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The effect of energy intake of gilts on the supply of metabolizable energy and protein deposition

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Summary

Two trials with 16 gilts of 35 kg and 16 gilts of 64 kg were carried out to determine the effects of supplying different amounts of energy combined with similar amounts of protein on metabolizable energy content of the ration. The rations were prepared by mixing two basal feeds in different ratios. Four different energy levels were used in which energy was expressed as multiples of maintenance (M) requirement (treatments: 1 = 2.8 – 3.0 M; 2 = 2.4 – 2.6 M; 3 = 2.1 – 2.2 M; 4 = 1.8 – 1.9 M). Digestibility of energy was not influenced by treatment (mean 83.5 %). However, the different treatments consisted of diets made up with various ratios of two basal feeds. Feed components (except protein) were significantly better digested in animals at a larger weight (e.g. energy 3.2 and crude fibre 5.7 percentage units). However, the rations of weight class 2 were based on a different ratio of the basal feeds than the rations of weight class 1. Metabolizable energy content of the ration was similar for the four diets (mean 12.4 kJ g^{-1}). After correcting for differences in feed composition the metabolizability tends to be slightly depressed at the high levels of energy intake. Protein gain was determined for each gilt. The protein and fat gain were calculated from the rate of gain and daily energy intake at the same amount of digestible protein intake. Protein gain was reduced at a level of energy intake below 2.5 M. These results indicate that protein was used as energy source. Fat gain was influenced far more by feeding level than protein gain. Fat gain was diminished when energy intake was reduced.

Introduction

Factors affecting the digestibility of nutrients have been investigated in many studies (Kidder and Manners, 1978). The effect of feed intake on nutrient digestibilities is less clearly established. Some investigations have shown an inverse digestibility with an increasing level of feed intake (Cunningham et al., 1962, Close et al., 1983; Roth & Kirchgessner, 1984). From other studies it appears that feed intake does not affect digestibility as long as overfeeding is avoided (Dammers, 1964; Peers et al., 1977). The composition of the feed clearly affects the digestibility of the nutrients (see review by Kidder & Manners, 1978; Fernandez et al., 1979). The digestibility of nutrients can also be affected by the weight or age of the pigs (Nordfeldt, 1954; Fernandez et al., 1979; Wenk, 1982; Roth & Kirchgessner, 1984). Therefore, in order to estimate the intake of digestible or metabolizable energy it is necessary to know the composition of the feed, the feeding level and the weight of the pigs.

Den Hartog (1984) performed an experiment with 680 gilts using four different levels of energy intake, while the protein intake remained the same, to study the effects of energy intake on the development of body weight in relation te reproduction.

The intake of metabolizable energy and the rate of gain at various feeding levels must be known accurately in order to calculate fat and protein gain (Cöp, 1974).

In order to calculate the metabolizable energy (ME) content of the ration supplied at the various levels of feed intake, composed from two basal diets, it was decided to determine the digestibility and the metabolizable energy content of these different rations. This experiment was performed with two weight classes of animals.

In addition, the nitrogen balance in growing pigs was determined to compare protein gain by the balance technique with protein gain by the method of Cöp (1974).

Material and methods

Animals

32 Dutch Landrace (DL) gilts from the herd of the Agricultural University were used. Animals were weaned at 5 weeks of age. Creep feed was given until 10 weeks of age. Thereafter, a high feeding level (treatment 1) was given until two weeks before transferring them into cages suited for collection of urine and faeces. During the two weeks the gilts were fed the mean level of the four treatments. The trial commenced when the gilts weighed either 35 kg or 64 kg (defined weight classes 1 and 2, respectively). The gilts were randomly allocated to feeding level treatments. They were fed once daily according to body weight. Water was freely available.

Feeding

Four different treatments were applied. Treatments differed with respect to energy level above the maintenance requirement. Protein allowance was similar in all treatments.

Protein

Lysine is usually the first limiting amino acid for growing pigs (ARC, 1981), therefore the requirement of this amino acid is taken as reference for the supply of protein.

