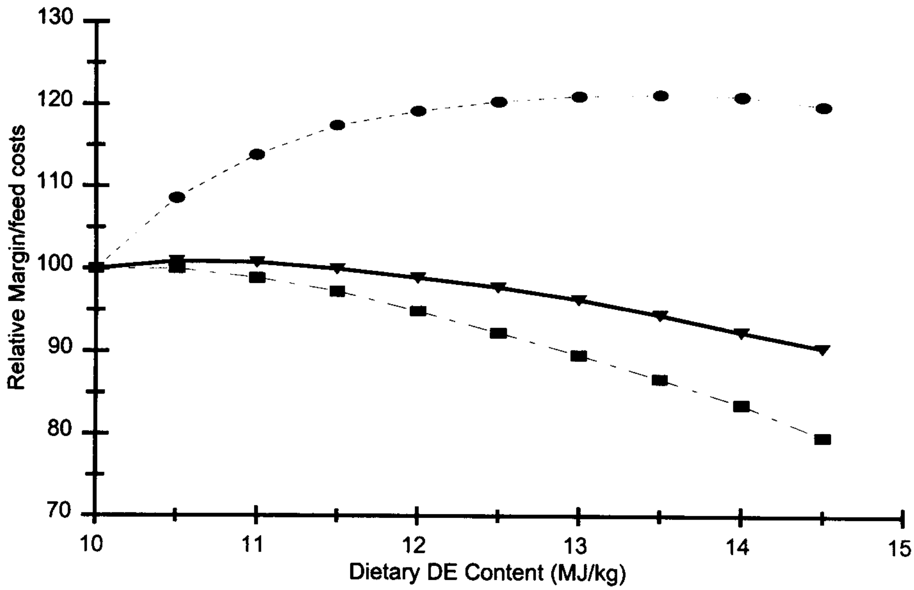

Figure 5 Relative margin over feed costs (100 = 10 MJ/kg) for balanced diets at different dietary energy levels for growing pigs between 10 and 90 kg live weight. (—▼—) represents the response to using FCE = 10.58 + 29.69 × DE across all weights to determine food intake. The response to using different FCE equations for 10–30 kg, 30–60 kg and 60–90 kg weight ramges for Lean genotypes is indicated by (---●---) and (—■—) for Fat genotypes.

According to Figure 5 if a single FCE equation were used to estimate food consumption then it would pay to feed a diet of 11.0 MJ/kg DE over the whole growing period. If one considers the effect of genotype and the associated reduction in FCE with live weight the optimum dietary energy level would be 10.5 MJ/kg for fatter genotypes and 13.5 MJ/kg for modern genotypes. This assumes that one is feeding three different diets over the three different weight ranges. The discrepancy in recommended energy level is probably due to the overestimation of FCE and therefore both food consumption and total feed costs are underestimated. This is particularly noticeable on low energy levels where feed intakes should be much higher. The result is a bias toward the use of low energy diets because they cost less and are not prejudiced by an expected increase in food intake.

From a production point of view it is important to consider what energy levels would result in minimum feed costs during the growing period. Ideally it would be necessary to provide numerous different weight groups. However, owing to the limitations already discussed, only three weight groups will be considered in this paper. Figure 6 shows the within-weight group response of feed costs to DE concentration. Feed cost rather than margin over feed costs is used because of the difficulty in placing an intrinsic market related value on a 30 kg pig.

From Figure 6 it is clear that it would pay to feed high energy levels (at least 14.5 MJ/kg, 0.75 g lysine per MJ DE) to modern genotypes during the early growing period (10 to 30 kg) and then decrease the levels to 13.0–13.5 MJ/kg for the 30 to 60 and 60 to 90 kg weight intervals (0.65 g lysine/MJ DE and 0.55 g lysine/MJ DE). These values are similar to those recommended in the literature (Campbell *et al.*, 1985a). It is important to note that using empirical linear models to estimate optimal responses to energy over various weight periods does not consider the carry-over

