Artificial rearing of pigs

8. Effect of dietary protein level on performance, nitrogen retention and carcass composition

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1. The requirement of the artificially-reared pig for crude protein (nitrogen × 6·38; CP) was estimated between 2 and 28 d of age. The pigs were given one of five diets, each containing 270 g soya-bean oil/kg and either dried skim-milk and dried whey in different proportions to supply 150, 180, 210 or 240 g CP/kg, or dried skim-milk alone which supplied 270 g CP/kg. The energy content of the diets was approximately 22 MJ digestible energy/kg.

2. The diets were obtained as spray-dried powders, reconstituted in water, and fed as a liquid containing 200 g DM/l. The pigs were fed at hourly intervals to a scale based on live weight.

3. N retention (g/d per kg live weight) and the proportion of CP in the carcass indicated a CP requirement of 240 g/kg for pigs from 2–28 d of age. There was no significant difference ($P > 0·05$) in performance between levels of dietary CP of 210, 240 or 270 g/kg. Although there was no increase in the proportion of CP in the carcass above a dietary CP level of 240 g/kg, a linear reduction in the proportion of lipid occurred as dietary CP level increased from 150 to 270 g/kg. Mortality, which was associated with scouring, was increased when the diet contained less than 210 g CP/kg.

4. There was a linear response in N retention to the level of CP in the diet at 7 d of age, whereas at 19 d of age, N retention reached a maximum with 240 g CP/kg diet, suggesting that the CP requirement may be greater during the first week of life.

5. Excretion of endogenous N in the urine was found to be 250 mg N/d per kg live-weight$^{0·75}$ in pigs between 7 and 19 d of age (2·0–6·4 kg live weight).

The protein requirement of the artificially-reared pig has received little attention, and reported estimates vary considerably. Part of this variation is attributable to differences in the age of the pigs, the energy content of the diet, and the source and quality of the protein in the diet.

Protein requirements decrease with age. Reber *et al.* (1953) reported that up to 22 d of age 410 g crude protein (nitrogen × 6·38; CP)/kg diet was needed for maximum performance and N retention, but at 49 d of age 200 g CP/kg diet produced optimal performance. Peo *et al.* (1957) also found that the age of the pig had a similar effect; 300 g CP/kg diet was required for maximum growth rate between 7–21 d of age, but only 200 g CP/kg diet between 7–35 d of age.

Protein requirements are also related to the energy density of the diet. A requirement of 250 g CP/kg from 2–28 d of age was reported when the diet contained less than 10 g fat/kg (Manners & McCrea, 1962), but if the fat content of the diet was increased to 210 g/kg, then the protein requirement was increased to 310 g/kg (Manners & McCrea, 1963).

Protein sources vary in digestibility, which will affect the requirement for CP. In the very young pig, milk protein is highly digestible. During the first month of life, the apparent digestibility of N in cow's milk was 0·99 (Braude *et al.* 1970), compared with 0·92 for soya-bean protein and 0·88 for fish protein (Cunningham & Brisson, 1957). The apparent digestibility of non-milk proteins increases with age; the digestibility of soya-bean protein increased from 0·78 at 14 d of age to 0·82 at 35 d of age, whereas the digestibility of milk protein remained constant at 0·96 (Hays *et al.* 1959).

Table 1. *Composition of the spray-dried diets*

Ingredient (g/kg)	Diet A	Diet E
Dried skim-milk	182	730
Dried whey	548	—
Soya-bean oil	270	270
Calculated crude protein (nitrogen × 6·38) (g/kg)	150	270
Chemical analysis		
Dry matter (g/kg)	981	976
Crude protein (g/kg)	158	265
Total lipid (g/kg)	292	293
Non-casein N (g/kg total N)	520	240
Calcium (g/kg)	9·5	10·9
Phosphorus (g/kg)	5·4	7·1

