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Protein requirement of baby pigs on low-fat diets

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For some time studies have been made in this laboratory on the use of the baby pig as an experimental animal, and during this work diets low in fat have been found to support satisfactory performance (Tribe, 1954; McCrea & Tribe, 1956). This finding is somewhat surprising in view of the fact that sow's milk is very rich in fat. For routine rearing of piglets a low-fat diet is preferable to one rich in fat because it is easy to prepare and can be stored with less risk of deterioration. In the three experiments described the protein content of the diet was varied within wide limits in order to determine the optimum protein content in low-fat diets.

EXPERIMENTAL

Experimental design and analysis

A randomized block layout was used. Groups of litter-mates of uniform weight were chosen for the experimental blocks, and the members of these groups were allocated at random to the different treatments. Four treatments were replicated five times in Expt 1. In each of Expts 2 and 3, four treatments were replicated eight times. The significance of differences between treatments was tested by analysis of variance.

Animals

Large White × Wessex piglets were used for Expts 1 and 3 and for half of Expt 2. The remaining four replicates in Expt 2 were with pure-bred Wessex.

Diets

Details about the diets used in the three experiments are given in Tables 1 and 2. The diets used in Expts 1 and 2 were very similar and included several carbohydrates and protein from several sources. In Expt 3 glucose was chosen as the sole carbohydrate as other workers had shown it to be well utilized by the very young pig, whereas there was some doubt about the utilization of maize starch and sucrose (Becker, Ullrey & Terrill, 1954). Casein had been the major source of protein in Expts 1 and 2 and was the sole source of protein in Expt 3.

Management

The piglets were taken from their dams at 2–3 days of age and were kept on the experimental diets until 28 days old. They were reared singly in modified rabbit cages. The cages were 19 in. wide × 24 in. deep and 16 in. high and had a door at the

Table 1. *Expts 1 and 2. Diets used*

Constituent	Expt 1, diet A	B	C	D	Expt 2, diet E	F	G	H
			Calculated composition					
Crude protein (%)	19·8	24·8	29·8	34·8	24·8	31·5	38·1	44·8
Fat (%)	3·5	3·6	3·7	3·8	3·6	3·7	3·8	4·0
			Variable quantities					
Crude casein (lb)	15·8	21·7	27·6	33·5	21·7	29·6	37·4	45·3
Maize starch (lb)	36·2	30·3	24·4	18·5	28·7	20·8	13·0	5·1
			Fixed quantities					
Sucrose (lb)	20	20	20	20	20	20	20	20
Dried whole milk (lb)	10	10	10	10	10	10	10	10
D.D.S./D.G.* (lb)	10	10	10	10	10	10	10	10
Dried yeast (lb)	4	4	4	4	4	4	4	4
Super Mindif† (lb)	3	3	3	3	3	3	3	3
Supplementary minerals‡	+	+	+	+	+	+	+	+
Vitamin and antibiotic premix§	+	+	+	+	+	+	+	+
Choline chloride solution (70%, w/v) (ml)	50	50	50	50	116	116	116	116

* A mixture of dried distiller's solubles (30 parts) and dried grains (70 parts).

† A proprietary mineral mixture (Boots Pure Drug Co. Ltd) containing 17·4% calcium, 11·4% phosphorus, 0·75% sulphur, 0·24% iron, 30% NaCl, 1800 p.p.m. copper, 300 p.p.m. cobalt, 510 p.p.m. manganese and 240 p.p.m. iodine.

‡ Expt 1: 250 g $Ca_3(PO_4)_2$, 105·6 g KCl, 4·476 g $MnSO_4.4H_2O$, and 33·4 g calcined magnesite. Expt 2: 787 g $CaCO_3$, 250 g $Ca_3(PO_4)_2$, 105·6 g KCl, 4·476 g $MnSO_4.4H_2O$, and 33·4 g calcined magnesite.

§ Expt 1: 60000 i.u. vitamin A, 15000 i.u. vitamin D_3, 350 mg α-tocopheryl acetate, 10 mg riboflavin, 130 mg calcium pantothenate, 42 mg pyridoxine hydrochloride, 26 mg folic acid, 1100 μg cyanocobalamin and 670 mg procaine penicillin. Expt 2: 72000 i.u. vitamin A, 18000 i.u. vitamin D_3, 350 mg α-tocopheryl acetate, 94 mg riboflavin, 576 mg calcium pantothenate, 109 mg pyridoxine hydrochloride, 50 mg folic acid, 4400 μg cyanocobalamin and 670 mg procaine penicillin.

