Studies on digestion and absorption in the intestines of growing pigs

5*. Measurements of the flow of nitrogen

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1. Digesta were collected from twenty-three pigs, initially of 30 kg live weight, and fitted with single Ash re-entrant cannulas in either the duodenum, jejunum or ileum. A further twenty-four pigs were used in a conventional digestibility trial.

2. Three approximately isonitrogenous diets were used; they contained: barley, fine wheat offal, white fish meal, minerals and vitamins (diet BWF), starch, sucrose, maize oil, cellulose, minerals, vitamins and either groundnut (diet SSG) or casein (diet SSC).

3. The flow-rates of nitrogen (N), liquid-fraction N (LN) and non-protein liquid-fraction N (NPLN) were measured hourly in the duodenum and jejunum and every 6 h in the ileum during 24 h collection periods. Faeces were collected during 5 d periods.

4. Marked increases in flow of N, LN and NPLN were seen in the duodenum and jejunum after feeding each diet, but not in the ileum.

5. Values for, N output:intake from the duodenal, jejunal or ideal cannulas and in faeces in 24 h periods were respectively: 0·98, 0·88, 0·25 and 0·21 for diet BWF; 1·00, 0·97, 0·22 and 0·24 for diet SSG; 0·98, 0·73, 0·09 and 0·03 for diet SSC. The corresponding values for LN in the duodenum, jejunum and ileum respectively were: 0·53, 0·53 and 0·12 for diet BWF; 0·46, 0·60 and 0·13 for diet SSG; 0·57, 0·50 and 0·06 for diet SSC. The corresponding values for NPLN in the duodenum, jejunum and ileum respectively were: 0·41, 0·38 and 0·09 for diet BWF; 0·35, 0·36 and 0·08 for diet SSG; 0·46, 0·38 and 0·04 for diet SSC.

6. The results are discussed in relation to similar studies, particularly in pigs with duodenal cannulas, in which widely different observations were made.

Recent studies on the processes of digestion and absorption of nutrients by growing pigs have been reviewed by Low (1976, 1977). Some of these studies have been made to assess the nutritive value of various feedstuffs while others have been concerned with the basic characteristics of digestion, and in particular with the amount of nitrogen (N) passing through the duodenum in 24 h. Sites of digestion and absorption in the small intestine between the proximal duodenum and terminal ileum have been little studied.

The flow of N during 24 h periods in the small and large intestines is described in this paper. The results obtained in the duodenum are compared with other published results. The methods used and the flow and pH of the digesta were described by Braude *et al.* (1976). The flows of dry matter, ash and water in the digesta were reported by Low *et al.* (1978) and the detailed mineral composition was described by Partridge (1978). The amino acid composition of the digesta from these pigs is presented by Low (1979). The flows of carbohydrate and of lipid were described by Sambrook (1978).

EXPERIMENTAL METHODS

Animals. Castrated male Large Whige pigs were used. Single re-entrant cannulas (Ash, 1962) were fitted as follows: (*a*) duodenum, approximately 0·15 m from the pylorus and distal to the bile and pancreatic ducts (twelve pigs); (*b*) jejunum, 2·0–2·5 m from the pylorus (i.e. 13–17% of the distance along the small intestine) (five pigs), or (*c*) the ileum, 0·3 m

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Table 1. *Composition of experimental diets (g/kg diet)*

Ingredients	Diets BWF and BWF_f*	Ingredients	Diet SSG	Diet SSC
Barley meal	713·5	Maize starch	277·0	612·7
Fine wheat offal	200·0	Sucrose	276·9	100·0
White fish meal	70·0	Maize oil	30·0	30·0
NaCl	2·7	Solka Floc‡	20·0	30·0
$CaHPO_4.2H_2O$	5·6	Groundnut meal	350·0	—
$CaCO_3$	6·2	Casein	—	184·0
Vitamin mix no. 1†	2·0	Trace mineral mix§	10·0	10·0
$CuSO_4.5H_2O$	1·0	$CaHPO_4.2H_2O$	17·9	20·6
		$CaCO_3$	4·6	4·6
		Vitamin mix no. 2‖	2·0	2·0
		Choline hydrochloride	1·1	1·1
		NaCl	5·0	5·0
		L-lysine hydrochloride	2·5	—
		DL-methionine	3·0	—

* Diet BWF after milling through a 1 mm mesh; this diet was given to pigs with ileal re-entrant cannulas and to some pigs in the digestibility trial.

† Supplied (/kg diet): 0·75 mg retinol, 7·50 μg cholecalciferol, 3·25 mg riboflavin, 30·00 μg cyanocobalamin, 15·75 mg nicotinic acid, 13·00 mg pantothenic acid, 3·25 mg pyridoxine, 200·00 mg choline chloride, 2·00 mg DL-α-tocopheryl acetate.

