DIGESTION IN THE PIG

INTRODUCTION

JANE LEIBHOLZ*

A knowledge of the sites of digestion and extent of digestion of nutrients is essential for the formulation of diets to meet the requirements of pigs. This is of particular importance for young pigs, where there is rapid gastrointestinal development, but it must be taken into consideration in formulating diets from birth, through pregnancy and lactation. The following four papers discuss the development of the digestive system and digestibility, with particular emphasis on proteins.

GASTRIC DIGESTION IN THE YOUNG PIG

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A knowledge of gastrointestinal development and its regulation is essential for successful formulation of diets for young pigs. Protein digestion commences in the stomach by the action of HCl which both activates the proteolytic enzymes and denatures the ingested proteins, rendering their internal peptide bonds more accessible to enzymatic hydrolysis. Thus, the rate at which the capacity of the stomach to secrete HCl and proteolytic enzymes develops could well impose limitations on the type and amount of protein which can be fed to young pigs. The physiology of gastric function in the pig has been reviewed by Kidder and Manners (1978), Titchen et al. (1980), Corring (1982), Laplace (1982) and Simoes-Nunes (1982). It is the purpose of this section to examine more recent information, particularly that dealing with quantitative aspects and to present some previously unpublished data.

(i) <u>Stomach size</u> Data on the size (weight) of the stomach in young pigs indicate, that there is a positive linear relationship between stomach weight and liveweight (Hartman et al. 1961; Braude 1981; Cranwell and Stuart 1983). The data of Hartman et al. (1961) showed that pigs weaned onto dry diets at one week of age had higher stomach weight to liveweight ratios than sucking pigs. More recent data, presented in Table 1, indicates that both diet and age have significant effects on the relative size of the stomach.

TABLE 1 The stomach weight to liveweight ratio in pigs either reared solely by the sow and with no access to solid food (milk-fed, M) or reared by the sow until weaning at three to four weeks and given access to solid food at two weeks (creep-fed, C)

Age (d)		1 - 14[+θφ]		15 - 28[+θφ]		29 - 42[θφ]	
Liveweight (kg)		1.0 - 5.6		5.3 - 11.6		6.2 - 14.30	
Stomach weight (g)		5 - 27		24 - 54		36 - 89	
		Mean	SE	Mean	SE	Mean	SE
Stomach weight: liveweight (g/kg)	M	5.33	0.16(26)[§]	4.55	0.08(12)	4.91	0.21(15)
	C	-	-	4.94	0.18(19)	6.71	0.15(21)

§ Number of pigs in parenthesis
+ Noakes (1972), θ Cranwell (1977), φ Cranwell (unpublished).

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(ii) HCl secretion Many of the studies on the development of the porcine stomach reviewed by Cranwell et al. (1976), Kidder and Manners (1978) and Simoes-Nunes (1982) indicated that acid secretion was not well developed until the pigs were two to four weeks old. The failure by some of the earlier workers to detect free HCl in stomach contents may have been due to the buffering properties of milk, saliva, gastric mucus, and regurgitated bile and pancreatic juice, and not necessarily to the absence of acid secretion. Conversely, evidence of marked acidity, based on pH measurements, may have reflected the presence of organic acids produced by gastric fermentation rather than HCl secretion. It is also possible that the presence of large amounts of lactic acid in the stomach may partly or completely inhibit HCl secretion (Cranwell et al. 1976).

That the stomach of the newborn pig is capable of secreting HCl has been demonstrated by Forte et al. (1975) using an in vitro technique and by Cranwell et al. (1976), Cranwell and Titchen (1974) and Titchen et al. (1980), using three different in vivo techniques. However, the acid secretory capacity of the stomach of the newborn pig is significantly lower than that of older pigs (Table 2). During the first six weeks of life, liveweight and change of diet from sow's milk to solid food, have significant positive effects on acid secretory capacity (Cranwell and Stuart 1984; Table 2).