Lysine supply (g d^{-1}) = protein gain[1] × 0.072^2 × 2.2^3 in which:

[1] daily protein gain was assumed to be related to live weight (W) according to the equation of van Kempen & den Hartog (1979, unpublished data). This equation was obtained from results of balance trials with 95 crossbred pigs, as follows:

$$\text{protein gain } (\text{g d}^{-1}) = 0.0088W^2 + 1.8218W + 45.4831 \qquad (1)$$

It was decided to use Equation 1 as the study was carried out with modern type pigs. This equation will give slightly higher protein gain than the averages in the literature review of Berschauer (1977). However, Berschauer also used older data obtained from pigs of a more fatty type.

[2] protein in the body contains 7.2% lysine (Oslage & Schulz, 1977)

[3] to ensure maximum protein gain even when protein was used as an energy source, an excess of 120 % was given over and above the amount of lysine deposited in the protein gain.

Energy

For all treatments *maintenance* requirement of the animals housed in the cages was assumed to be 460 kJ ME $W^{-3/4}$ (ARC, 1981).

Energy supply for production purposes differed between the four treatments. Energy supply was calculated from energy required for the deposition of protein and fat for all the animals in treatment 1. Treatment 1 was thought to be adequate for protein and fat deposition at a high rate of gain. Protein deposition was calculated from live weight with equation 1. Fat deposition was calculated from the live weight (W) on the basis of summarized literature data (Cöp, 1974). From Cöp's data it can be derived that in pigs fed ad libitum about 4 g fat per kg body weight (W) is deposited daily (fat gain (g d^{-1}) = 4 W). In gilts of 25 kg, therefore, about 100 g of fat is deposited daily and in animals of 100 kg about 400 g of fat daily. Although castrated males may deposit more fat than gilts, the difference between sexes in the weight ranges studied here will be of minor importance (Cöp, 1974). Therefore the mean as derived by Cöp was used. In order to calculate the daily requirement of metabolizable energy (ME) for protein and fat deposition it is necessary to know the energetic efficiencies. Protein retained from ME intake was calculated with an assumed partial efficiency (k_p) of 54 % (ARC, 1981). Energy deposited in fat was assumed to have a partial efficiency (k_f) of 74 % (Kielanowski, 1972b; Fowler et al., 1979; ARC, 1981; Close & Verstegen, 1981). Energy required for protein and fat deposition was calculated using these partial efficiency values.

Treatments 2, 3 and 4 differed with respect to the supply of energy above maintenance and these levels were 75, 56.25 and 42.18 %, respectively, of that in treatment 1. This resulted in a calculated total energy intake of about 3, 2.5, 2.1 and 1.8 times maintenance for treatments 1 to 4, respectively.

Feed composition

In order to obtain the same protein supply on all treatments the rations used for pre-

Table 1. Composition of the feeds.

Ingredients	Mass fraction (%)	
Maize	50.1	
Milo	10.0	
Wheat	15.0	
Barley	15.0	
Animal fat	1.4	
Cane molasses	5.0	5.0
Soya bean meal solvent extracted (with 44-47 % crude protein)		45.3
Meat meal tankage (< 12.0 % crude fat)		11.0
Fish meal (8.3 % crude fat)		10.0
Dried potato protein		17.0
Limestone	1.1	1.2
Calcium hydrogen phosphate	1.6	10.0
Salt	0.3	
Minerals/vitamins premix[1]	0.5	0.5
Calculated contents		
Energy (MJ ME kg^{-1})	13.80	10.50
Crude protein (%)	8.95	47.30
Lysine (%)	0.265	3.224

[1] Guaranteed contents: Ca 197 g/kg, P 108 g/kg, Cu 2000 mg/kg, Mn 4800 g/kg, Zn 8000 mg/kg, Fe 16.000 mg/kg, Co 50 mg/kg, J 80 mg/kg, Se 10 mg/kg, retinol equivalent 14.000 μg/kg, cholecalciferol equivalent 7000 μg/kg, riboflavin 700 mg/kg, nicotinamide equivalent 3600 mg/kg, pantothenic acid 1400 mg/kg, choline 50.000 mg/kg, vitamin B^{12} 3 mg/kg, α-tocopherol equivalent 940 mg/kg, dl-methionine 40 g/kg.

