# Digestion in the pig between 7 and 35 d of age
# 3. The digestion of nitrogen in pigs given milk and soya-bean proteins

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1. In two separate experiments, forty-four pigs weaned at 4–5 d of age were fed on diets containing milk or soya-bean protein until slaughtered at 14, 28 or 35 d of age.

2. Daily amounts of nitrogen flowing through the stomach and proximal small intestine of pigs were similar with both sources of protein fed.

3. Endogenous N flows in the duodenum, jejunum and ileum of pigs given an N-free diet were 22·9, 7·4 and 4·6 g N/kg dry matter (DM) intake. Endogenous N in faeces was 0·970 g N/kg DM intake.

4. The apparent and true digestibility of N to the ileum of 28-d-old pigs was 0·86 and 0·92 for the pigs given the milk-protein diets, 0·80 and 0·86 for the pigs given the isolated soya-bean protein (ISP; Promine D) diets and 0·51 and 0·62 for pigs given the soya-bean meal (SBM)-protein diet. These values over the entire gastro-intestinal tract were 0·98 and 1·00 for milk, 0·92 and 0·95 for ISP and 0·82 and 0·85 for SBM.

5. The apparent and true digestibility of N to the ileum of 14-d-old pigs given a liquid milk diet was 0·92 and 0·94, while the values for the pigs given a pelleted milk diet were 0·86 and 0·87. At 35 d of age there were no differences in the apparent digestibility of the N in the liquid and pelleted milk diets.

6. The apparent digestibility of N to the ileum and over the entire gastro-intestinal tract of pigs given ISP (Supro 610) increased with increasing age of pigs from 0·83 at 14 d of age to 0·88 at 35 d of age.

7. Of the N in the stomach 14–32% could not be precipitated by trichloroacetic acid (TCA; 30 g/l).

8. In the jejunal and ileal contents an average of 46 and 24% of the N was precipitated by TCA in pigs given soya-bean proteins and milk proteins respectively.

It is well known that the performance of pigs of 14 d of age or less is lower when they are fed on diets containing soya-bean protein than diets containing milk proteins (e.g. Hays *et al.* 1959). The over-all apparent digestibility of soya-bean protein is less than that of milk protein, but there have been no studies on the sites of nitrogen absorption and endogenous N secretions in pigs up to 35 d of age, although similar studies have been made with older pigs (e.g. Zebrowska, 1973). Hence, a study of the absorption of N was carried out with young pigs given milk or soya-bean proteins.

## EXPERIMENTAL

### *Animals and diets*

*Expt* 3. Thirty-six pigs (mean weight 2·05 kg, mean age 7 d) were allocated to six diets as a 3 × 2 factorial with three replicates of two pigs per replicate. Three protein sources were compared in isonitrogenous diets: milk, isolated soya-bean protein (ISP) (Promine D; Central Soya Co., Chicago, Ill.) and soya-bean meal (SBM), each with and without methionine supplementation, and lysine supplementation of the ISP and SBM diets. The composition of the diets is given in Wilson & Leibholz (1981 *a*). After 17 d, one pig per pen was removed and the remaining eighteen pigs were given the experimental diets sprayed with indigestible markers for a further 5 d. The pigs were then slaughtered at 28 d of age as described in Wilson & Leibholz (1981 *b*).

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*Expt* 4. Twenty-four pigs (mean weight 2·43 kg, mean age 7 d) were allocated to three diets: an all-milk-protein diet fed either pelleted or liquid or a pelleted diet in which the protein source was ISP (Supro 610; Ralston Purina, St Louis, Mo.). There were eight replicates of one pig per replicate. The composition of the diets is given in Wilson & Leibholz (1981 *a*). Twelve pigs were fed the diets *ad lib.* from 4–5 d of age until 9 d of age and then at 2 g nitrogen/kg live weight$^{0.75}$ per d for 5 d until slaughter at 14 d of age. The other twelve pigs were given the diets *ad lib.* until 30 d of age and then at 2 g N/kg live weight$^{0.75}$ per d for 5 d until slaughter at 35 d of age. An N-free diet was fed to a further two pigs from 30–35 d of age at 45 g DM/kg live weight$^{0.75}$ per d which was similar to the DM intakes of pigs given the protein diets. The pigs were given equal amounts of food every 2 h over the 5 d preceding slaughter. Indigestible markers were administered to the pigs immediately preceding each 2 h feed. The composition of the N-free diet is given in Wilson & Leibholz (1981 *b*).