‡ Brown & Co., Berlin, New Hampshire, USA.

§ Supplied (/kg diet): 4·47 g K_2CO_3, 1·73 mg $MgCO_3.H_2O$, 0·33 g $FeSO_4.7H_2O$, 60 mg $MnSO_4.H_2O$, 0·10 g $ZnCO_3$, 8·00 mg NaF, 17·50 mg $CuSO_4.5H_2O$, 6·00 mg $CoCl_2$.

‖ Supplied (/kg diet): as vitamin mix no. 1 (omitting choline chloride) and in addition 2·00 mg thiamin, 50·00 μg biotin, 0·50 mg pteroylmonoglutamic acid, 20·00 mg *p*-aminobenzoic acid, 194·00 mg *myo*-inositol, 30·00 mg ascorbic acid, 2·00 mg menaphthone.

from the ileo-caecal junction (i.e. more than 98% of the distance along the small intestine) (six pigs). The initial live weight of the pigs was approximately 30 kg.

A further twenty-four pigs of initial live weight 17–19 kg and without cannulas were used for a conventional digestibility trial.

Housing. Details of the housing and metabolism cage design were as described by Braude *et al.* (1976).

Diets. Diets BWF, SSG and SSC (for details, see Table 1) contained, respectively, 23·7, 24·7 and 24·5 g N/kg diet (average values for the various batches of diets used). Because of previous experience of frequent blockages of ileal re-entrant cannulas after feeding diet BWF (ingredients milled through a 3 mm mesh), this diet was finely-milled through a 1 mm mesh (diet BWF_f); this diet was offered to pigs with re-entrant cannulas and subsequently to six of the pigs without cannulas used in the digestibility trial. The dry diet was mixed with water (1:2·5, w/v) and offered twice daily at 09.00 hours and 15.00 hours. The animals were weighed weekly and fed on a scale based on their live weight (Barber *et al.* 1972). On this scale pigs of 20 kg live weight received 1·05 kg air-dry diet/d; the amount increased linearly to 2·40 kg at 60 kg live weight. The cannulated pigs received each diet for approximately 14 d (including a 5 d change-over period between diets). The pigs without cannulas received one diet throughout.

Cannula design, surgery and digesta and faeces-collection procedures

These were as described by Braude *et al.* (1976).

Sample preparation. During 24 h collections 5% of the digesta collected from pigs with duodenal or jejunal cannulas was removed every hour and accumulated in a bottle kept at 1° to provide a single sample representative of the flow in 24 h. Every 6 h 20% of the digesta collected from pigs with ileal cannulas was similarly pooled. Samples were taken from these pooled samples for N analysis immediately after the end of each 24 h collection. In addition, hourly samples were taken from the last six pigs with duodenal cannulas and all the pigs with jejunal cannulas; samples were also taken every 6 h from all pigs with ileal cannulas; all of these samples were analysed immediately for N.

In order to obtain a picture of the distribution of N in the solid and liquid phases, digesta samples were separated by centrifugation ('Minor' centrifuge; MSE Ltd, Crawley, Sussex) at 2500*g* for 15 min. The supernatant fraction was decanted, its volume was measured, and duplicate samples were then taken for N analysis; this was called the liquid-fraction N (LN). Duplicate 2 ml samples of the supernatant fraction were mixed with an equal volume of trichloroacetic acid (200 g/l) in 15 ml centrifuge-tubes and allowed to stand overnight at 4° in order to allow complete precipitation of the protein in the LN fraction. The tubes were then spun at 2500*g* for 15 min and then 2 ml of the supernatant fraction was analysed for N; this was called the non-protein liquid-fraction N (NPLN). Gel filtration of the NPLN showed that the maximum molecular weight of the N-containing compounds was below 500 (i.e. mainly tri- and dipeptides and free amino acids in a state ready for absorption).

Analysis. Samples of whole digesta and faeces were digested by the Kjeldahl method in 250 ml flasks. Samples of the LN and NPLN fractions were digested by the Kjeldahl method in 25 ml tubes. The catalyst was applied in tablet form ('Kjeltab SM', each tablet containing 1·20 g potassium sulphate and 0·50 g mercuric oxide; Thompson and Capper Ltd, Liverpool). After digestion the samples were analysed automatically (Technicon AutoAnalyser, Technicon Instruments Ltd, Basingstoke, Hants).

PRESENTATION AND STATISTICAL ANALYSIS OF RESULTS

The amounts of N, LN and NPLN have been expressed as weight collected in a specified time: weight of N in diet eaten in 24 h (output: intake).

To aid interpretation of the results Table 4 shows the weights of N eaten and outputs in 24 h for a 40 kg pig receiving 1·70 kg air-dry diet and 4·25 l water/24 h. The average weight of the cannulated pigs and those used in the digestibility trial was 40 kg.