paring the four treatments were made up by mixing two basal feeds in different ratios. The composition of the basal feeds are given in Table 1. The net energy contents were calculated from chemical composition and digestibility coefficients of the Dutch feeding table according to Schiemann et al. (1971). For reasons of simplicity the ME was calculated from the net energy by using the value of 70 %. This value is based on a summary of many experiments reported in the literature (Cöp, 1974). This approach results in a calculated ME content of 13.8 and 10.5 for feed A and B, respectively. The daily amount of the basal feeds in the rations was calculated from the following equations:

energy requirement in MJ ME $d^{-1} = 13.8A + 10.5B$
lysine requirement in g $d^{-1} = 2.65A + 32.24B$

in which A and B are kg d^{-1} of the basal feeds. In Table 2 details about the intake of feed components for the four treatments are given.

Digestibility and balance trial

Each gilt was allowed an adaptation period for five days to its ration after being transferred into the cage. Thereafter, digestibility and metabolizability of the ra-

Table 2. Number of balances, initial live weight (kg) and intake of feed and feed components.

	Weight class 1 (35-45 kg)				Weight class 2 (65-75 kg)			
Treatment	1	2	3	4	1	2	3	4
Number of balances	10	6	6	10	10	6	6	10
Initial live weight (kg)	37	36	34	37	66	67	68	64
Feed intake (kg d^{-1})	1.61	1.37	1.15	1.07	2.58	2.25	1.92	1.61
Feed A/feed B ratio	3.24	2.37	1.76	1.43	4.58	3.56	2.69	2.05
Measured energy intake (MJ ME d^{-1})	19.5	16.5	13.8	13.0	33.0	29.0	24.5	20.1
Calculated energy intake (MJ ME d^{-1})	20.9	17.5	14.5	13.3	34.1	29.4	24.8	20.5
Feeding level (multiples of maintenance requirement)	2.8	2.4	2.1	1.8	3.0	2.6	2.2	1.9
Protein intake (g d^{-1})	274	260	244	247	375	361	340	317
Crude fibre intake (g d^{-1})	44	39	34	31	74	67	60	52
Energy to protein ratio (kJ ME g^{-1})	71.2	63.5	53.1	52.6	88.0	80.3	72.1	63.4

Table 3. Experimental scheme for the two weight classes

Animal number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Period 1: treatment	1	2	1	3	1	4	2	3	2	4	3	4	1	4	1	4
Period 2: treatment	2	1	3	1	4	1	3	2	4	2	4	3	4	1	4	1

tion were determined during a five-day total collection period (period 1). Each animal was then reassigned to another treatment followed by an additional adaptation period of five days. Then, a similar procedure was followed (period 2) as during period 1. Sixteen animals were used in each weight class. The experimental design is presented in Table 3. Each gilt was thus subjected to two collection periods representing two different treatments. Faeces and urine were collected separately with the use of a metal plate which divided urine from faeces directly after urine was voided and led it into a container. 100 ml of 25 % H_2SO_4 was put in the container before collection of urine started. Faeces were preserved by adding formaline (4 ml daily). Nitrogen was determined by Kjeldahl in feed, faeces and urine and was expressed as crude protein (6.25 × N).

The ash content of feed and faeces was determined by ashing at 550 °C. Crude fibre was determined by the method of NEN-3326 (1966). Crude fat in the faeces was determined by diethylether extraction after treatment with HCl. Energy content in feed, faeces and urine was determined by bomb calorimetry.

Analysis of data

Data were analysed by a least squares method (Nie et al., 1975). First it was tested whether a treatment in period 1 had an effect on the treatment in period 2 (carry-over effect). The effects of previous treatment and effects of period within weight class were not significant ($P > 0.05$). Data were therefore analysed again with treatment and weight class as factors only. No interaction was found between treatment and weight class ($P > 0.05$).