### *Indigestible markers*

The indigestible markers used were the $^{51}$Cr complex of ethylenediaminetetra-acetic acid (EDTA) ($^{51}$Cr EDTA) (Downes & McDonald, 1964) and $^{103}$Ru-labelled Tris-(1,10-phenthroline)-ruthenium (II) chloride ($^{103}$Ru-P) (Tan *et al.* 1971). Flow rates were calculated as described by Wilson & Leibholz (1981 *b*).

### *Analytical techniques*

Total N was determined on food, total homogenized digesta and faecal samples by the Kjeldahl method using copper and selenium as catalysts.

Protein-N content of digesta samples was determined by the method of Ternouth *et al.* (1974) by precipitating the protein N with trichloroacetic acid (30 g/l; TCA).

### *Statistical methods*

The results were subjected to analysis of variance with treatment means being statistically compared using least significant difference comparisons (Steel & Torrie, 1960). The values obtained from the pigs given the N-free diet were not included in the statistical analysis.

## RESULTS

There were no significant differences in the flow of total N in the digesta due to amino acid supplementation in Expt 3. The results of this experiment have, therefore, been calculated by combining the amino acid treatments for each protein source and are presented as the means of six pigs per treatment.

The influence of dietary protein source on the flow of total N through the stomach and small intestine was similar to that observed for the flow of dry matter (DM) (Wilson & Leibholz, 1981 *b*). Greater amounts of N flowed through the stomach and anterior small intestine of pigs given the milk-protein diet than those fed the isolated soya-bean protein (ISP; Promine D; Central Soya Co., Chicago, Ill.) and soya-bean meal (SBM) diets (Table 1). The N intake of the milk-fed pigs was, however, significantly greater than that of the pigs given soya-bean proteins and there were no differences in the flow of digesta N when these values were expressed as a percentage of the N intake. There was a significantly greater flow of N to the ileum in pigs given the SBM diet than for pigs given the milk and ISP diets. Also, significantly more N flowed through the large intestine and was excreted in the faeces of pigs given the SBM diet in Expt 3.

In Expt 4 (Table 2) the pigs were fed daily at 2 g N/kg live weight$^{0.75}$ per d. There were no differences in the amounts of N flowing through the anterior small intestine between the three treatments. Greater amounts of N flowed to the ileum of pigs given the ISP (Supro 610; Ralston Purina, St Louis, Mo.) diet at 14 d of age than those fed the milk diets, but

Table 1. *Expt 3. Flow of nitrogen through the gastro-intestinal tract of pigs given diets containing milk or soya-bean protein*

| | Protein source | | | |
|---|---|---|---|---|
| | Milk | Isolated soya-bean protein† | Soya-bean meal | SEM |
| N intake (g/d)... | 15·50 | 10·53 | 11·33 | 0·922** |
| Intestinal section (g/d) | | | | |
| Stomach | 16·46 | 13·74 | 12·62 | 1·244 |
| Duodenum | 23·51 | 17·74 | 16·16 | 1·910* |
| Jejunum | 13·09 | 9·26 | 12·96 | 1·779 |
| Ileum | 3·10 | 3·27 | 5·56 | 0·483** |
| Caecum | 1·32 | 2·20 | 3·99 | 0·306*** |
| Large intestine | 0·93 | 1·66 | 3·32 | 0·267*** |
| Faeces | 0·21 | 1·10 | 1·98 | 0·139*** |
| N (% of intake) | | | | |
| Stomach | 107·5 | 133·1 | 106·5 | 10·27 |
| Duodenum | 151·0 | 167·4 | 118·7 | 13·66 |
| Jejunum | 84·4 | 96·6 | 115·3 | 17·90 |
| Ileum | 21·0 | 35·7 | 49·0 | 4·11** |
| Caecum | 8·6 | 21·9 | 34·4 | 2·80*** |
| Large intestine | 6·0 | 16·1 | 28·2 | 2·30*** |
| Faeces | 1·4 | 10·9 | 16·6 | 1·34*** |