A higher protein requirement has been reported when casein has been used as the source of protein compared with dried skim-milk, and may be partly due to differences in protein quality. Using casein, requirements have been reported of 410 g CP/kg diet (Reber *et al.* 1953) and 320 g CP/kg diet (Sewell *et al.* 1953), whereas Becker *et al.* (1954) found that 220 g CP/kg diet gave maximum performance when spray-dried skim-milk was used as the source of protein. The protein quality of dried-milk products for the baby pig can be affected by the drying procedure. Braude *et al.* (1971) showed that a small reduction in performance of pigs from 2–28 d of age will occur if the whey proteins are completely denatured during the spray-drying of skim-milk, compared with a mild heating which leaves the majority of the whey proteins undenatured.

In a previous experiment at this Institute with diets containing dried skim-milk as the source of protein, Braude *et al.* (1976) showed that increasing the level of CP in the diet from 210 to 260 g/kg improved performance up to 7 d of age, but over the whole period of the experiment from 2–28 d of age had no effect. The proportion of N in the carcass was also increased when the higher levels of CP were given in the diet, but no differences were observed in N retention. Braude *et al.* (1977) further showed that between 290 and 320 g CP/kg diet, performance was unchanged, even when the fat content of the diet was increased from 270 to 400 g/kg diet, although there was a tendency for small increases in N retention and proportion of N in the carcass in pigs given the diet with 320 g CP/kg. A study of the response of pigs from 2–28 d of age to diets containing between 150 and 260 g CP/kg, supplied by dried skim-milk and dried whey, is now reported using the criteria of performance, N retention and carcass composition.

EXPERIMENTAL

Diets and method of feeding

Two spray-dried powders (diets A and E) were prepared from mixtures of skim-milk and soya-bean oil, and skim-milk, whey and soya-bean oil. The composition of the diets is shown in Table 1. Before spray-drying, butylated hydroxytoluene was added to the ingredients as an antioxidant to give a final concentration of 14 mg/kg dry matter (DM). Denaturation of whey proteins during spray-drying was minimized by using a mild-heat process. The preparation of liquid diets containing 200 g DM/l from the spray-dried powders and supplementation with retinol, cholecalciferol, α-tocopherol and phylloquinone was carried out as previously described (Braude & Newport, 1973). Diet A was also supplemented with a solution of $NaH_2PO_4.2H_2O$ so that the total phosphorus content was equal to that of diet E. A further three diets with CP concentrations intermediate between those in diets A (150 g/kg) and E (270 g/kg) were prepared by mixing the latter two diets, in liquid form, in the following proportions 3:1 (diet O), 1:1 (diet N) and 1:3 (diet M), giving CP contents of 180, 210 and 240 g/kg respectively. The five diets were fed to the pigs at hourly intervals on the scale based on live weight described by Braude & Newport (1973).

Experimental design and statistical analysis

Twelve litter-mate blocks of 2-d-old pigs were allocated to the five diets on the basis of live weight and sex. Separate rearing rooms were used to house the pigs given each of the five diets (Braude *et al.* 1970). The experiment, which terminated at 28 d of age, was carried out in three replicates, with four pigs/diet in each replicate. Seven of the pigs given each diet were slaughtered at 28 d of age for chemical analysis of the carcass.

As there appeared to be an effect of level of dietary CP on mortality, calculation of missing values was inappropriate. The effects of litter origin were insignificant and standard errors for diet comparisons were based on the pooled variation between pigs within diets. The results of this analysis are given in Table 2. The N retention values were subjected to the same analysis since values were confined to a few observations and were not obtained from complete litter-mate blocks. As complete litter-mate blocks were selected for carcass analysis, standard errors were based on the interaction between diets and litters.

N retention

Urine was collected into polyethylene bottles containing 25 ml glacial acetic acid. The volume was measured daily for four consecutive days, between 6 and 9, and 18 and 21 d of age, and 100 ml/l stored at 4°. The amount of faecal N was negligible and was ignored in the estimation of N retention. Portions of the diet and of the urine were analysed for total N.