Table 2. *Expt 3. Diets used*

Constituent	Diet I	J	K	L
	Calculated composition			
Crude protein (%)	20·1	25·1	30·1	35·1
Fat (%)	0·25	0·31	0·37	0·43
	Variable quantities			
Crude casein (lb)	23·53	29·41	35·29	41·18
Glucose (lb)	68·68	62·80	56·91	51·03
	Fixed quantities			
Super Mindif* (lb)	3	3	3	3
Supplementary minerals†	+	+	+	+
Vitamin premix‡	+	+	+	+
Choline chloride solution (70%, w/v) (ml)	148	148	148	148

* A proprietary mineral mixture (Boots Pure Drug Co. Ltd) containing 17·4% calcium, 11·4% phosphorus, 0·75% sulphur, 0·24% iron, 30% NaCl, 1800 p.p.m. copper, 300 p.p.m. cobalt, 510 p.p.m. manganese and 240 p.p.m. iodine.

† 1348 g $Ca_3(PO_4)_2$, 216·620 g KCl, 33·158 g calcined magnesite, 145·149 g iron and ammonium citrate and 4·851 g $MnSO_4.5H_2O$.

‡ 72000 i.u. vitamin A, 18000 i.u. vitamin D_3, 6·000 g inositol, 1·814 g nicotinic acid, 1·233 g calcium pantothenate, 357 mg α-tocopheryl acetate, 268 mg riboflavin, 146 mg pyridoxine hydrochloride, 136 mg thiamine, 50 mg folic acid, 36 mg menaphthone, 7 mg biotin and 4520 μg cyanocobalamin.

front which was hinged at the top. Feed troughs were semicircular in cross-section, 2 in. deep, and had compartments for feed and water. The piglets were fed twice daily at 9.15 a.m. and 4.15 p.m. At each feeding time the empty troughs were taken out and replaced with troughs that had been thoroughly washed and then placed for at least 20 min in boiling water or in hypochlorite solution.

In Expts 1 and 2 background heating in the experimental room was maintained at 16–21°. Direct heating was provided for each piglet by 250 W infrared lamps. In Expts 1 and 2 a lamp was suspended directly over each cage until the piglets were 3 weeks old. During the last week of the experiment half the lamps were switched off and the remaining ones were moved to a position above the junction between two cages so that the piglets could choose whether or not to lie near the lamps. In Expt 3 the background temperature of the room was kept at 21° and throughout the experiment a 250 W infrared lamp was placed over the junction between two cages, as in the latter part of the previous experiments. Piglets were weighed to the nearest ½ oz every 3 or 4 days. They were dosed with anti-anaemia paste (500 mg reduced iron per dose, Boots Pure Drug Co. Ltd) at 3, 10 and 17 days in Expt 1, and at 2, 7 and 14 days in Expt 2. In Expt 3 supplementary iron was included in the diet. In Expt 1 an injection of 250000 i.u. vitamin D_2 was given at 7 days of age.

Method of feeding

Expt 1. For the first 3 days the diets were mixed with 200 ml cow's milk/feed, and drinking water was supplied *ad lib.* The amount of the experimental diet was regulated so that very little was left at the next feeding time. After the 3rd day no milk was given and the diet was mixed into a gruel with 200 ml water. Drinking water was given *ad lib.* in a separate compartment of the trough. The weight of feed residue was estimated visually by comparison with weighed amounts of diet mixed with water.

Expt 2. The piglets were fed twice daily according to the feeding scale shown in Fig. 1 (derived from the food intake of piglets in Expt 1). They were given 200 ml cow's milk/feed for the first 3 days of the experiment and 10 g diet/feed were arbitrarily deducted to allow for the milk solids. For the 1st week after cow's milk was withdrawn the diets were mixed with water at the rate of 1 ml water/g diet. Drinking water was given *ad lib.* separately. It was found that the 45% protein diet (H), and the 38% protein diet (G) to a lesser extent, absorbed water very rapidly and the mixture in the proportions stated was of a very stiff consistency. When the piglets were 12 days old, the amount of water added to the diets was raised to 1·5 ml for diets E, F and G, and 2 ml/g for diet H, thus producing a gruel of similar consistency with each diet.

Expt 3. No cow's milk was given. Piglets were fed twice daily according to the feeding scale shown in Fig. 1. Water was added to the diets at the rate of 1 ml/g diet. The total water intake of the piglets in three blocks was measured. Evaporation was allowed for by measuring water loss from a trough under identical heating conditions in the experimental room while the experiment was in progress.