* $P < 0·05$, ** $P < 0·01$, $P < 0·001$.
† Promine D; Central Soya Co., Chicago, Ill.

there were no differences at 35 d of age. Significantly more N flowed through the large intestine and was excreted in the faeces of pigs at both age groups when given the ISP (Supro 610) diet than in those given the milk-protein diets.

The mean daily amounts of N flowing through the stomach and duodenum of pigs given the diets in Expt 3 were greater than the N intakes (Table 1). The apparent endogenous secretion of N in the stomach and duodenum was similar after feeding the three protein sources and ranged from 0·8 to 3·2 g in the stomach, and from 4·8 to 8·0 g in the duodenum. By the jejunum N flow still exceeded the N intake in the pigs given the SBM diet, but not in those given the other diets. At the ileum, there was a significantly greater flow of total N expressed as a percentage of N intake for pigs given the SBM diet (49%) than for pigs given the milk (21%) or ISP (35·7%) diets. This trend continued through the caecum and large intestine.

In Expt 4 the amount of N flowing through the stomach was less than the N intake for the pigs given the liquid-milk diet, and similar to the N intakes of the pigs given the pelleted diets. At 35 d of age the amount of N at the duodenum and jejunum was approximately half of the N intake. There was no significant difference due to the age of the pigs for the flow of N, expressed as a percentage of N intake, to the ileum. The N flow through the large intestine and excreted in the faeces, expressed as a percentage of N intake, was greater for the pigs given the ISP (Supro 610) diet than for pigs given the milk diets.

The flow of endogenous N with pigs given the N-free diet at 35 d of age in Expt 4 was 1·03, 4·22, 1·37 and 0·82 g/24 h at the stomach, duodenum, jejunum and ileum respectively. N excreted in the faeces of pigs given the N-free diet was 0·18 g/24 h. Expressed in relation to the DM intake, the endogenous N flow to the ileum and faeces was 4·61 and 0·970 g/kg DM intake respectively.

Table 2. *Expt 4. Flow of nitrogen (g/d) through the gastro-intestinal tract of pigs given diets containing milk (pelleted or liquid) or soya-bean protein (pelleted)*