Flow pattern during 24 h periods. The mean values for N flow in digesta were calculated from the average values for all 24 h collections completed by each pig on a diet. For pigs with duodenal and jejunal cannulas the mean values are for each hour of the 24 h collection periods and for those with ileal cannulas are for the four successive 6 h periods of the 24 h collection periods. Hourly measurements of N flow were not made in the first six pigs with duodenal cannulas.

Total flow in 24 h periods. The average output: intake values for the whole of each 24 h collection period for each pig on a diet were subjected to analysis of variance. The average values for the four faeces collection periods from each of the pigs without cannulas were similarly treated.

The standard error of the difference between the means was not the same for each pair of cannula sites or for each pair of diets because different numbers of animals completed collections for the various site-diet combinations. The least and greatest values for standard error of difference are given in Tables 2 and 3. The statistical methods used in these studies were described in more detail by Braude *et al.* (1976).

RESULTS

During the course of this study a total of thirty-five pigs were fitted with re-entrant cannulas. However, because of a variety of difficulties in maintaining pigs with re-entrant cannulas, satisfactory results were obtained from only twenty-three of these pigs. A detailed

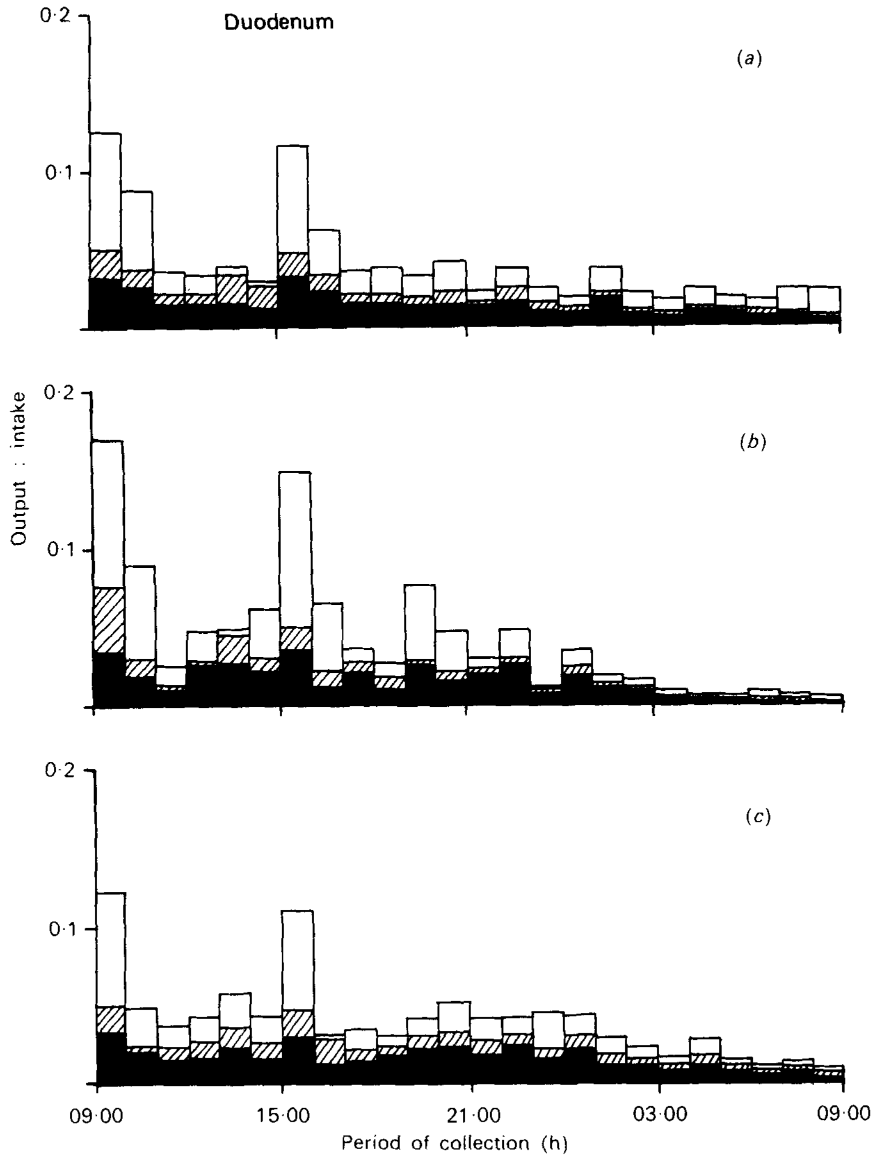

Fig. 1. Mean hourly flow in the duodenum of nitrogen (N) (□), liquid-fraction N (LN) (▨) and non-protein liquid-fraction N (NPLN) (■) (output:N intake) in the duodenum of pigs fitted with re-entrant cannulas, and given successively diets BWF(*a*), SSG(*b*) and SSC(*c*) (for details, see Table 1) with six, two and six pigs completing collections respectively. Pigs were fed at 09.00 hours and 15.00 hours.

account of the reasons for the unbalanced numbers of pigs used for the various site and diet combinations was given by Braude *et al.* (1976). The small number of pigs completing collections on diet SSG in the ileum should be noted.