Blood studies

Haemoglobin was measured (Sahli) on blood from the marginal ear vein of twenty-four of the piglets in Expt 2 at 28 days of age. At the end of Expt 3 haemoglobin (by the cyanmethaemoglobin method), packed cell volume and serum protein (by the biuret method) were measured.

RESULTS

Experiment 1

The results are summarized in Table 3. Some of the piglets showed bending of the legs. Since all were given vitamin D_2 by injection as well as vitamin D_3 in the diet, the mineral content of the diet appeared to be insufficient. As a result of a separate investigation, the dietary calcium was raised from 0·8% in Expt 1 to 1·5% in Expts 2 and 3.

Table 3. *Expt* 1. *Summary of results*

	Diet				Least significant difference	
	A	B	C	D	$P < 0.01$	$P < 0.001$
Protein content of diet (%)	19·8	24·8	29·8	34·8	—	—
No. of piglets	5	5	5	5	—	—
Mean 3rd-day weight (lb)	4·56	4·42	4·43	4·50	—	—
Mean 28th-day weight (lb)	12·68	15·53	15·88	16·43	2·27	3·20
Mean daily gain from 3rd to 28th day (lb)	0·324	0·444	0·458	0·477	0·093	0·132
Mean food eaten/lb gain, 6th–28th day (lb)	1·78	1·38	1·37	1·30	0·31	0·44

Weight gain. The rate of gain in weight was depressed temporarily when milk was withdrawn. The diet was eaten less readily when mixed with water than when mixed with milk. Over the period from 3 to 28 days of age the differences in weight gain of the piglets on the 25, 30 and 35% protein diets were not significant. The gain of piglets on the 20% protein diet, however, was significantly less ($P < 0.01$) than that of piglets on the other three diets.

Economy of food conversion. Over the 6th–28th day period the differences between the piglets on diets B, C and D were not significant; those between the piglets on diet A and on the three diets containing greater quantities of protein were significant ($P < 0.01$).

Food consumption. The food consumption of the piglets on diet A was not considered to be representative of that of normal thrifty pigs and was not included in the calculations of food intake. The mean food consumption of individual piglets between successive weighing days was calculated for those on diets B, C and D and was found to be significantly correlated with the mean live weight ($r = +0.938$, $P < 0.001$). The regression between mean food consumption and mean live weight was calculated to be $y = 39x - 72$, when y = daily food consumption (g), and x = mean live weight (lb).

Construction of a feeding scale for use in future experiments. The regression between food consumption and live weight in Expt 1 was used as a basis for equalizing food intake in subsequent experiments. For this purpose the regression coefficient was increased by 5 % to allow for wastage and the food requirement was calculated from the modified equation, $y = 41x - 72$. Piglets in Expts 2 and 3 were weighed twice weekly and daily feed increments for successive days between weighings were based on a standard expected live-weight gain. The requirement/feed and daily increments of food can be read directly from Fig. 1.

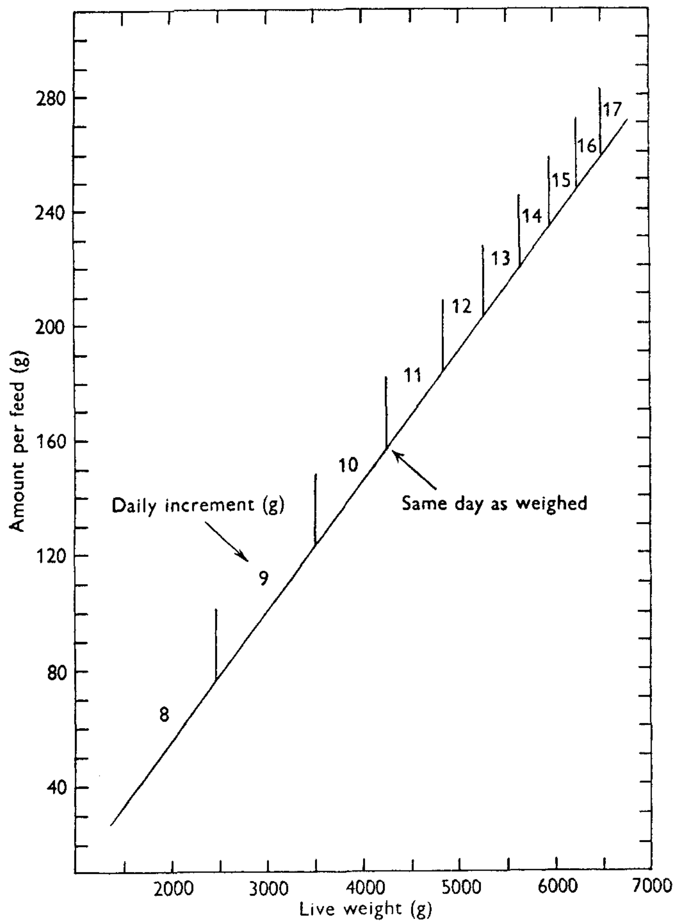

Fig. 1. Feeding scale used in Expts 2 and 3.