TABLE 2 Maximal acid output in response to Histalog infusion[Θϕ] (3 mg/kg/h, IV) or Histalog injection (3 mg/kg/15 min, IM) in pigs either reared solely by the sow and with no access to solid food (milk-fed, M) or reared by the sow until weaning at three weeks and given access to solid food at 12 and 14 d (creep-fed, C)

Age (d)		< 1[+]		4 - 14[Θϕ]		18 - 22[Θϕ]		25 - 42[Θϕ]	
Liveweight (kg)		1.0 - 1.6		1.8 - 4.3		4.0 - 7.3		6.2 - 12.9	
No. of pigs/ treatment		8		14		9		18	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acid output	M	0.56	0.07	2.84	0.34	3.35	0.69	5.93	0.90
(mmol H^+/h)	C	-	-	-	-	5.91	0.70	9.84	0.97
Liveweight	M	0.41	0.05	0.92	0.05	0.55	0.11	0.58	0.07
(mmol H^+/kg/h)	C	-	-	-	-	1.02	0.09	1.06	0.09

[+]Cranwell and Tudor (unpublished), 'Cranwell (1977), [ϕ]Cranwell (unpublished).

(iii) Proteolytic enzymes The two major proteolytic enzymes secreted by the stomach of the young pig are chymosin (rennin, EC3.4.23.4) and pepsin A (EC3.4.23.1) (Foltmann 1981a). Pepsin C (gastricsin, EC3.4.23.3) is also present but information about its importance is limited (Foltmann et al. 1981).

Prochymosin has been found in the gastric mucosa of the pig; its period of highest concentration is during the prenatal period and up to the end of the first week after birth (Foltmann et al. 1981). The properties of pig chymosin have been reported by Foltmann et al. (1978), Foltmann and Axelsen (1980), Foltmann et al. (1981) and Foltmann (1981a,b). Pig chymosin is closely related to calf chymosin in immunological and enzymatic properties; it is primarily a milk clotting enzyme with limited proteolytic activity. Prochymosin requires only hydrogen ions to initiate the formation of fully active chymosin and this can occur at pH<5.5. Chymosin has a milk clotting activity to general proteolytic activity ratio that is more than ten times greater than pig pepsin. The proteolytic activity of pig chymosin at pH 3.5 is only about 2% of that of pig pepsin at pH2.0. Although similar to calf chymosin, pig chymosin has a much higher clotting activity against porcine milk than bovine milk as does pig pepsin.

The study of the development of pepsin secretion in the newborn pig has been mainly confined to determinations of the proteolytic activity of extracts of gastric mucosa and gastric contents (Hartman et al. 1961; Decuypere et al. 1978) and to studies on secretion from separated Heidenhein gastric pouches (Cranwell and Titchen 1976). The results of these studies indicate that the mucosa, gastric contents and pure gastric juice of the newborn pig contain little or no proteolytic activity and that the amount of proteolytic activity in the mucosa and its concentration in gastric juice increases with age with a dramatic increase occurring three to four weeks after birth. Foltmann et al. (1978, 1981), using immunological techniques, have confirmed these earlier observations.

Studies on the effect of diet on the development of proteolytic enzyme secretion (Hartman et al. 1961; Decuypere et al. 1978) indicate that following a change of diet from sow's milk to solid food there is a significant increase in the concentration of pepsin in the mucosa and gastric contents. More recent evidence, presented in Table 3, confirms that both age and diet have significant effects on the capacity of the stomach to secrete proteolytic enzymes. Proteolytic activity found in the gastric secretion from pigs up to two weeks old is probably due to chymosin and/or gastricsin rather than pepsin (Foltmann 1981b).

TABLE 3 Maximal proteolytic enzyme output (expressed as units of activity at pH 2.0) in response to Histalog infusion$^{\Theta\phi}$ (3 mg/kg/h, IV) or Histalog injection^{+} (3 mg/kg/15 min, IM) in pigs either reared solely by the sow and with no access to solid food (milk-fed, M) or reared by the sow until weaning at 3 weeks and given access to solid food at 12 to 14 d (creep-fed, C)

Age (d)		< 1^{+}		4 - 14$^{\Theta\phi}$		18 - 22$^{\Theta\phi}$		25 - 42$^{\Theta\phi}$	
Liveweight (kg)		1.0 - 1.6		1.8 - 4.3		4.0 - 7.3		6.2 - 12.9	
No. of pigs/ treatment		8		14		9		17	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Proteolytic enzyme output (k units/h)	M	0.4	0.08	1.85	0.28	4.44	0.92	13.12	3.18
	C	-	-	-	-	12.42	1.89	45.40	6.04
(k units/kg LW/h)	M	0.31	0.06	0.75	0.18	0.74	0.14	1.74	0.23
	C	-	-	-	-	2.18	0.33	4.88	0.64

$^{\Theta}$Cranwell (1977), $^{+\phi}$Cranwell (unpublished).