24 *h patterns of flow*. The mean hourly flow patterns of N in the duodenum and jejunum are shown in Figs. 1 and 2. For each diet the highest flow rates were observed immediately after feeding at the duodenal and jejunal cannula sites; in general the flow-rate dropped

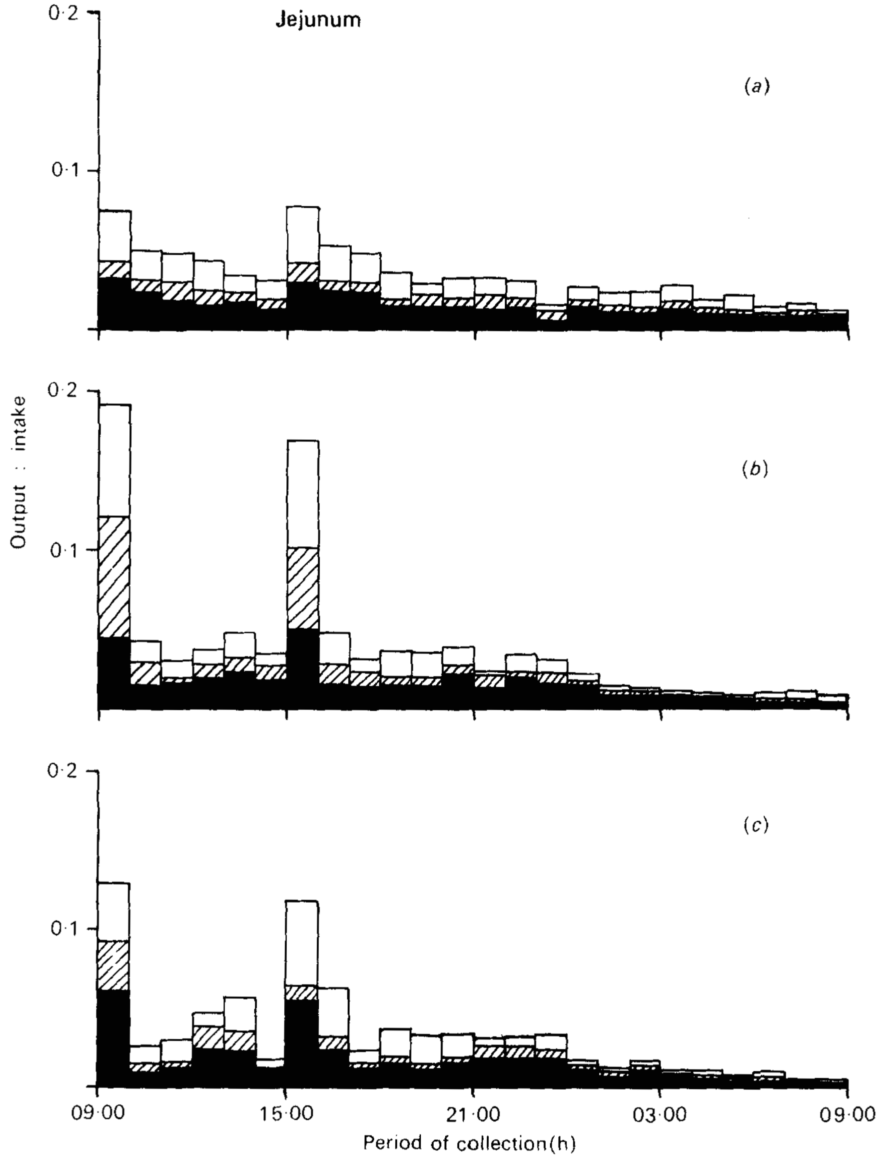

Fig. 2. Mean hourly flow in the jejunum of nitrogen (N) (□), liquid-fraction N (LN) (▨) and non-protein liquid-fraction N (NPLN) (■) (output:N intake) in the jejunum of pigs fitted with re-entrant cannulas, and given successively diets BWF(*a*), SSG(*b*) and SSC(*c*) (for details, see Table 1) with six, two and six pigs completing collections respectively. Pigs were fed at 09.00 hours and 15.00 hours.

with increasing period of time after feeding. Some flow of N, LN and NPLN occurred in every hour of 24 h periods. In general the flow of N in the duodenum was more uniform for diet BWF than for the other diets. More than half the N in the duodenum was in the LN fraction and more than half the LN was NPLN in form, except immediately after feeding. In the jejunum LN always formed 50–75 % of the N and usually more than half of this was NPLN in form. For diets SSG and SSC, LN and NPLN tended to form a larger proportion of N with increasing period of time after feeding, particularly when the flow-rate was low.