| Protein source | Form | Age (d) | N intake | Intestinal section: Stomach | Duodenum and jejunum | Ileum | Caecum | Large intestine | Faeces |
|---|---|---|---|---|---|---|---|---|---|
| Milk | Pelleted | 14 | 4·28 | 3·83 | 1·84 | 0·60 | 0·21 | 0·37 | 0·14 |
| | | 35 | 10·56 | 11·89 | 5·33 | 1·76 | 0·39 | 0·37 | 0·17 |
| | | Mean | 7·42 | 7·86 | 2·86 | 1·18 | 0·30 | 0·37 | 0·15 |
| Milk | Liquid | 14 | 4·12 | 3·36 | 0·94 | 0·32 | 0·13 | 0·18 | 0·05 |
| | | 35 | 9·38 | 7·95 | 3·88 | 1·15 | 0·18 | 0·31 | 0·08 |
| | | Mean | 6·75 | 5·65 | 2·41 | 0·74 | 0·15 | 0·25 | 0·07 |
| Isolated soya-bean protein† | Pelleted | 14 | 4·29 | 3·78 | 1·08 | 0·72 | 0·36 | 0·67 | 0·27 |
| | | 35 | 8·62 | 9·03 | 3·97 | 1·01 | 0·32 | 0·64 | 0·37 |
| | | Mean | 6·37 | 6·41 | 2·52 | 0·87 | 0·34 | 0·65 | 0·32 |
| Mean | | 14 | 4·23 | 3·66 | 1·28 | 0·55 | 0·23 | 0·41 | 0·15 |
| | | 35 | 9·52 | 9·62 | 4·39 | 1·31 | 0·30 | 0·44 | 0·21 |
| Statistical significance and SEM due to: | | | | | | | | | |
| Protein | | | 0·314 | 0·400** | 0·617 | 0·116* | 0·031** | 0·030*** | 0·031*** |
| Age | | | 0·260*** | 0·327*** | 0·504*** | 0·094*** | 0·025 | 0·024** | 0·025 |
| Protein × age | | | 0·444 | 0·565* | 0·872 | 0·164** | 0·044 | 0·042 | 0·044 |
| Nitrogen-free diet | | | — | 1·03 | 2·80 | 0·82 | 0·23 | 0·27 | 0·18 |

* $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$.
† Supro 610; Ralston Purina, St Louis, Mo.

Table 3. *Expt 3. True and apparent digestion of nitrogen to the ileum and in the total intestinal tract of pigs given diets containing milk or soya-bean protein*

| | Ileum | | Total | |
|---|---|---|---|---|
| Diet | Apparent | True‡ | Apparent | True‡ |
| Milk | 0·800 | 0·888 | 0·986 | 1·007 |
| Isolated soya-bean protein† | 0·689 | 0·745 | 0·891 | 0·917 |
| Soya-bean meal | 0·510 | 0·616 | 0·822 | 0·848 |
| SEM | 0·041*** | 0·045*** | 0·012*** | 0·013*** |

*** $P < 0·001$.
† Promine D; Central Soya Co., Chicago, Ill.
‡ Corrected for endogenous N secretion to the ileum (4·61 g N/kg dry matter intake) and faeces (0·970 g N/kg dry matter intake) obtained from 35-d-old pigs given an N-free diet in Expt 4.

Table 4. *Expt 4. True and apparent digestion of nitrogen to the ileum and in the total intestinal tract of pigs given diets containing milk or isolated soya-bean protein*

| | | | Apparent digestion | | True digestion‡ | |
|---|---|---|---|---|---|---|
| Protein source | Form | Age (d) | Ileum | Total | Ileum | Total |
| Milk | Pelleted | 14 | 0·856 | 0·968 | 0·872 | 0·998 |
| | | 35 | 0·831 | 0·983 | 0·921 | 1·002 |
| | | Mean | 0·844 | 0·976 | 0·897 | 1·000 |
| Milk | Liquid | 14 | 0·932 | 0·989 | 0·938 | 1·012 |
| | | 35 | 0·879 | 0·991 | 0·961 | 1·012 |
| | | Mean | 0·901 | 0·990 | 0·950 | 1·012 |
| Isolated soya-bean protein† | Pelleted | 14 | 0·828 | 0·937 | 0·841 | 0·959 |
| | | 35 | 0·883 | 0·957 | 0·976 | 0·978 |
| | | Mean | 0·855 | 0·947 | 0·909 | 0·969 |
| Mean | | 14 | 0·869 | 0·964 | 0·884 | 0·990 |
| | | 35 | 0·864 | 0·977 | 0·952 | 0·997 |
| Statistical significance and SEM due to: | | | | | | |
| Protein | | | 0·013* | 0·005*** | 0·012* | 0·005** |
| Age | | | 0·011 | 0·004* | 0·010*** | 0·004 |
| Protein × age | | | 0·018 | 0·007 | 0·017** | 0·007 |

* $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$.
† Supro 610; Ralston Purina, St Louis, Mo.
‡ Corrected for endogenous N secretion to the ileum (4·61 g N/kg dry matter intake) and faeces (0·97 g N/kg dry matter intake) obtained from 35-d-old pigs given an N-free diet.