Species such as the pig and ruminants, in which the presence of chymosin-like enzymes have been demonstrated (Foltmann 1981b), also have postnatal uptake of immunoglobulins (Porter 1976). Pig pepsin A can cleave and digest that part of IgG which is necessary for its uptake in the gut (Foltmann and Axelsen 1980). This means that a large amount of pepsin in the gastric juice of the neonatal pig would be detrimental for the uptake of immunoglobulins. Evidence about the proteolytic action of pig chymosin on porcine immunoglobulins is not available, however the preliminary evidence of Foltmann (1981b) suggests that the degradation of bovine colostral IgG by calf chymosin is minimal. Foltmann (1981b) hypothesizes that during the evolution of mammals the chymosins have been adapted as proteases with great milk-clotting activity but with such a weak general proteolytic activity that extensive damage of the immunoglobulins does not occur. That the gastric acid secretory capacity of the neonatal pig is significantly lower than that of older pigs (Table 2) could also be related to this hypothesis.

(iv) Hormones and gastric development The evidence presented here and by Cranwell and Stuart (1984) indicatesthat pigs fed on solid food have larger stomachs, a greater amount of acid and proteolytic enzyme secretory tissue (fundic mucosa) and greater acid and proteolytic enzyme secretory capacities than pigs fed on sow's milk. The different rates of gastric development in pigs fed sow's milk and those fed solid food are probably related to a number of factors. These include differences in the physical and chemical nature of the diets, changes in the patterns of feeding and gastric emptying, and the effect of weaning. How important each of these factors is in gastric development is as yet unknown.

A humoral agent may be involved in the development of the pig stomach since acid and proteolytic enzyme secretion from isolated, denervated, fundic pouches increased during the first six weeks of life (Cranwell and Titchen 1976). Cranwell and Hansky (1980) have found that basal serum gastrin levels are higher in both weaned and sucking pigs than in adult animals and that the postprandial response to intake of food is greater in pigs fed solid food than in those suckled by the sow. Gastrin is a trophic hormone for the fundic mucosa (particularly for the parietal or acid secreting cells) in adult animals (Johnson 1981) and could therefore be acting in this way in young developing pigs.

Other hormones implicated in the development of the stomach are ACTH and corticosteroids which cause an increase in the proteolytic enzyme content of the gastric mucosa in rats and mice (Henning 1981). Weaning can be a time of stress for the pig and can cause prolonged rises in plasma cortisol concentrations (Hennessy and Cranwell unpublished).

In conclusion it should be pointed out that gastrin and the corticosteroids are probably not the only hormones or agents involved in the maturation of the gastric mucosa. There are a number of reports implicating thyroxine as a permissive hormone in the development of gastrointestinal enzyme activity (Kumegawa et al. 1980; Henning 1981; Baintner and Nemeth 1982) and epidermal growth factor is a potent trophic hormone for the fundic mucosa (Johnson 1981).

DIGESTION OF PROTEIN BY THE YOUNG PIG

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Artificial rearing of pigs from two days of age has been successful on diets of cow's milk in the liquid form (Braude et al. 1970), but dry pelleted diets eliminate the need for liquid feeding equipment and reduce the incidence of diarrhoea. Wilson and Leibholz (1979) found that pigs could be reared on dry diets from four days of age with weight gains of 250 g/day and feed conversion ratios of 0.78 between four and 28 days of age. These diets contained milk proteins, and it was found that maximum performance of pigs occurred with diets containing at least 270 g crude protein/kg of diet.