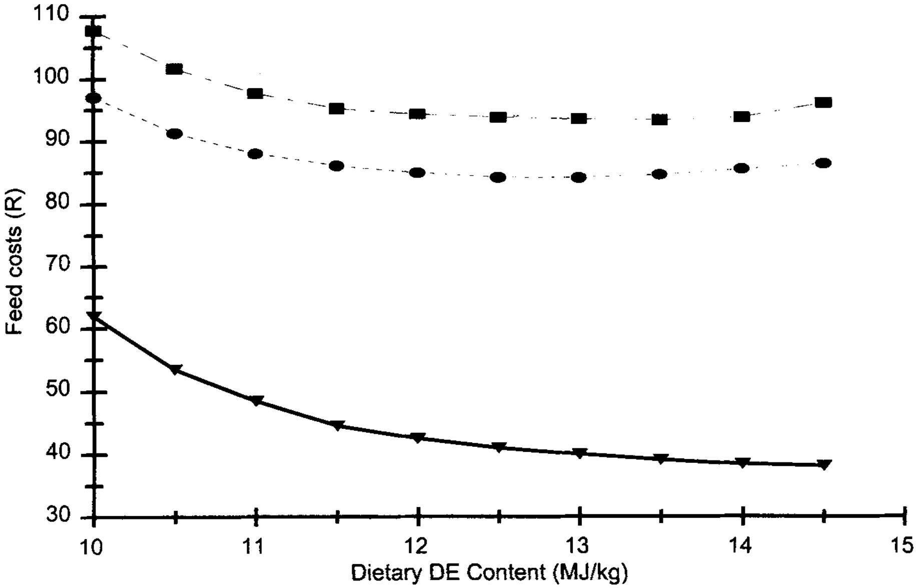

Figure 6 Cost of feed over three different live weight periods at different dietary energy levels for growing pigs. (—▼—) 10–30 kg live weight using 0.75 g lysine/MJ DE; (---●---) 30–60 kg live weight using 0.65 g lysine/MJ DE; (—■—) 60–90 kg live weight using 0.55 g lysine/MJ DE.

effect of differences in growth rate and carcass composition on the subsequent growth phase. Taking the different energy levels that resulted in minimum feed costs for each weight range and applying them will result in the optimum feeding strategy in terms of maximising margin over feed costs. Figure 7 compares the response of using the same energy levels for the three different weight ranges with using those energy levels that minimized feed costs in each of the respective weight groups. It is clear that feeding to minimise feeding costs for each growth period will improve profitability. The difficulty in practice is to define which energy level will minimise feed costs over what live weight range.

Effect of genotype

A further practical consideration in formulating feeds to optimize productivity is what energy levels should be required for different types of pigs. There are considerable differences in response to energy in the literature partly because of differences in pigs used in the experiments (O'Grady & Bowland, 1972; Kyriazakis & Emmans, 1995). From the FCE results in Table 4 it is clear that there will be differences in margin over feed cost responses to DE between different types of pigs. The slower, fatter growing type pig will require lower energy levels to attain maximum efficiency as compared to the faster, leaner growing pig. The extent of the differences will depend on the specific genotype of pigs. Figure 5 compares the response to energy between Lean and Fat type pigs with fatter pigs requiring lower energy levels than leaner pigs to maximise profits or that the lean type of animal can utilize more energy for the deposition of lean. Although the categorization into Fat and Lean type pigs is an oversimplification of the many different types of pigs it does highlight the principle that different genotypes have different optimum nutrient densities. Formulating one feed for a range of genotypes is a major constraint to optimizing profitability and should be avoided. Figure 5