Results

Data on intake of feed and feed components for the animals in both weight classes are presented in Table 2. Crude fibre was associated with a high energy to protein ratio in the diet; unfortunately protein intake appeared to differ between the four treatments. The planned energy intake was 3 M, 2.5 M, 2.1 M and 1.8 M. The realized energy intake differed somewhat from that. Energy intake expressed as multiples of maintenance requirement was higher in weight class 2 than in weight class 1. The contents of lysine analysed appeared not to be the same as the calculated contents. The lysine content in g kg^{-1} calculated and analysed for feed A were 2.7 and 3.1, respectively and for feed B they were 32.2 and 29.7, respectively. Despite this difference, however, the energy to protein ratio (kJ g^{-1}) in the diet decreased clearly at a lower feeding level (Table 2).

Digestion and metabolizability

The effects of treatment and live weight on apparent digestibility of feed components and energy are presented in Table 4. The effects of treatment, although treatments consisted of different ratios of two basal feeds, and weight class on the digestibility of the major nutrients and on the level of metabolizable energy were

Table 4. Influence of treatment and weight class on various digestion coefficients and metabolizability of the energy.

	Treatment				Weight class		Coefficient[1] of variation (%)	Significance	
								treat-ment	weight class
	1	2	3	4	1	2			
Number of balances	20	12	12	20	32	32			
100 (DE/GE)	83.5	83.8	83.5	83.4	81.9	85.1	2.0		**
100 (ME/DE)	96.1	95.7	95.2	94.4	95.0	95.7	0.5	**	**
Digestion coefficients (%)									
Organic matter	85.8	86.2	85.8	85.5	84.4	87.2	1.8		**
Crude protein	78.2	79.6	80.8	81.6	79.4	80.5	3.5	**	
Crude fibre	38.6	43.2	47.5	48.1	41.2	46.9	20.5	**	*
Crude fat (after DEE-HCl)	53.7	54.3	51.9	53.0	50.5	56.0	12.9		**
NFE (after DEE-HCl)	92.2	92.6	92.1	91.6	90.9	93.2	1.0	*	**
N retention (g d^{-1})	19.6	18.8	16.9	13.7	15.4	18.8	23.5	**	**

* $P < 0.05$

** $P < 0.01$

[1] calculated as (residual standard deviation/mean) × 100

Table 5. Percentage of digested protein which is retained

	Treatment			
	1	2	3	4
Weight class 1	51.9	49.0	44.8	42.1
Weight class 2	45.6	46.4	44.6	33.3

significant in many cases ($P < 0.05$). At the treatments with higher energy intake the digestion coefficients of crude protein and crude fibre were lower than at the treatments with a low energy intake ($P < 0.01$). The digestibility of energy, organic matter and crude fat were not significantly influenced by treatment.

All coefficients of digestion were higher in animals of weight class 2 ($P < 0.05$) compared with animals of weight class 1. However, the apparent digestibility of protein was not different between these classes. According to the different ratios of the basal feeds an ME content of 13.10, 12.92, 12.77 and 12.58 kJ g^{-1} was expected from Table 1 for the four treatments, respectively. The measured ME content of the feed was similar for the four treatments: 12.46, 12.47, 12.37 and 12.26 kJ g^{-1}, respectively. By considering the difference between the expected and the measured values an increased difference at a higher energy level is found. This at least suggests a slight depression of metabolizability of the energy at a higher energy intake. As a result the increased supply of digestible and metabolizable energy, the heavier gilts (weight class 2, 65-75 kg) consumed per gram feed 0.65 kJ ME more than the gilts in weight class 1 (35-45 kg). N-retention increased significantly for treatments with high energy intake and was highest for weight class 2 (Table 4). A smaller portion of digested protein is retained at treatments with a low level of energy intake (Table 5). The determined protein (based on N balance) gain for animals with treatment 1 was only slightly higher than calculated according to Equation 1 (weight class 1 110 and 104 g, weight class 2 135 and 130 g, respectively).