Various protein sources such as fish meal, soya-bean meal and peanut meal have been evaluated as complete or partial replacements of milk protein in liquid and solid diets for young pigs (e.g. Maner et al. 1961; Mateo and Veum 1980; Wilson and Leibholz 1981; Leibholz 1982). In general the performance of pigs given milk protein is superior to that of pigs given other sources of protein. This rnay be related to differences in the rate of digestion and absorption of these proteins.

The digestion of protein begins in the stomach. In 60 kg pigs about 85% of the dietary protein is hydrolysed by the duodenum (Zebrowska 1973) and probably due to the action of pepsin in the stomach (Table 1). However, the young pig, at birth,

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has a limited capacity for the secretion of pepsin and acid, but this increases with age (Cranwell and Titchen 1976). In the 28 day old pig the pH of the stomach contents is 5.3-5.5, and there is little gastric hydrolysis of protein (Table 1). By 56 days of age gastric pH has decreased to about 4, and about 50% of dietary protein is hydrolysed in the stomach while more than 80% of dietary protein is hydrolysed in growing pigs when gastric pH is l-3. The optimum pH for the conversion of pepsigen to the active pepsin is 2 (Ryle 1960).

TABLE 1 Effect of age and protein concentrate on the pH of stomach contents and gastric digestion

Age of pigs (days)	Protein concentrate	Stomach pH	Hydrolysis of dietary protein in stomach (%)	Reference
28	Milk	5.3	6	Leibholz (1981)
	Soya	5.5	2	
56	Milk	3.8	53	Leibholz (1983)
	Soya	3.9	35	
120	Soya	2.2	-	Lawrence (1970)
150	Casein		88	Zebrowska (1973)
	Soya		84	

Gastric hydrolysis of milk proteins is greater than that of soya proteins at all ages. However, the difference between the two proteins is greater in the younger pigs (Table 1). Thus, the major site of hydrolysis of dietary protein in young pigs is not the stomach, but the duodenum and jejunum (Table 2). It would appear that at least half of this hydrolysis is due to the action of proteolytic enzymes secreted by the pancreas in 28 day old pigs but pancreatic enzymes are of less importance in older animals (Pekas et al. 1964). It is unlikely that the poorer performance of pigs given soya-bean proteins than those given milk proteins is due to a deficiency of proteolytic enzymes as hydrolysis of protein prior to feeding does not improve the performance of pigs (Leibholz 1981).

TABLE 2 The effect of age and protein concentrate on the ratio of protein to total nitrogen in the digestive tract of the pig (%)

Age of pigs (days)	Protein concen-trate	Site				Reference
		Duodenum	Jejunum	Ileum	Large intestine	
28	Milk	27	22	25	76)	Leibholz (1981)
	Soya	44	34	69	82)	
56	Milk	19	20	36	56)	Leibholz (1983)
	Soya	21	28	41	55)	
150	Casein	15	20	37	-)	Zebrowska (1978)
	Mixed	32	33	55	-)	

When the digesta reaches the ileum and large intestine much of the digestible nitrogen has been absorbed leaving a greater proportion of the less digestible protein than nonprotein nitrogen in the tract. The hydrolysis of soya protein is less than that of milk proteins, but it appears that the hydrolysis of soya protein improves with increasing age of pig, particularly between 28 and 56 days of age (Table 2). This agrees with the observation of Hays et al. (1959) which showed better performance of pigs and higher digestibility of soybean protein with increasing age.

There is little or no absorption of nitrogen in the stomach or duodenum of pigs (Table 3). The major site of nitrogen absorption in pigs of all ages is the lower two-thirds of the small intestine. In the younger pigs the major site of nitrogen absorption of pigs given milk as the protein concentrate is the jejunum while for pigs given soya protein the major absorption sites are the jejunum and ileum. By 150 days of age, there appears to be no difference in the site of absorption of nitrogen from milk or soya protein (Table 3).