Carcass analysis

Samples of carcass were prepared for analysis by mincing, homogenizing and freeze-drying as described by Florence & Mitchell (1972).

Analytical methods

The determinations of DM, ash, total and non-casein N and total lipid have been described by Braude *et al.* (1970) and Braude & Newport (1973). Samples were ashed before the determination of calcium by atomic absorption spectroscopy. P was determined after ashing by colorimetric estimation of the phosphovanadomolybdate complex as described by Cavell (1955).

RESULTS

Performance

From 2 d of age, to either 7 or 28 d of age, growth rate increased with dietary CP level (Table 2). The decreased weight gain with 240 g CP/kg diet during the period from 2–7 d of age was unexpected, but was not significantly different ($P > 0.05$) from the weight gain with other dietary CP levels. The feed:gain ratio decreased with increasing level of CP in the diet (Table 2). Only the feed:gain ratio from 2–28 d of age showed a significant ($P < 0.05$) curvilinear effect.

Mortality tended to be greater when pigs received the lower levels of CP in the diet, and was particularly severe among pigs given the diet containing 180 g CP/kg (Table 2). Mortality only occurred after a period of scouring.

Table 2. *Effect of dietary crude protein (nitrogen × 6·38; CP) concentration on performance of pigs from 2–28 d of age*

Age (d)	Diet* ...	A	B	C	D	E	Pooled standard error of a single observation (45 df)
	CP level (g/kg)	150	180	210	240	270	—
	No. of pigs surviving	10	7	10	11	12	—
	No. of deaths	2	5	2	1	0	—
2–7	Live-wt gain (g/d)	89	124	134	119	146	32·8
	Feed:gain ratio†	1·26	0·94	0·92	0·91	0·83	0·202
2–28	Live-wt gain (g/d)	179	243	263	270	296	37·4
	Feed:gain ratio	1·17	0·99	0·97	0·94	0·91	0·087

There were initially twelve pigs/treatment with a mean live weight of 1·6 kg.
* For details of diet composition, see Table 1 and p. 96.
† g DM consumed/g live-weight gain.

Table 3. *Effect of dietary crude protein (nitrogen × 6·38; CP) concentration on N retention in pigs of 7 or 19 d of age*

Age (d)	Diet* ...	A	B	C	D	E	Pooled standard error of a single observation†
	CP level (g/kg)	150	180	210	240	270	
7	No. of pigs	3	2	5	4	4	—
	N in urine (g/d per kg live wt)	0·22	0·16	0·18	0·20	0·26	0·057
	N retained (g/d per kg live wt)	1·18	1·56	1·79	2·16	2·47	0·225
	N retained (g)/kg N consumed	879	905	915	915	904	25·9
19	No. of pigs	3	3	3	4	3	—
	N in urine (g/d per kg live wt)	0·19	0·21	0·14	0·35	0·68	0·096
	N retained (g/d per kg live wt)	1·51	1·55	1·41	1·98	1·73	0·251
	N retained (g)/kg N consumed	887	880	901	851	720	36·1

* For details of diet composition, see Table 1 and p. 96.
† 13 df at 7 d of age, 11 df at 19 d of age.

N retention

In the 7-d-old pig, the excretion of urinary N and the N retained in relation to ingested N was not affected by the level of CP in the diet, but daily N retention/kg live weight increased linearly ($P < 0·001$) with level of CP in the diet (Table 3).

There was an increase in the excretion of urinary N and a decrease in the proportion of ingested N which was retained when pigs were given diets containing the higher levels of CP (240 or 270 g/kg) at 19 d of age (Table 3). There was some increase in daily N retention/kg live weight with level of CP in the diet.