Experiment 2

The results, shown in Table 4, were surprisingly uniform considering the wide range of protein in the diets, and the 45 % protein diet was the only one that showed signs of inferiority. The piglets on this diet scoured at times. No leg abnormalities were observed during this experiment.

Gain in weight. After the withdrawal of cow's milk piglets continued to gain weight satisfactorily, presumably because less water was added to the diet than in the previous experiment. The differences in weight gain between diets were not statistically significant.

Economy of food conversion. Mean values for the piglets on the four diets are given in Table 4. None of the differences between diets was statistically significant.

Blood studies. Haemoglobin values (Sahli) for the blood of twenty four of the piglets at 28 days of age averaged 6·6 g/100 ml. This value is much lower than that of 11·9 g/100 ml found by J. A. J. Venn (1958, personal communication) in sow-reared piglets of the same age reared on grass. We therefore changed the source of supplementary iron in subsequent experiments.

Table 4. *Expt* 2. *Summary of results*

	Diet				Least significant difference
	E	F	G	H	$P < 0·05$
Protein content of diet (%)	24·8	31·5	38·1	44·8	—
No. of piglets	7*	8	8	8	—
Mean 2nd-day weight (lb)	3·41	3·54	3·52	3·55	—
Mean 28th-day weight (lb)	12·59	13·54	12·73	11·58	2·07
Mean daily gain from 2nd to 28th day (lb)	0·354	0·385	0·354	0·309	0·073
Mean food eaten/lb gain, 5th–28th day (lb)	1·38	1·29	1·30	1·46	0·52

* Eight piglets were used but one died at 72 h of age after having epileptiform convulsions.

Table 5. *Expt* 3. *Summary of results*

	Diet				Least significant difference	
	I	J	K	L	$P < 0·05$	$P < 0·01$
Protein content of diet (%)	20	25	30	35	—	—
Weight gain and food conversion						
No. of piglets	8	8	8	8	—	—
Mean 2nd-day weight (lb)	3·74	3·77	3·87	3·84	—	—
Mean 28th-day weight (lb)	10·62	12·03	12·03	11·51	1·21	1·65
Mean daily gain from 2nd to 28th day (lb)	0·265	0·317	0·314	0·295	0·047	0·064
Mean food eaten/lb gain, 2nd–28th day (lb)	1·48	1·36	1·33	1·42	0·09	0·12
Blood measurements						
No. of piglets	6	6	6	6	—	—
Haemoglobin (g/100 ml)	11·7	12·4	12·4	12·8	1·2	1·6
Packed cell volume (%)	40·4	41·0	42·1	42·8	3·4	4·6
Mean cell haemoglobin concentration (%)	29·0	30·1	29·3	29·9	—	—
Serum protein* (g/100 ml)	4·62	4·82	5·07	5·15	0·29	0·40

* Biuret method.

Experiment 3

The diets used in this experiment were not readily accepted and the piglets were slow in clearing up their food. The diets mixed easily with water, in contrast with those used in earlier experiments, but tended to stick to the floors and sides of the cages. Their stickiness increased as the glucose content increased. Table 5 summarizes the results.

Gain in weight. The piglets on diets J, K and L gained weight at closely similar rates. Those on diet I grew more slowly than those on diets J or K ($P < 0·05$). The difference in weight at 28 days between piglets on diet I and diet L was not significant.

Economy of food conversion. The 20 % protein diet produced results inferior to those with the 25 and 30% protein diets ($P < 0{\cdot}01$). The difference between the 25 and 30% protein diets was not significant. Economy of food conversion on the 35% protein diet was less ($P < 0{\cdot}05$) than that on the 30% protein diet.