Discussion

Development of pigs depends on environmental conditions, on feeding level and composition of the feed and on animal traits. It can be stated that the value of a ration given to a pig depends on those characteristics. Therefore it is important that the feeding value is determined with the kind of animals at the feeding level and composition which will be used in the experiment of den Hartog (1984). It had been decided that protein allowance should be similar for pigs given various energy levels. This had as a consequence that the components of the feed are not the same in the various rations. However ME content of the basal feeds were similar to that assumed (see Table 1). From the data in Table 2 it was computed that ME content of feed A was 13.4 kJ g^{-1}, and for feed B it was 10.1 kJ g^{-1}.

Digestibility

Feeding level

Results of the digestibility trials indicate that a high energy level does not necessarily reduce the digestibility of energy. This agrees with results of studies by Dammers (1964) and by Peers et al. (1977). Digestibility of some feed components was reduced somewhat in treatments with a high energy intake (protein, crude fibre). However, it may also be the result from differences in level of crude fibre intake (Table 2) and sources of crude fibre (Table 1), since different ratios of feed A and feed B were applied. The increase of apparent digestibility of N at a lower energy intake may also be due to the relative smaller contribution of metabolic faecal nitrogen (MFN) (P. J. van Soest, personal communication, 1982). Since after the correction for MFN (2 g N per kg dry matter in the ration; Homb, 1972) the true digestibility of N did not differ significantly between treatments.

Crude fibre digestibility was lowest at the high energy level. This may be a true effect of energy intake, as observed by Cunningham et al. (1962). As stated previously the differences in digestibilities associated with the levels of energy intake have to be interpreted with respect to the rations made up from two basal feeds differing in composition.

Age

An increase in age (live weight) was found to be associated with an increased digestibility of all components ($P < 0.05$) except for protein. It should be noted that the rations of weight class 2 had another ratio of the basal feeds than those of weight class 1 (see Table 2). The differences in digestibility between the weight classes could be attributed to this. Fernandez et al. (1979), Wenk (1982) and Roth & Kirchgessner (1984) also found that increase in weight of the pigs is associated with an increase in the digestibility of feed components.

Metabolizability

Losses of CH_4 were considered to be negligible, since they are 0.7 % or less when related to the intake of gross energy (van der Honing et al., 1982). Metabolizability of gross and digestible energy was clearly depressed in the treatments with a decreased energy intake. However, the difference between the highest and lowest level of energy intake was less than expected. It was found that the difference in ME/GE ratio between treatment 1 and 4 was 1.5 % (Table 2) and it was expected that this difference would be 3.6 % (calculated from ME expected and GE found). This suggests that at the treatments with high energy intake the metabolizability of the energy was slightly depressed. Metabolizability of digestible energy was lower in animals of about 35 kg because ratio of protein to energy in the diet of these animals was higher than in animals of about 64 kg.

Fat and protein deposition

Variation in the ratio between fat and protein deposition in growing pigs can be achieved by varying the level of energy intake (Thorbek, 1975, Gütte et al., 1979; Metz et al., 1980).

Composition of the gain in fat and protein was calculated from rate of gain and energy intake.

Ash deposition and increase in gut-fill were assumed to be 3 and 5 %, respectively, of the total weight gain (Whittemore & Fawcett, 1974).

The ratios of ash to protein and water were assumed not to be affected (Gütte et al., 1979). Protein and water deposition were closely correlated and depended on weight. Cöp (1974) analysed energy balance data derived from the literature and found that the ratio of water + protein to protein content of pigs from 2 to 150 kg could be formulated by:

$$(1.030W^{0.836} + 0.176W^{0.954})/0.176W^{0.954} \qquad (2)$$

in which W = weight in kg.

From the ratio in Equation 2, the increase in gut-fill and ash deposition, Equation 3 can be derived:

$$0.92 \times \text{rate of gain} = F + P\,(1.030W^{0.836} + 0.176W^{0.954})/0.176W^{0.954} \qquad (3)$$

in which: F = gain in fat (g d^{-1})
P = gain in protein (g d^{-1})
W = body weight (kg)

Energy required for production was calculated from the energy cost of fat and protein deposition (54 and 44 kJ ME, respectively):

$$\text{energy for production (kJ ME intake} - ME_m) = 54F + 44P, \qquad (4)$$

in which ME_m = 460 kJ $W^{-3/4}$
F = gain in fat (g d^{-1})
P = gain in protein (g d^{-1})

The daily rates of gain in fat and protein were calculated with Equations 3 and 4. Protein gain calculated from Equations 3 and 4 and protein gain determined from N balance are presented in Fig. 1. With the exception of treatment 4 the rate of protein gain determined by both methods was higher in weight class 65-75 kg than in weight class 35-45 kg.