TABLE 3 The effect of age and diets on the flow of nitrogen and dry matter (% of intake)

	Age of pigs (days)	Protein concen-trate	Site					Reference
			Stomach	Duo-denum	Jejunum	Ileum	Large intest-ine	
Nitrogen	28	Milk	110	106	64	18	7	Leibholz (1981)
		Soya	110	92	84	34	16	Wilson and Leibholz (1981b)
	56	Milk	89	79	42	26	16	Leibholz (1983)
		Soya	87	88	68	31	18	
	150	Casein	112	89	61	22	-	Zebrowska (1978)
		Mixed	114	100	75	28	-	
Dry matter	28	Milk	97	39	19	11	8	Leibholz (1981)
	56	Milk	98	51	36	31	17	Leibholz (1983)
	150	Casein	97	75	53	20	-	Zebrowska (1978)
		Mixed	118	74	38	29	27	Horszczaruk(1971)

The major site of absorption of dry matter in pigs given lactose as the major source of carbohydrate at 28 days of age is the duodenum, while in older pigs given wheat or barley there is some digestion of dry matter in the duodenum. However, a greater proportion of the apparent digestion occurs in the jejunum (Table 3). This would suggest that the form of carbohydrate in the diet affects the site of absorption and may influence the efficiency of utilization of nutrients, but the rate of passage of digesta through the duodenum and jejunum is rapid, about 50 min (Leibholz 1981).

In conclusion, the sites and extent of protein digestion in pigs vary with age and diet given to the pigs. This may explain the differences observed in the performance of pigs given various protein concentrates.

PROTEIN DIGESTION IN THE PIG - APPLIED ASPECTS

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The processes of digestion and absorption of proteins in the pig have been extensively studied. Much of this work has been reviewed (e.g. Low 1976, Rerat 1978) and from a practical aspect, many of the amino acid digestibility values for various feeds have been compiled (Low 1980). Thus there is a large body of information available for practical application by the pig industry for diet formulation. However, in some cases there has been a reluctance to use this information.

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For example, in its review of amino acid requirements, the ARC (1981) would not advocate the use of amino acid digestibility data for describing either pig requirements or dietary ingredients.

The purpose of this paper is to examine the measures of amino acid digestibility in pigs and their contribution to the pig industry for feed formulation.

There has been considerable effort for the last 35 years in the development of techniques for measuring amino acid digestibility in pigs. Kuiken and Lyman (1948) were among the first workers to report values for amino acid digestibility in pigs using faecal analysis. However, when it was first suspected (and later proved by Zebrowska 1975) that amino acids disappear but are not absorbed from the large intestine, it became apparent that for an accurate measure of amino acid absorption it is necessary to measure amino acid output from the ileum. Cho and Bayley (1972) achieved this by slaughtering animals to recover ileal digesta. However, for repeated sampling of ileal digesta with conscious pigs, cannulation techniques have been developed. Cunningham et al. (1962) reported a technique of re-entrant ileal cannulation that workers such as Holmes et al. (1974) used to measure amino acid digestibility. There have been various developments of this technique (Easter and Tanksley 1973; Darcey et al. 1980) but it remains a most difficult procedure. Therefore, there has been increased interest in the use of simple cannulae. This reduces many of the technical difficulties associated with the re-entrant cannula method yet provides similar values for amino acid digestibility (Zebrowska et al. 1978; Taverner et al. 1982). Moreover, the utility of the method has been further improved by the use of radioactive dietary markers (Wilson and Leibholz 1981).

Compared with any technique of ileal analysis, faecal analysis of protein digestibility is less technically difficult. Furthermore, for some feeds there is a good correlation between ileal and faecal values of amino acid digestibility. For example, Taverner and Farrell (1981) found that the variation among cereal grains in faecal digestibility values did reflect those expected in ileal digestibility. Similarly, Just (1980) concluded that faecal protein digestibility was the best practical estimate of amino acid availability for pigs.

There are however, fundamental objections to the use of faecal analysis as a measure of dietary amino acid absorption. For example, it has been reported (Low 1982a) that up to 90% of faecal amino acids are from non-dietary sources. Thus, any similarities between amino acid digestibilities measured at the ileum and in faeces are due to the similar composition of dietary and endogenous protein in ileal digesta and of the predominantly bacterial and endogenous protein in faeces (Low 1982b). Indeed, the majority of faecal protein is of bacterial origin (Mason et al. 1976) and thus the amino acid composition of faeces from pigs fed different diets and of bacterial protein are all very similar (Zebrowska 1980; Taverner et al. 1981a).