There was no increase in the daily loss of N through urinary excretion until the dietary CP level exceeded 210 g/kg, at either 7 or 19 d of age. The urinary N excretion calculated

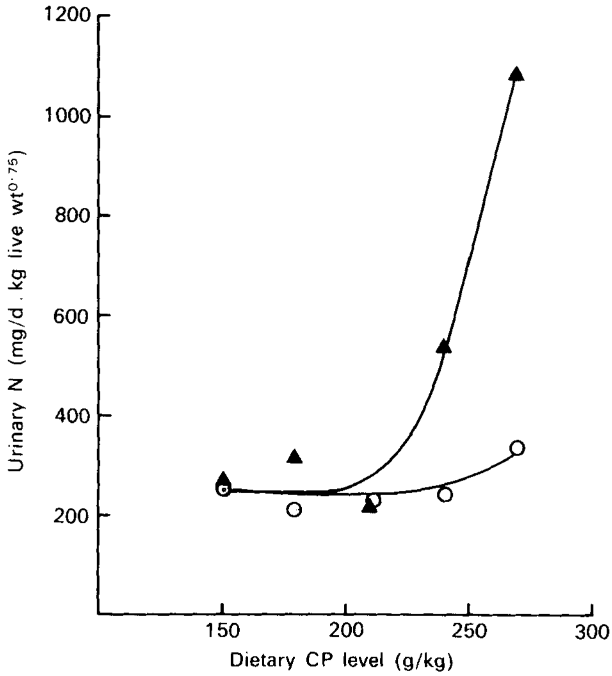

Fig. 1. Effect of dietary crude protein (nitrogen × 6·38; CP; g/kg) on urinary N excretion (mg/d per kg live-weight$^{0.75}$) of pigs at 7 (○) and 19 (▲) d of age.

Table 4. *Effect of dietary crude protein (nitrogen × 6·38; CP) concentration on carcass weight and proportions of dry matter* (DM), *CP* (*N* × 6·25), *total lipid and ash in the carcass of* 28-*d-old pigs*

(Mean values for seven pigs/treatment)

Diet* ...	A	B	C	D	E	Standard error of a difference (24 df)
CP level (g/kg)	150	180	210	240	270	
Wt (kg)	5·76	7·45	7·44	7·63	8·75	0·532
DM (g/kg)	353	346	334	328	335	8·6
CP (g/kg DM)	355	387	410	418	416	15·0
Total lipid (g/kg DM)	515	511	460	454	433	13·6
Ash (g/kg DM)	91	91	94	95	100	4·1

* For details of diet composition, see Table 1 and p. 96.

as mg N/d per kg live weight$^{0.75}$ is shown in Fig. 1; the mean value (± SE) for the nineteen observations from pigs receiving diets containing 210 g CP/kg or less was 250 ± 12·7 mg N/d per kg live weight$^{0.75}$, and probably represented the endogenous urinary loss.

Carcass composition

Carcass weight, which was (mean ± SE) 89 ± 4·2 % of live weight, increased linearly with dietary CP level (Table 4). The proportion of DM in the carcass decreased with increasing level of CP in the diet. There was a significant quadratic effect ($P < 0·05$) of dietary CP level on the proportion of carcass CP. The proportion of lipid in the carcass showed a highly significant ($P < 0·001$) linear reduction with increasing level of dietary CP.

DISCUSSION

There was a linear response in performance to level of dietary CP, both during the first week, and for the whole experimental period from 2–28 d of age. There was, however, no significant difference ($P > 0.05$) in performance with dietary CP levels of between 180 and 270, and 210 and 270 g CP/kg at 2–7, and 2–28 d of age respectively, indicating that the requirement for CP is within this range. A quadratic response ($P < 0.05$) in the feed:gain ratio to the level of CP in the diet was found between 2–28 d of age. Although the range of dietary CP levels was too restricted to justify this type of analysis, this response does suggest that the optimum level of dietary CP probably does not exceed 270 g CP/kg. This agrees with a previous experiment (Braude *et al.* 1977) in which performance was not improved by an increase in CP from 290 to 320 g/kg diet, but suggests that the requirement may be greater than 220 g CP/kg diet as reported by Becker *et al.* (1954).