The mean six-hourly flow patterns of N in the ileum are shown in Fig. 3. At least half

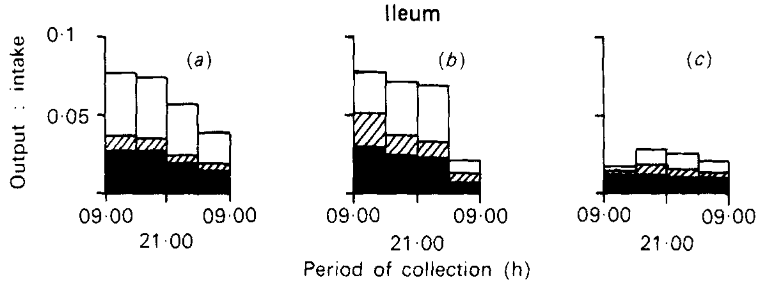

Fig. 3. Mean six-hourly flow in the ileum of nitrogen (N) (□), liquid-fraction N (LN) (▨) and non-protein liquid-fraction N (NPLN) (■) (output:N intake) in the ileum of pigs fitted with re-entrant cannulas, and given successively diets BWF_f(*a*), SSG(*b*) and SSC(*c*) (for details, see Table 1) with five, two and six pigs completing collections respectively. Pigs were fed at 09.00 hours and 15.00 hours.

Table 2. *Mean 24 h output: intake values for Nitrogen in whole digesta (N), the liquid fraction of digesta (LN) and the non-protein liquid fraction of digesta (NPLN) from pigs with intestinal cannulas at one of three sites*

(No. of pigs completing collections in parentheses. N, LN and NPLN values were analysed separately for between-site and between-diet differences)

Site of re-entrant cannula*	Digesta fraction	Diet BWF†	Diet SSG	Diet SSC
Duodenum	N	0·98 (12)	1·00 (8)	0·98 (6)
	LN	0·53	0·46	0·57
	NPLN	0·41	0·35	0·46
Jejunum	N	0·88 (5)	0·97 (5)	0·73 (4)
	LN	0·53	0·60	0·50
	NPLN	0·38	0·36	0·38
Ileum	N	0·25 (5)	0·22 (2)	0·09 (6)
	LN	0·12	0·13	0·06
	NPLN	0·09	0·08	0·04

SE of difference between site means (range): N 0·063–0·099 LN 0·049–0·077 NPLN 0·043–0·068.
SE of difference between diet means (range): N 0·022–0·050 LN 0·014–0·055 NPLN 0·011–0·047.
* For details of sites, see p. 137.
† Diet BWF was finely-milled (diet BWF_f) when fed to pigs with ileal cannulas; for details of diets, see Table 1.

the N in the digesta from diet BWF_f was in the solid fraction, and NPLN formed most of the LN. A greater proportion of the N in the digesta was LN for diets SSG and SSC than for diet BWF_f.

Between-diet comparisons of total flow in 24 h. The mean 24 h output: intake values for N, LN and NPLN are shown in Table 2. The values for N flow were similar for each diet, but the values for LN and NPLN were lower for diet SSG than for the other diets: however this difference was only significant ($P < 0·05$) for NPLN. In the jejunum there were larger differences for N flow than in the duodenum: the value for diet SSC was significantly lower ($P < 0·05$) than for the other diets. The mean values for LN were lower for diets BWF and SSC than for diet SSG but the difference was not significant. In the ileum there was significantly ($P < 0·01$) less N, LN and NPLN for diet SSC than for the other diets. The results in the ileum for each fraction were similar for diets BWF_f and SSG. In the faeces there was significantly ($P < 0·05$) less N for diet BWF_f than for BWF, indicating that fine milling influences the over-all digestion of N in this diet. In view of this, comparisons between the duodenum or jejunum and the ileum for diets BWF and BWF_f must be made with caution.

Table 3. *Mean 24 h output:intake of nitrogen in faeces of pigs without cannulas, given diets BWF, BWF_f, SSG and SSC**

(Mean values for 6 pigs/diet)

Diet BWF	Diet BWF_f	Diet SSG	Diet SSC
0·26	0·21	0·24	0·03

SE of difference between diet means 0·012.
SE of difference between means for ileal digesta (for diets BWF_f, SSG and SSC) (see Table 2) and faeces: lowest value 0·017, highest value 0·024.
* For details of diets, see Table 1.