The amount of dietary protein degraded by bacteria in the hind gut depends upon the digestibility of dietary protein and carbohydrate in the stomach and small intestine. As their digestibility at the ileum decreases, the substrate available for the hind gut flora, and also their activity, increases and the accuracy of faecal digestibility as a measure of amino acid absorption is reduced. An example of the variation among feedstuffs that can occur between faecal and ileal digestibility values is shown in Table 1.

For well digested proteins such as soyabean meal (SBM), the differences between digestibility assays would not be of practical significance and faecal N digestibility would provide a useful practical measure of amino acid absorption. However, this was not the case for meat and bone meal (MBM): Taverner et al.

(1983) found that only 65% of amino acids were absorbed by the pig but a further 15% disappeared in the large intestine. Thus, a faecal analysis would indicate that 80% of the protein in MBM was available to the pig whereas only 65% was actually absorbed.

Therefore, as the Australian pig industry is dependent on a number of poorer quality protein sources such as MBM, cottonseed meal and sunflower meal, there would be unacceptable errors involved in a feed specification system incorporating adjustments for amino acid availability based on faecal protein digestibility.

TABLE 1 Differences between faecal N digestibility and ileal amino acid digestibility values

Amino acid	Soyabean[1] meal	Meat and bone[2] meal
Lysine	- 3.3	- 14.7
Threonine	- 7.1	- 21.5
Methionine	+ 2.1	- 9.3
Average of all amino acids	- 2.9	- 16.5

[1]Taverner (unpublished); [2]Taverner et al. (1983).

The apparent ileal digestibility (AD) of amino acids is calculated as the difference between dietary amino acid intake and its output from the ileum, divided by the intake. The calculation of true digestibility (TD) is similar except that the amount of endogenous amino acid is subtracted from the total amounts leaving the ileum. Although there are considerable problems with the measurement of endogenous amino acid levels, there is a broad measure of agreement among the results obtained by a variety of methods and using different diets and feeding levels (Low 1982b).

Low (1980, 1982b) claimed that on a practical basis, AD values are more meaningful than TD because they account for the total amounts of amino acids, irrespective of origin, that are lost to the pig. However, this approach assumes that the AD of amino acids for individual ingredients remains constant when these components are mixed in a diet. Such additivity has been demonstrated for TD values by Eggum and Jacobsen (1976) but seems unlikely to apply to AD values which are considered by Eggum (1973) to be meaningful only under standardized conditions. TD values on the other hand, are considered to be characteristic of a protein source and unaffected by dietary conditions. For example, Taverner (1979) found that the ileal AD of lysine in wheat was markedly influenced by dietary protein level whereas TD was unaffected.

Some agreement is required to standardize dietary conditions for measuring AD of amino acids in pig feeds so that these values might be more meaningful for practical diet formulation.

The practical application of amino acid digestibility values is their use in diet formulation as estimates of amino acid availability in feeds. Unfortunately, there have been few direct comparisons between amino acid digestibility and availability measurements. Indeed, there have been few direct measurements of amino acid availability and most have dealt with lysine using the pig growth assay described by Batterham et al. (1979). An indirect comparison of digestibility and availability values is shown in Table 2 with lysine availability values determined by pig growth assay by Batterham (1980) and ileal digestibility values for lysine from various other sources.

TABLE 2 Lysine availability and digestibility values in various protein sources for pigs

Protein meal	Availability (growth assay)	Digestibility (ileal assay)	Source
Soyabean	90	88	Taverner (unpublished)
Peas	90	90	"
Meat and bone	45 - 90	67	Taverner et al. (1983)
Cottonseed	45	62	Tanksley et al. (1982)
Lupins	55	93	Taverner et al. (1982)
Rapeseed	70 - 90	74	Sauer et al. (1982)

Clearly, this information is inadequate to indicate a relationship between digestibility and availability of lysine. Nevertheless, it appears that for many feeds there is little evidence of any major discrepancy between these measurements. This is supported by a recent brief report by Low et al. (1982b) who found they could accurately predict carcass lysine deposition in pigs fed lysine-limiting diets from levels of ileal digestible lysine.