Protein gain determined by the balance technique is 5-25 % higher than protein gain obtained from slaughter technique (Just Nielsen, 1970). In the present study such a difference was found when the results obtained with the N balance method (N retention × 6.25) were compared with those obtained by calculation. Calculated protein gain was derived with results of slaughter trials by the method of Cöp (1974). However, in relative terms the two different methods were able to show

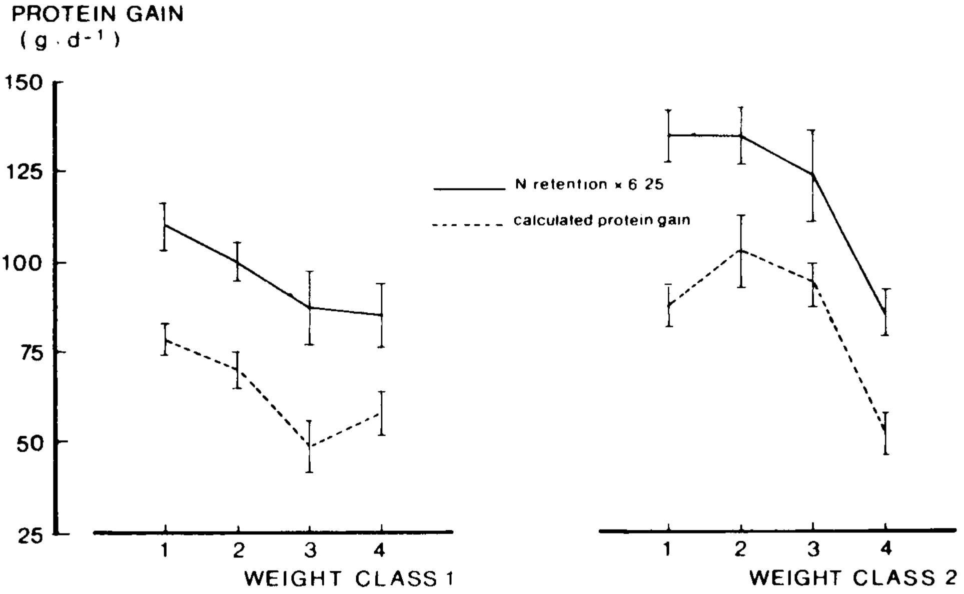

Fig. 1. Protein balance (N retention × 6.25) and calculated protein gain in the two weight classes.

similar differences due to treatments. The daily rate of gain and the fat gain estimated with Equations 3 and 4 are given in Fig. 2. Fat gain is closely associated with feeding level and weight class. Interaction of weight class with feeding level was significant ($P < 0.001$). Fat gain at the highest energy level in period 1 was 48 % of that in period 2, while the percentage for the lowest level was 44. Table 6 presents the coefficients of correlation between protein gain and rate of gain. The correlation coefficients between protein gain as determined by both methods ranged from 0.42 to 0.63 and were lower than correlation coefficients between N balance and rate of gain. Calculated protein gain was related more to the rate of body weight gain than to the measured protein gain. This can be expected because these characteristics are partly autocorrelated.

The aim of the experiment of den Hartog (1984) was to study the effect of a reduction in energy intake on the development of gilts. It was tested whether an equal N intake resulted in equal protein gain. Results showed that at the low energy level, protein gain is reduced (Fig. 1). This means that protein gain is reduced at limited levels of energy intake despite of the abundancy of protein in the feed.