The apparent digestion of N to the ileum was significantly different for the three protein sources fed in Expt 3 (Table 3). The values were 0·800, 0·689 and 0·510 for pigs given the milk, ISP (Promine D) and SBM diets respectively. Over the entire gastro-intestinal tract, the values were 0·986, 0·891 and 0·822 respectively.

The apparent digestion of N to the ileum of 14-d-old pigs given the liquid milk diet (0·923) was significantly greater than for pigs given the pelleted diets (0·856 and 0·828 for the milk

Table 5. *Expt 3. Trichloroacetic acid-precipitable-nitrogen: total N in the gastro-intestinal tract of pigs given diets containing milk or soya-bean protein*

| | Protein source | | | |
|---|---|---|---|---|
| Intestinal section | Milk | Isolated soya-bean protein† | Soya-bean meal | SEM |
| Stomach | 0·773 | 0·716 | 0·763 | 0·0326 |
| Jejunum | 0·219 | 0·311 | 0·283 | 0·0269 |
| Ileum | 0·236 | 0·591 | 0·475 | 0·0538** |
| Caecum | 0·601 | 0·847 | 0·810 | 0·0180*** |
| Large intestine | 0·693 | 0·812 | 0·646 | 0·0300** |
| Faeces | 0·610 | 0·917 | 0·852 | 0·0239*** |

** $P < 0{\cdot}01$, *** $P < 0{\cdot}001$.
† Promine D; Central Soya Co., Chicago, Ill.

Table 6. *Expt 4. Trichloroacetic acid-precipitable-nitrogen: total N in the gastro-intestinal tract of pigs given diets containing milk or isolated soya-bean protein*

| | | | Intestinal section | | | | |
|---|---|---|---|---|---|---|---|
| Protein source | Form | Age (d) | Stomach | Duodenum and jejunum | Ileum | Caecum | Large intestine |
| Milk | Pelleted | 14 | 0·842 | 0·217 | 0·279 | 0·700 | 0·689 |
| | | 35 | 0·839 | 0·240 | 0·298 | 0·868 | 0·775 |
| | | Mean | 0·840 | 0·228 | 0·289 | 0·784 | 0·732 |
| Milk | Liquid | 14 | 0·858 | 0·208 | 0·196 | 0·763 | 0·745 |
| | | 35 | 0·855 | 0·260 | 0·246 | 0·873 | 0·768 |
| | | Mean | 0·856 | 0·234 | 0·221 | 0·817 | 0·756 |
| Isolated soya-bean protein† | Pelleted | 14 | 0·828 | 0·391 | 0·550 | 0·807 | 0·818 |
| | | 35 | 0·676 | 0·478 | 0·622 | 0·850 | 0·863 |
| | | Mean | 0·752 | 0·435 | 0·586 | 0·828 | 0·840 |
| Mean | | 14 | 0·843 | 0·272 | 0·342 | 0·757 | 0·751 |
| | | 35 | 0·790 | 0·326 | 0·389 | 0·863 | 0·802 |
| Statistical significance and SEM due to: | | | | | | | |
| Protein | | | 0·0405 | 0·0291*** | 0·0244*** | 0·0337 | 0·0317** |
| Age | | | 0·0330 | 0·0237 | 0·0200 | 0·0273* | 0·0259 |
| Protein × age | | | 0·0572* | 0·0411 | 0·0345 | 0·0476 | 0·0448 |

* $P < 0{\cdot}05$, ** $P < 0{\cdot}01$, *** $P < 0{\cdot}001$.
† Supro 610; Ralston Purina, St Louis, Mo.

and ISP diets respectively (Table 4). Similar results were obtained with the apparent digestion of DM to the ileum for 14-d-old pigs (Wilson & Leibholz, 1981 *b*). At 35 d of age there were no significant differences between the apparent digestion of N to the ileum for pigs given the two milk-protein diets.