Table 4. *Daily intakes (g) of nitrogen (N), and amounts in digesta and faeces (N), the liquid fraction of digesta (LN) and non-protein liquid fraction of digesta (NPLN) collected during 24 h periods calculated for a pig of 40 kg live weight given 1·7 kg air-dry diet and 4·25 l water/d**

	Diet BWF or BWF_f†			Diet SSG			Diet SSC		
	N	LN	NPLN	N	LN	NPLN	N	LN	NPLN
Diet	40·3	—	—	42·0	—	—	41·6	—	—
Duodenum	39·5	21·4	16·9	42·0	19·3	14·7	40·8	23·7	19·2
Jejunum	35·5	21·4	15·3	40·7	25·2	15·1	30·4	20·8	15·8
Ileum	10·1†	4·8†	3·6†	9·2	5·4	3·3	3·7	2·5	1·6
Faeces	10·5	—	—	10·1	—	—	1·2	—	—
	8·5†	—	—	—	—	—	—	—	—

* For details of diets, see Table 1.
† Diet BWF was normally-milled when fed to pigs with duodenal and jejunal cannulas but was finely-milled (diet BWF_f) when fed to pigs with ileal cannulas. Both versions of this diet were compared in the digestibility trial.

Between-site comparison of total flow in 24 h. Although there were lower flows in the jejunum than in the duodenum for each of the diets and for the N, LN and NPLN fractions, these were only significant in the instance of N for diet SSC ($P < 0·01$) and LN for diet SSG ($P < 0·05$). Major absorption of N, LN and NPLN occurred between the jejunum and the ileum: this was significant ($P < 0·001$) for all diets. The extent of N absorption during transit through the large intestine was small and was significant ($P < 0·01$) only for diet SSC (two-thirds of the N entering the large intestine for this diet was absorbed in this region).

The amounts of N apparently absorbed in the first 15% of the small intestine were 14, 4 and 28% for diets BWF, SSG and SSC, respectively, indicating that casein was the most rapidly digested and absorbed of the dietary N sources studied. Between the jejunum and ileum casein was again more completely apparently absorbed than the cereal and fish proteins in diet BWF or the groundnut protein in diet SSG. Differences between the protein sources were evident in the ileum where 52, 41 and 33% of the N remained in the solid (i.e. undigested) fraction of digesta for diets BWF_f, SSG and SSC, respectively.

DISCUSSION

For each diet and at each intestinal site the pattern of N flow during 24 h collection periods was similar to that for dry matter during the same collections (Low *et al.* 1978); the similarity between dry matter and N flow has also been noted by Kvasnitskii (1951), Horszczaruk (1971*b*), Zebrowska & Buraczewska (1972) and Ivan & Farrell (1976) in pigs with duodenal re-entrant cannulas fed on a wide range of different diets.

It is of interest to note that the mean output:intake values of dry matter for diets SSG and SSC (Low *et al.* 1978) were 25% and 14% higher respectively than those for N in the duodenum in the first hour after the morning feed, whereas the output:intake values for dry matter and for N were similar for diet BWF. Diets SSG and SSC contained 280 and 100 g/kg sucrose respectively and this may have left the stomach faster than the dietary protein: such an effect was seen by Peraino *et al.* (1959) when rats were given casein with sucrose, but when glucose was substituted for sucrose the emptying rates of casein and glucose were similar.

The observation that more than half the N from diets BWF and SSC in the duodenum was in the LN fraction except immediately after feeding corresponds with the results of Ivan & Farrell (1976) for the digestion of hard and soft wheats.

The total flows of N in 24 h in the duodenum are of interest because the output:intake values did not exceed 1·0 although the digesta at this site contained endogenous N from saliva, gastric juice, intestinal juice, bile, pancreatic juice and shed epithelial cells. These results suggest that the secretion of endogenous N was balanced by N absorption in the stomach and proximal duodenum (N absorption has not been demonstrated in the stomach of the pig, however). When these results are compared with values in similar studies reported in the literature a confusing picture emerges, as Table 5 shows. Low & Zebrowska (1977) attempted to explain why such variable values were found; they concluded that the site of the cannulas in the duodenum or the nature of the diet were of little importance but that the method of collection of digesta was a major influence on the results. However, this does not appear completely to explain the differences summarized in Table 5 since all studies except Low & Zebrowska (1977) used manual digesta collection. The studies of Holmes *et al.* (1974), Ivan & Farrell (1976) and Low & Zebrowska (1977) were made using pigs with re-entrant cannulas in the proximal duodenum (less than 150 mm from the stomach), while in the other studies the pigs had cannulas in more distal parts of the duodenum. The pigs used by Holmes *et al.* (1974) had cannulas sited cranial to the pancreatic duct opening into the duodenum so the digesta passing the cannulas did not contain N from the pancreas. It is possible that cannula site, diet, collection method and age of pig may all have an influence on N flow in the duodenum. A noticeable feature of the studies listed in Table 5 is the small number of animals used: in view of the considerable between-pig and within-pig variability that is found in measurements of N in the duodenum caution must be exercised in interpretation of many of the results shown.