Pigs fed a low energy level are not able to express their full genetic capacity for protein deposition (Kielanowski, 1972a; Metz et al., 1980). Apparently, energy intake levels at 1.8 and 2.1 times maintenance (1.8 M and 2.1 M) are too low for high protein gain. The present experiment also showed that at the low level of 1.8 M, the estimated fat deposition was 56 and 129 g d^{-1} in the two weight classes, respectively. Apparently, protein will only be deposited at a maximum rate if fat can be depos-

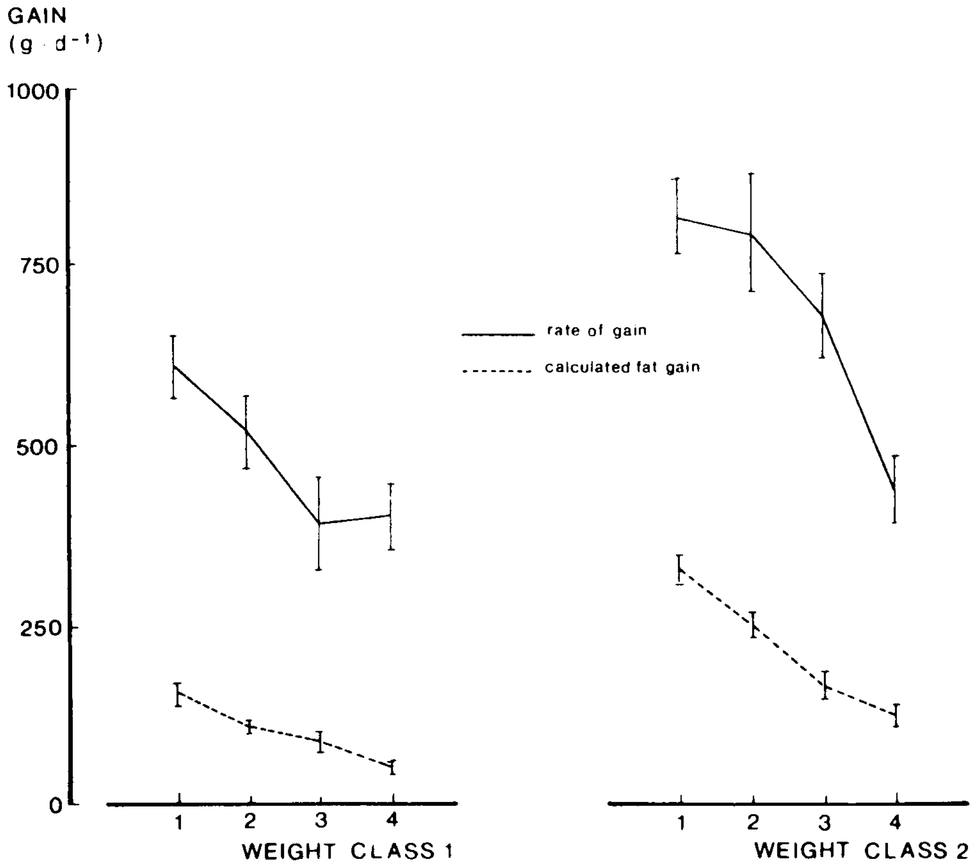

Fig. 2. Rate of gain and calculated fat gain in the two weight classes.

Table 6. Coefficients of correlation between protein gain and rate of gain.

	Between-treatment means	Within treatment			
		1	2	3	4
Calculated protein gain and N balance	0.97**	0.42*	0.63**	0.55*	0.61**
Calculated protein gain and rate of gain	0.94**	0.87**	0.94**	0.97**	0.97**
N balance and rate of gain	0.99**	0.66**	0.80**	0.65**	0.67**

* $P < 0.05$
** $P < 0.01$

ited at a level as high as the maximum protein gain (Figs. 1 and 2).

Wenk et al. (1976) found that at a high feeding level the extra fat is mostly deposited intra-muscular. In addition, Metz et al. (1980) found that energy restriction in pigs affected muscular protein deposition less than total body protein deposition.

Any effect of nutrient restriction of pigs may have a different consequence for development of different tissues and organs depending on the level of nutrients required for each tissue and organ and their respective priority. It can therefore be expected that any specific effects of nutrient supply on reproduction will be associated with this phenomenon.

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