Correction of the apparent digestibility values for endogenous N flow to the ileum for pigs in Expt 4 showed a significant improvement in the digestion of N with age of pigs from 14 to 35 d of age when given the two pelleted diets (Table 4). If the apparent digestion in other sections of the gastro-intestinal tract were corrected for endogenous N secretion, there was a similar increase in the digestion of N with age of the pigs given the pelleted diets.

The TCA-precipitable-N: total N value in the digesta of pigs on Expts 3 and 4 are shown in Tables 5 and 6. There was no difference in the extent of hydrolysis of protein in the stomach of pigs in Expts 3 and 4 but the results show that soya-bean proteins were hydrolysed to a lesser extent in the small intestine than milk proteins. This trend continued through the caecum and large intestine although it was not significant in all instances.

## DISCUSSION

The capacity of the young pig to secrete pepsin and acid is limited at birth and increases with age (Cranwell & Titchen, 1976; Decuypere *et al.* 1978). Pig pepsinogens are hydrolysed to pepsin in acid conditions, slowly at pH 4 and rapidly at pH 2. The pepsins have two pH optima, one at approximately 2·0 and the other at approximately 3·5 (Taylor, 1959). The pH of the stomach contents in the present experiments were 3·8–4·3 (Wilson & Leibholz, 1981 *b*). These high pH values would allow only limited proteolysis. The amount of true protein-N in the stomach digesta relative to the total N was high indicating that little proteolysis had occurred in the stomach. Similar results were observed in the stomach of 28-d-old pigs given homogenized cows' milk (Braude *et al.* 1970).

Zebrowska (1973) has shown that in 60 kg-live-weight pigs approximately 85% of the N was in the form of peptides and free amino acids in the digesta reaching the duodenum. This would indicate some gastric protein hydrolysis in these pigs as would be expected by the lower gastric pH values of adult pigs as shown by Lawrence (1972).

There was a small increase in the N content of the stomach digesta above the dietary N intake, which would indicate some net secretion of gastric juice. Horszczaruk (1971) also observed that the composition of stomach contents taken 2·5–4·5 h after feeding growing pigs differed only slightly from dietary intake with small but not significant increases in the total N content. Other workers (Zebrowska & Buraczewska, 1972; Zebrowska, 1973; Zebrowska *et al.* 1975) feeding diets with different levels of protein or protein sources to 50–60 kg pigs with re-entrant cannulas found that up to the proximal duodenum the N flow was 6·0–7·0 g/24 h or 3·0–3·5 g N/kg DM intake greater than the N intake. Low & Zebrowska (1977), however, demonstrated that the value for endogenous N up to the duodenal cannulas is influenced by the technique of collection and becomes zero if the collection is made at luminal pressure. The technique used in the present experiments should provide an unbiased measure for endogenous N secretion.

The protein in the pancreatic secretions has been shown to contribute approximately 19 g/d for 45 kg-live-weight pigs (Corring, 1975), and could be approximately 1·5–2·0 g N/d in the 4 kg pigs used in the present experiments. Measuring the secretion of intestinal juice in the isolated jejunal loop in 70 kg pigs, Horszczaruk *et al.* (1971) calculated that the secretion into the small intestine from the intestine wall would have been 10–11 g N on the normal diet and 8–10 g N on the protein-free diet. The length of intestine in the 4 kg pig would be approximately 5 m compared to 14 m in the 70 kg pig (Vodovar *et al.* 1964) resulting in a secretion of approximately 3 g N. The apparent endogenous secretion of N of pigs given the N-free diet in Expt 4 was 4·2 g/ d to the duodenum and 2·8 g/d to the jejunum.