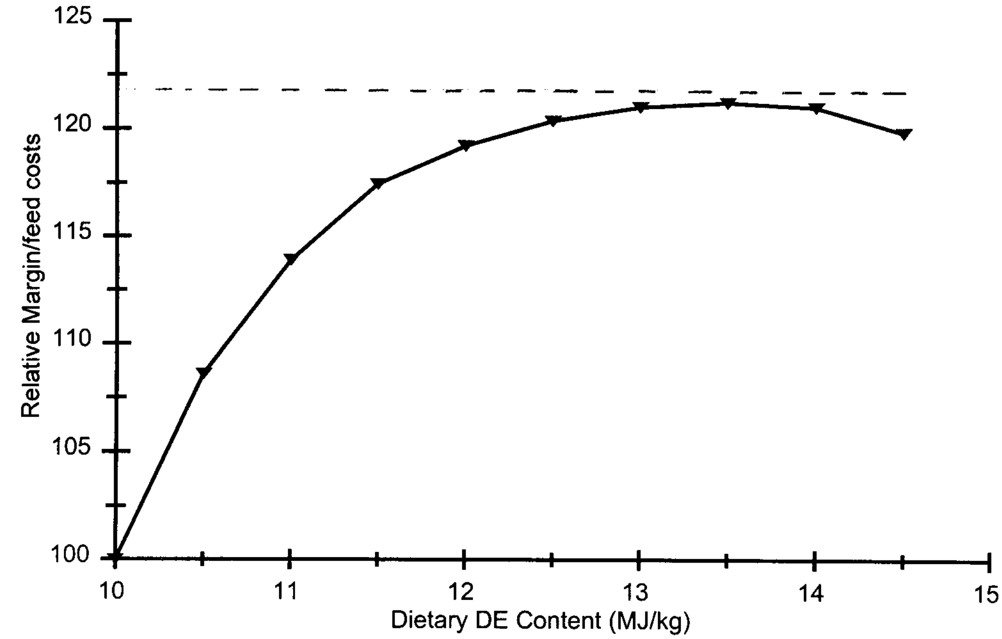

Figure 7 Margin over feed costs at different dietary energy levels for growing pigs. (-▼-) represents the response using the same energy level for the 10–30 kg, 30–60 kg and 60–90 kg weight period. (– – –) is the response using the energy levels that resulted in the lowest feed costs in each of the respective weight groups as shown in Figure 6.

indicates that it does pay to feed pigs according to their growth potential.

Effect of lysine : energy ratio

Another important nutritional consideration is what lysine:energy ratio should be used for a given dietary energy level to optimize profits. As protein sources and specifically amino acids are the most expensive components of any ration, the lower the levels the cheaper the ration. However, cheaper rations may not necessarily mean higher profits. Figure 8 illustrates the effect of increasing the lysine : energy ratios on profitability.

The indications are that when the lysine : energy ratios are increased, the optimum energy content decreases. A reduction in body fat, an improvement in ADG and FCE are the likely biological responses to an increase in the lysine : energy ratio (Lawrence, 1977; Kyriazakis *et al*., 1995). These improved biological responses would suggest a possible increase in proftability through reduced time to market and superior carcass quality, and hence it could be argued that optimum dietary energy levels should be higher with an increased lysine : energy ratio. However, where the market price is fixed, irrespective of rate and composition of growth, and the cost of feed is the only determinant of profit margins, the effect of an increase in lysine : energy ratio on the response to DE will be to select a feed with a lower energy content so as to reduce the cost of feed as the amino acid concentration increases. The extent of the reduction in energy will be sensitive to feed ingredient costs and in particular the cost of added fat and synthetic lysine (assuming it is the most limiting amino acid). The cheaper the source of either fat or synthetic lysine the higher their inclusion level in the high energy diets and therefore the cheaper these will be. This will reduce the difference in response to DE between the lower and higher lysine : energy ratios.