The results of the studies of N retention indicated that there may be a greater requirement for CP in the diet during the first week of life. Daily N retention/kg live weight increased linearly with the dietary CP level in 7-d-old pigs (Table 3), and may have responded to dietary CP levels above 270 g/kg diet, although previously an increase in N retention did not occur above 290 g/kg diet (Braude *et al.* 1977). However, at 19 d of age (Table 3), maximum daily N retention/kg live weight was obtained with diets containing 240 g CP/kg. The efficiency of N retention, expressed as the proportion of N retained relative to the amount ingested, remained high and was not affected ($P > 0.05$) by the level of dietary CP at 7 d of age. However, at 19 d of age, the efficiency of N retention was lower at the two highest levels of dietary CP and corresponded to an increase in the rate of excretion of N in the urine. Therefore, at 7 d of age, the efficiency of N retention may be maintained at levels of dietary CP above 270 g/kg diet, whereas at 19 d of age, the efficiency of N retention decreased when the diet contained 240 or 270 g CP/kg. With pigs of 7–9 kg live weight, Muller *et al.* (1973) reported that the proportion of the ingested N that was retained decreased only when the dietary CP level, supplied by milk protein, exceeded 270 g/kg diet.

The loss of endogenous N in the urine in this experiment with pigs of 2.0–6.4 kg live weight of 250 mg N/d per kg live weight$^{0.75}$ (Fig. 1) was greater than values reported for older pigs. Gebhardt & Stein (1970) found a value of 160 mg N/d per kg live weight$^{0.67}$ in pigs of 9–11 kg live weight, and between 20 and 50 kg live weight, Armstrong & Mitchell (1955) reported that endogenous urinary N amounted to 106 mg N/d per kg live weight$^{0.734}$. These results suggest that excretion of endogenous urinary N/d per kg live-weight$^{0.75}$ (metabolic body-weight) decreases with age.

Dietary CP level had a marked effect on the proportions of CP and lipid in the carcass of 28-d-old pigs (Table 4). Increasing the dietary CP level above 240 g/kg diet gave no further increase in the proportion of CP in the carcass, whereas the proportion of lipid in the carcass decreased linearly with increasing dietary CP level. In an earlier experiment, Braude *et al.* (1976) found that the proportion of CP in the carcass was greater when the diet contained 260 compared with 210 g CP/kg, but the interpretation of this result was complicated by differences in the energy content of the diets. With isoenergetic diets, higher levels of dietary CP did not affect the carcass composition, and the proportions of CP and lipid were similar when the diet contained either 290 or 320 g CP/kg (Braude *et al.* 1977). However, other workers have reported that the proportion of CP in the carcass is increased by higher levels of dietary CP. In 39-d-old pigs, the CP content of the carcass was greatest when the diet contained 390 g CP/kg when protein was supplied by skim-milk and casein (Kirchgessner & Kellner, 1972), but when the source of protein was soya bean and skim-milk, or soya bean alone, the maximum proportion of CP in the carcass was attained with diets containing 340 g CP/kg (Kellner & Kirchgessner, 1973; Muller, Kirchgessner & Kellner, 1974). In these latter two experiments, as also in the present experiment, a further reduction in the fat content of the carcass was found when the level of dietary CP exceeded that required for maximum CP content in the carcass.

N retention estimated from balance studies or carcass analysis indicated that the requirement for CP from 2–28 d of age was approximately 240 g/kg in a diet containing approximately 22·0 MJ digestible energy/kg. No precise estimate of the requirement can be made from the performance results, and this suggests that N retention may be a more sensitive method than performance in defining optimum CP requirements. Analysis of the performance results showed that there was some curvilinear response in the feed: gain ratio to level of CP in the diet, suggesting that a larger-scale experiment over a wider range of dietary CP levels might permit a better estimate of the response in performance to level of CP in the diet.

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