It has been shown that endogenous secretion in the stomach and duodenum of pigs is unaffected by the level of protein in the diet (Zebrowska & Buraczewska, 1972) or the frequency of feeding (Zebrowska & Horszczaruk, 1975). However, the amount of endogenous N was found to be influenced by the source of dietary protein (Zebrowska, 1973; Buraczewska *et al.* 1975). In the present experiments it appears that the pigs given the milk-protein diet in Expt 3 had greater endogenous secretions of N than the pigs given the ISP (Promine D) or SBM protein diets. However, this could also be explained by differences in N absorption from the stomach and duodenum and by the greater N and DM intakes of pigs fed the milk-protein diet.

When pigs were fed regularly at restricted levels (Expt 4) either the amount of endogenous secretion in the stomach and duodenum was considerably less than for pigs fed *ad lib.* or the absorption of N in the stomach and duodenum was greater.

The flow of N to the ileum was greater in pigs given the soya-bean-protein diets than the milk-protein diets. This may be due both to the greater endogenous N secretion in the pigs given soya-bean protein and to the lower absorption of exogenous and endogenous N before the terminal ileum. The digestibility of endogenous N is less than the dietary N (Buraczewska *et al.* 1975; Zebrowska *et al.* 1976); while Zebrowska (1973) has shown that amounts of endogenous N of pigs given SBM, particularly in the proximal small intestine, were twice that obtained from pigs given other protein sources.

The flow of endogenous N to the ileum measured in pigs given the N-free diet was 4·61 g N/kg DM intake. A value of 3·00 g N/kg DM intake was reported by Zebrowska *et al.* (1975) in 60 kg-live-weight pigs and 2·50 g N/kg DM intake in 45 kg-live-weight pigs by Holmes *et al.* (1974).

The values of the present experiment may be explained by the younger age of the pigs and by the frequency of feeding. The pigs in Expt 4 were fed every 2 h while those of Holmes *et al.* (1974) and Zebrowska *et al.* (1975) were fed twice daily. This frequent feeding may stimulate greater digestive secretions as Corring *et al.* (1972) showed that there was an increase in protein secretion by the pig's pancreatic secretions in response to feeding.

Endogenous N reaching the faeces was 0·970 g N/kg DM intake in the present experiment. Values of 0·910–1·140 g N/kg DM intake have been obtained in the faeces of pigs determined by extrapolation and by feeding N-free diets respectively (Armstrong & Mitchell, 1955; Carlson & Bayley, 1970).

The apparent digestibility of N to the ileum and over the entire gastro-intestinal tract was significantly greater for the 14-d-old pigs given the liquid milk diet compared to the pelleted diets. The mean retention time of digesta in the ileum of pigs given the liquid diet was greater (2·5 h) than for pigs given the pelleted diet (2·0 h) (Wilson & Leibholz, 1980*b*). This would allow a greater time for more complete digestion to occur. Searley *et al.* (1962) found that pelleted diets pass through the small intestine at a faster rate than meal diets. However, the lower digestibility of N in pigs given pelleted diets could be due to a greater endogenous N secretion in the intestinal tract of these pigs. Cuperlovic *et al.* (1975) demonstrated that pigs given pelleted diets consumed these diets more slowly, with more intense mastication and mixing of food with saliva than pigs given the same diet in a loose meal form. So pigs given the pelleted diets may have had a greater gastric endogenous N secretion than pigs given the liquid diet.

The value of 0·510 for the apparent digestion of N to the ileum for pigs given SBM protein (Expt 3) was considerably lower than values obtained with growing and adult pigs: 0·67 (Zebrowska, 1973), 0·799 (Holmes *et al.* 1974), but values reported by Carlson & Bayley (1970) and Holmes *et al.* (1974) for the apparent digestibility of SBM over the entire gastro-intestinal tract were similar to the value of 0·822 obtained in Expt 3.

The true digestibility of the milk-protein diets showed that the N in milk was readily absorbed with values being close to 1·00 to the ileum (0·872–0·961), and over the entire gastro-intestinal tract (0·959–1·012), which confirms the observations of Carlson & Bayley (1970).