Water consumption. Results for the first 3 days were excluded from the statistical analysis because some water was wasted by piglets during this period before they became fully accustomed to life in cages. Over the period 6th–28th day, daily water consumption was linearly related to live weight. There was considerable variation in

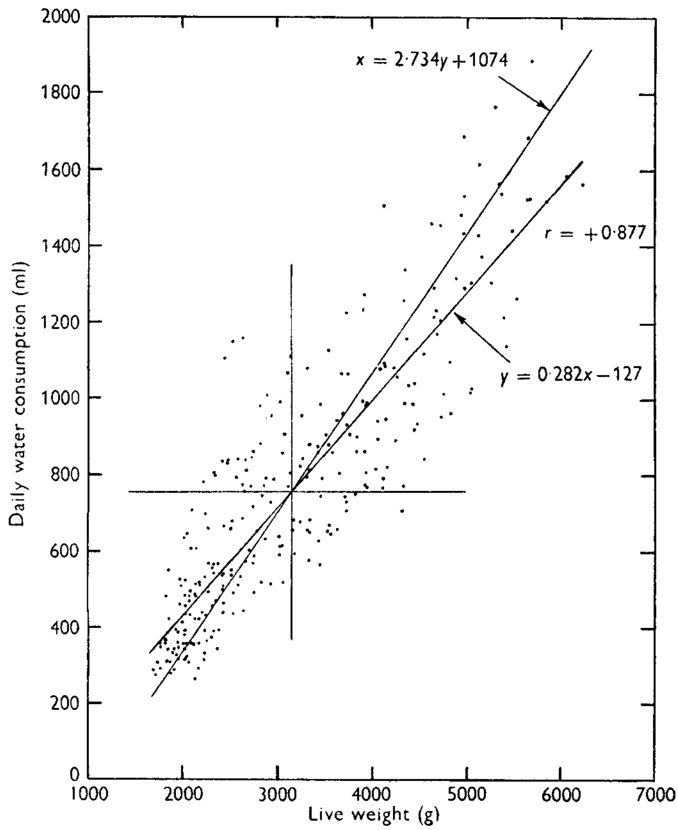

Fig. 2. Relationship between the daily water consumption of the piglets (y) and their live weight (x). $y = 0{\cdot}282x - 127$; $r = 0{\cdot}877$ (274 d.f.), $P < 0{\cdot}001$.

water consumption within diets and the protein content of the diet did not affect water consumption materially. The combined values for the twelve piglets (Fig. 2) gave the regression equation $y = 0{\cdot}282x - 127$, where y = daily water consumption (ml) and x = live weight (g). The correlation coefficient between these two variables was $+0{\cdot}877$, which is significant ($P < 0{\cdot}001$).

Haemoglobin values, packed cell volume, and mean cell haemoglobin concentration. These measurements were made to ensure that the piglets were receiving adequate supplies of iron in the diet. The values did not differ significantly between diets. Haemoglobin values at 28 days were almost double those in the previous experiment.

Serum protein

The concentration of serum protein tended to rise with dietary protein. The differences between diets I and J, J and K, and K and L were not significant; those between I and K, I and L, and J and L were significant ($P < 0.01$, $P < 0.01$, and $P < 0.05$ respectively).

DISCUSSION

The majority of studies of the nutritive requirements of pigs over the period from the 2nd or 3rd to the 28th day have been made with diets containing emulsified fat. Protein requirements have been studied with such diets by Reber, Whitehair & MacVicar (1953) and Sewell, Sheffy, Eggert & Loosli (1953) using 35–49 and 24·6% lard respectively in the diets. In both studies casein was the source of protein. Reber *et al.* found the protein requirement to be 41 % and Sewell *et al.* found 32 % protein in the diet to be the optimum. Becker *et al.* (1954), using diets based on dried skim milk and containing 5 % maize oil, found no advantage in giving more than 22 % protein.

It was noted by McCrea & Tribe (1956) that these three reports are consistent with the theory that protein requirement depends on the calorie density of the diet. Our finding that 25 % protein was adequate in a low-fat diet agrees fairly well with that of Becker *et al.*, the only other workers using diets of similar fat content. The difference between our findings and those of Becker *et al.* may perhaps be due to the fact that most of the protein in our diets came from casein, whereas they used dried skim milk, the mixture of proteins in the latter possibly providing a better balance of amino acids and thereby allowing optimum performance on a lower protein intake.

SUMMARY

1. In three separate experiments, involving a total of eighty-three piglets, a study was made of the optimum crude-protein content of low-fat diets for piglets in the first 4 weeks of life. The first experiment also provided data for the design of a feeding scale for use in subsequent experiments.

2. It was found that a minimum of 25 % crude protein was necessary for satisfactory growth and economy of food conversion by piglets weaned at 2–3 days of age and fed on low-fat diets up to 28 days of age.

3. The individual water consumption of twelve piglets was measured. It varied considerably and was not materially affected by the protein content of the diet.

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