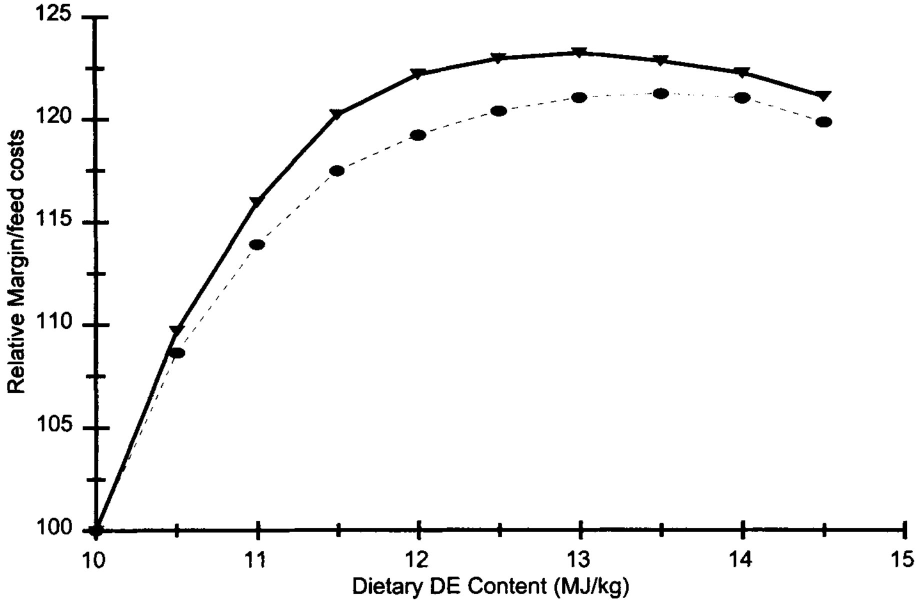

Figure 8 Margin over feed costs at different dietary energy levels for two different sets of lysine:energy ratios over three weight periods. (---● ---) 0.75, 0.65 and 0.55 g/MJ and (-▼-) 0.80, 0.75 and 0.70 g/MJ were used over the range 10–30 kg, 30–60 kg and 60–90 kg respectively.

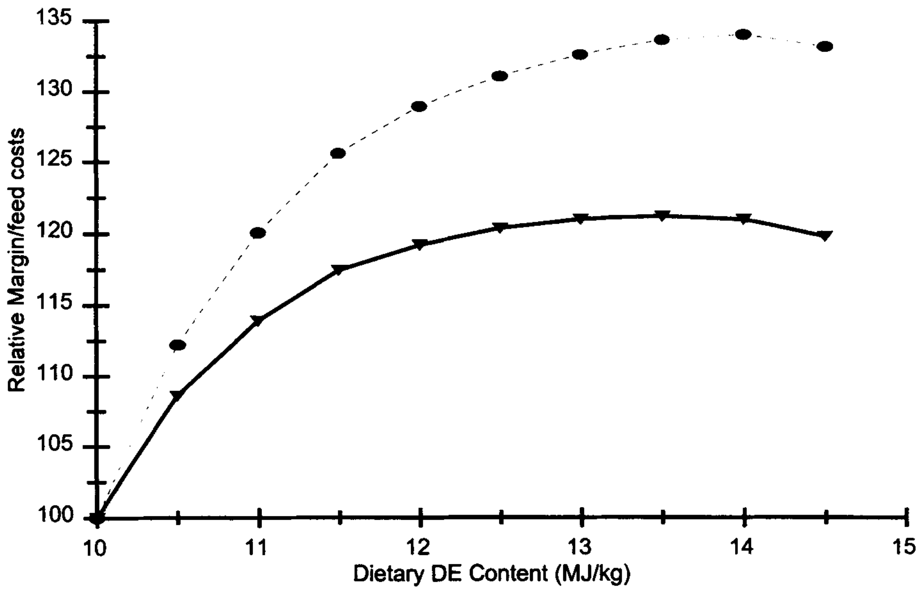

Figure 9 Margin over feed costs at different dietary energy levels with the addition of a R100/ton fixed cost. (-▼-) no fixed cost; (---● ---) additional R100/ton.

Effect of additional costs

The last production scenario to consider is the effect of additional feed surcharges such as those incurred when purchasing a commercial feed including diet preparation and transport costs. For the purposes of this discussion a surcharge of R100/ton of feed was incurred. The results in Figure 9 showed that the addition of a fixed increment moved the optimum energy level from 13.5 MJ/kg to 14.0 MJ/kg. The effect of a surcharge favours the higher energy levels because the cheaper, low energy diets require more tonnage to get a batch of pigs to a given finishing weight.

Considering the marked effect other incremental costs have on the optimum nutrient density it is recommended that optimum dietary energy concentrations be based on margin over total costs rather than margin over feed costs. Total costs would include fixed costs per pig produced (e.g. cost of producing weaners) and costs per pig per day (e.g. labour) both of which will change the optimum energy level. Costs based on time will favour higher energy levels that promote faster growth in order to reduce the time taken to slaughter.

In conclusion the results of this paper do not necessarily provide accurate estimates of optimum energy levels for general use. However they do show how estimates of responses can be used by producers to formulate feeds that will improve profitability. With a knowledge of the production level (FCE) and the appropriate rate of change (Table 4) a producer can determine the optimum energy level. To obtain more accurate estimates of the optimum nutrient density 'local' feed and market prices are required. Therefore, with more accurate levels of production it is possible to design feeding strategies including diets and when to feed them, that will optimize profitability.

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