Poppe & Meier (1977) found that the difference between the true digestibility of N to the ileum and in the faeces was only 1·8 digestibility units for pigs given casein when the ileal fistula was positioned 100–150 mm from the ileal–caecal junction. The difference between the true N digestibility to the ileum and in the faeces in the present experiments was less than that obtained by Poppe & Meier (1977), which would indicate that the microflora of the caecum and large intestine had no effect on the determination of the true digestibility of N. However, for pigs given less digestible protein sources, ISP and SBM, the difference between the true digestibility of N to the ileum and in the faeces increased.

The true digestibility of N to the ileum was lower for all diets in pigs at 14 d of age than at 35 d of age. This may be explained either by a lower digestion of the dietary proteins, due to inadequate enzyme secretions in the younger pigs, or that the endogenous N secretions were greater in pigs at 14 d of age than at 35 d of age. The digestibilities were corrected by using the value for endogenous N of 4·61 g N/kg DM intake measured in pigs of 35 d of age. Schurig & Poppe (1976) found that the endogenous N, as a proportion of food intake, was influenced by the live weight of pigs, being greater in pigs between 10–40 kg live weight than in pigs over 40 kg live weight. When corrections were made for the different levels of endogenous N in pigs of different live weight, Schurig & Poppe (1976) found no differences in the true digestibility of N in pigs between 10 and 100 kg live weight. There is no comparable information for pigs between the live weights 1·2–6·0 kg used in the present experiments.

It has been demonstrated that the apparent digestibility of N in the pig is influenced by the nature of the dietary starch (Mason & Just, 1976). The latter authors found the flow of bacterial N from the large intestine was greater after feeding potato starch than maize starch, and that the daily amounts of total N passing the ileum and at the rectum was greater for pigs given potato starch. Although the levels of lactose in all diets fed in the present experiments were constant, the carbohydrate component present in SBM may have resulted in a greater amount of bacterial N flow through the lower intestine.

Zebrowska (1973) showed that in pigs given casein, only 12% of the N at the duodenum was protein-N while the remainder was peptides and free amino acids. Braude *et al.* (1970) found that 11% of the N in the duodenum was insoluble and a total of 19% of the N was in the form of protein for young pigs given homogenized cows' milk. This agrees with the results of the present experiments for the pigs given the milk diets.

At the ileum, the TCA-precipitable fraction was 26% of the total N for pigs given the milk-protein diet, which compares with values of 36% reported by Zebrowska (1973) and 21% increasing to 31%, 1·5 h after feeding reported by Braude *et al.* (1970). The position of the cannulas used by Zebrowska (1973) was in the terminal ileum, and Braude *et al.* (1970) showed that the proportion of protein in the total N increased along the intestine. In the caecum, in the present experiments, approximately 76% of the N was in the form of protein-N.

Zebrowska (1973) found 15–20% of the N was in the form of protein at the duodenum of pigs given SBM, while in the present experiments using younger pigs, the average value was 37%. This may indicate that the hydrolysis of soya-bean protein in the small intestine improves with increasing age of the animal. This has been indirectly demonstrated by N balance experiments (Hays *et al.* 1959; Wilson & Leibholz, 1981*a*).

From these results it may be concluded that the digestion and absorption of N from milk-protein diets was extremely rapid and practically complete by the terminal ileum of young pigs. The N in ISP diets was more efficiently digested by young pigs than SBM protein. The apparent and true digestibility of N from milk protein remained similar for pigs at 14 and 35 d of age and was similar to values obtained with older pigs, while the true digestibility of ISP increased with increasing age of pigs. It appears that endogenous N flow may be influenced by the form of the diet fed (pelleted or liquid) and the age of pigs, as well as the relationship to DM intake and protein source fed.

It may be suggested that the performance of pigs given diets containing soya-bean protein is limited by the extent of protein hydrolysis in the small intestine.

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