It is difficult to estimate the amounts of endogenous N entering the duodenum of growing pigs: no estimates are available of the amounts of N from saliva, the oesophagus or the stomach. It has been estimated (I. E. Sambrook, personal communication) that approximately 2 g N/d were secreted in bile while Corring & Jung (1972) and Corring (1975) found that the pancreas secreted 3–4 g N/d (in both instances pigs of 35–40 kg were used). Furthermore, there are no estimates available of the amounts of mucosal cells in duodenal digesta. The amount of endogenous N in the duodenum has been estimated (in 40–50 kg pigs with re-entrant cannulas given protein-free diets) to be 5–7 g/d (Zebrowska *et al.* 1975; Low & Zebrowska, unpublished results). Whether this represents the amounts of endogenous N in the duodenum when pigs are fed on diets of normal protein composition is unclear. N is secreted by the wall of the small intestine throughout its length. The only estimates of the amount of N secreted have been made by Horszczaruk *et al.* (1974) in three pigs with isolated loops of small intestine 2·25–2·90 m long. These authors estimated that the N secretion could vary between 10 and 22 g/d depending on whether the juice was allowed to drain out of the loop freely or whether it was washed out, assuming that secretion occurred uniformly throughout the small intestine.

Table 5. *Summary from the literature of 24 h output:intake values of N in the duodenum of growing pigs with re-entrant cannulas*

Main protein source	N intake (g/24 h)	No. of pigs	Wt of pigs (kg)	Output: intake	Authors
Yeast, skim milk, fish meal, lucerne (*Medicago sativa*)	69·04	2	50	1·07	Horszczaruk (1971*b*)
Casein	56·6	2	50	1·10	Zebrowska & Buraczewska (1972)
Gluten	52·8	3	60	1·04	Zebrowska (1973*a*)
Unheated soya-bean	56·8	3	60	1·13	
Heated soya-bean	58·4	3	60	1·19	
Horse bean (*Vicia faba*)	52·2	3	60	1·10	
Barley	35·1	3	60	1·25	
Maize					
Dry	22·2	4	30	0·92	† Holmes, Bayley & Horney (1974)
Ensiled	22·6	4	30	0·90	
+Acetate	22·0	4	30	0·82	
+Propionate	22·0	4	30	0·81	
Maize, barley, soya-bean, fish meal	35·0	2	30	1·19	Cuperlovic, Hristic & Zebrowska (1975)
Maize, barley, soya-bean, sunflower oil +1·26 g lysine/kg	35·3	2	30	1·01	
Maize, barley, soya-bean, sunflower oil +3·8 g lysine/kg	32·1	2	30	1·06	
Casein	27·4	4	35	0·97	Ivan & Farrell (1976)
Hard wheat	27·1	4	35	0·96	
Soft wheat	25·5	4	35	0·94	
Barley, weatings, fish meal	38·4	4	40	1·15	Low & Zebrowska (1977)
Barley, weatings, fish meal	38·4	4	40	1·00*	
Barley, weatings, fish meal	40·3	12	40	0·98*	Present study
Groundnut	42·0	8	40	1·00*	
Casein	41·6	6	40	0·98*	

* Automatic digesta collection method.
† Cannula cranial to pancreatic duct.

The amounts of N flow in the ileum for diet SSC compare well with values published by Ivan & Farrell (1976) for a diet of similar composition. No information is available in the literature for comparison with diets BWF_f and SSG. The amount of endogenous N passing the terminal ileum in 24 h has been estimated to be 3 g in 60 kg pigs (Zebrowska *et al.* 1975).

The amounts of N apparently absorbed during passage through the large intestine were small in this study, but Livingstone *et al.* (1977) found that more than half the total apparent absorption of N occurred in the large intestine when pigs were given raw-potato diets. It has been shown that N (in the form of amino acids) infused into the terminal ileum is absorbed in the large intestine, and rapidly excreted into the urine (Zebrowska, 1973*b*). This suggests that the N absorbed in the large intestine is not amino acid in form and is of little nutritional value; it is likely that the amino acids are metabolized by the microflora before absorption occurs. Because of the unknown extent of the activity of the microflora of the large intestine it is currently thought that the most valid measurements of the apparent absorption of nutritionally-useful N are made in ileal digesta rather than in faeces (Payne *et al.* 1968).

The results presented in this paper contrast sharply with those of Dreibach & Nasset (1954) and Nasset & Ju (1961) who found that the N from dietary casein was diluted four times by endogenous secretions of N in the intestines of the dog and seven times in the rat (the measurements were made after slaughter). These results led Nasset (1964) to propose that this apparently massive secretion of endogenous N was a mechanism for maintaining homoeostasis of the gut N pool. Gitler (1964) suggested that Nasset's (1964) resultscould have been due to almost complete digestion and absorption of dietary N, but limited digestion of endogenous N. An alternative explanation of Nasset's (1964) results comes from studies in the sheep (Badawy *et al.* 1957) and indirectly in the pig (Horszczaruk, 1971 *a*) which showed that slaughter is accompanied by major shedding of the mucosal lining of the gut, thus making valid estimates of the progress of digestion and absorption of dietary N impossible.

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REFERENCES

Ash, R. W. (1962). *Anim. Prod.* **4**, 309.
Badawy, A. M., Campbell, R. M., Cuthbertson, D. P. & Fell, B. F. (1957). *Nature, Lond.* **180**, 756.
Barber, R. S., Braude, R., Mitchell, K. G. & Pittman, R. J. (1972). *Anim. Prod.* **14**, 199.
Braude, R., Fulford, R. J. & Low, A. G. (1976). *Br. J. Nutr.* **36**, 497.
Corring, T. (1975). *Annls Biol. anim. Biochim. Biophys.* **15**, 115.
Corring, T. & Jung, J. (1972). *Nutr. Rep. int.* **6**, 187.
Cuperlovic, M., Hristic, V. & Zebrowska, T. (1975). *Acta vet. Beogr.* **25**, 287.
Dreibach, K. & Nasset, E. S. (1954). *J. Nutr.* **53**, 523.
Gitler, C. (1964). In *Mammalian Protein Metabolism*, vol. 1, p. 35. [H. N. Munro and J. B. Allison, editors]. New York: Academic Press.
Holmes, J. H .G., Bayley, H. S. & Horney, F. D. (1974). *Br. J. Nutr.* **32**, 639.
Horszczaruk, F. (1971 *a*). *Biul. Inst. Genet. Hodow. Zwierz. pol. Akad. Nauk* no. 21, p. 117.
Horszczaruk, F. (1971 *b*). *Biul. Inst. Genet. Hodow. Zwierz. pol. Akad. Nauk* no. 21, p. 137.
Horszczaruk, F., Buraczewska, L. & Buraczewski, S. (1974). *Roczn. Nauk roln.* Ser. B **95**, (4), 69.
Ivan, M. & Farrell, D. J. (1976). *Can. J. Physiol. Pharmac.* **54**, 891.
Kvasnitskii, A. V. (1951). *Voprosȳ fiziologii pishchevarenija u svinei.* (Translated by D. E. Kidder). Moscow: Sel'Khozgiz.
Livingstone, R. M., Atkinson, T., Baird, B. & Crofts, R. M. J. (1977). *Proc. Nutr. Soc.* **36**, 58A.
Low, A. G. (1976). *Proc. Nutr. Soc.* **35**, 57.
Low, A. G. (1977). *Proc. Nutr. Soc.* **36**, 189.
Low, A. G. (1979). *Br. J. Nutr.* **41**, 147.
Low, A. G., Partridge, I. G. & Sambrook, I. E. (1978). *Br. J. Nutr.* **39**, 515.
Low, A. G. & Zebrowska, T. (1977). *Br. J. Nutr.* **38**, 145.
Nasset, E. S. (1964). In *The Role of the Gastrointestinal Tract in Protein Metabolism*, p. 83. [H. N. Munro, editor]. Oxford: Blackwell Scientific Publications.
Nasset, E. S. & Ju, J. S. (1961). *J. Nutr.* **74**, 461.
Partridge, I. G. (1978). *Br. J. Nutr.* **39**, 527.
Payne, W. L., Combs, G. F., Kifer, R. R. & Snyder, D. G. (1968). *Fedn Proc. Fedn Am. Socs exp. Biol.* **27**, 1199.
Peraino, C., Rogers, Q. R., Yoshida, M., Chen, M. L. & Harper, A. E. (1959). *Can. J. Biochem. Physiol.* **37**, 1475.
Sambrook, I. E. (1978). Studies on the digestion and absorption of carbohydrate and fat, and on the flow and composition of bile in the growing pig. PhD Thesis, University of Reading.
Zebrowska, T. (1973 *a*). *Roczn. Nauk roln.* Ser. B **95**, (1), 115.
Zebrowska, T. (1973 *b*). *Roczn. Nauk roln.* Ser. B **95**, (3), 85.
Zebrowska, T. & Buraczewska, L. (1972). *Roczn. Nauk roln.* Ser. B **94**, (1), 81.
Zebrowska, T., Buraczewska, L., Buraczewski, S. & Horszczaruk, F. (1975). *Roczn. Nauk roln.* Ser. B **96**, (3), 79.

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