In foods such as SBM and peas in which lysine is highly available, amino acids have also been found to be highly digestible using both faecal and ileal analyses. There are no direct comparisons for poorer quality proteins and although lysine digestibility values fall within the range of lysine availability values for rapeseed and MBM, lysine availability in cottonseed meal appears to be lower than digestibility values. Thus, there is the possibility that indigestibility does not account for all of the unavailable lysine in cottonseed meal. There is clearer evidence *for lupins however, that indigestibility was not the major factor influencing lysine availability (Taverner et al. 1983). The reason for this difference is unclear, particularly as lupins undergo no heating or processing other than crushing which is likely to damage its protein.

For most feedstuffs, digestibility values provide the only estimates of availability of amino acids other than lysine. However, the difference between the digestibilities of lysine and of other amino acids is relatively small for most feeds (Just 1980). Thus, where dietary amino acid constraints are expressed relative to lysine, there is little practical advantage in calculating digestibility values for each amino acid.

Pig growth assays are the most meaningful measures of amino acid availability. However, the long-term nature of these assays limits the number of feeds and amino acids that can be studied. Although considerably more work is required to establish the relationship between amino acid digestibility and availability in pig feeds, ileal digestibility assays appear to provide the next best option for estimating availability in a wider range of feeds and amino acids.

DIGESTION IN THE SOW

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There have been few studies investigating the digestion of nutrients in the sow and little comparison between growing gilts and mature sows in their ability to digest feedstuffs and diets. It has been generally assumed that the digestibility of feedstuffs by mature pigs is similar to that of growing pigs.

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An experiment was conducted to compare digestibility estimates obtained with growing gilts and those obtained with lactating sows.

MATERIALS AND METHODS

Digestibility estimates of three diets (Table 1) were obtained by using chromic oxide as the indicator material in these diets.

TABLE 1 Composition of experimental diets (air-dry basis)

Constituent	Diets		
	1	2	3
		g/kg	
Wheat	205	640	375
Barley	197	197	197
Starch	500		
Soyabean meal	44	100	320
Fish meal	11	25	80
Minerals and vitamins	40	35	25
Chromic oxide	3	3	3
Crude protein	77	164	282
Crude fibre	18	30	35

Twelve gilts (mean live weight ± SE; 64.6 ± 1.4 kg) were randomly allotted to one of the three diets and dry meal equivalent to 3.0 per cent of the live weight was fed to each pig as a wet mash once daily for a 14 day test period. Twelve first-litter sows (mean live weight ± SE after farrowing; 146.3 ± 2.3 kg) were also allotted to the diets. However, diets 1 and 2 were offered to sows during lactation at 4.5 kg/day whereas diet 3 was offered at 2.0 kg/day. The diets were given to the sows for a 14 day test period beginning at about day 8 of lactation. Total faecal collection was made from each gilt daily and a grab sample of faeces from each lactating sow was also collected daily over the last 4-5 days of each test period.

RESULTS

There were no interactions in the digestibility estimates obtained for growing gilts and lactating sows. The main effects are presented in Table 2. Despite differences in the digestibility estimates between diets the DMD, ND and DE estimates obtained for growing gilts were similar to those obtained for lactating sows (Table 2).

TABLE 2 Comparison of estimates of apparent dry matter digestibility (DMD), apparent nitrogen digestibility (ND) and digestible energy (DE) content of the diets when given to growing gilts and lactating sows. (Values with different superscripts are significantly different $P<0.05$)

Main effect		DMD (%)	ND (%)	DE (MJ/kg dm)
Diet 1		88.0^{a}	78.2^{c}	15.17^{a}
2		80.7^{c}	80.7^{b}	14.33^{b}
3		82.2^{b}	87.2^{a}	15.34^{a}
Type of pig	growing gilt	84.1	81.7	14.86
	lactating sow	83.2	82.4	15.03
Coefficient of variation (%)		1.3	2.4	2.1

DISCUSSION

Over the range of diets used in this experiment, a comparison of the digestibility of diets given to different classes of pigs revealed little difference in the DMD, ND or DE content of diets when given to growing gilts or lactating sows.

The diets used in this experiment contained relatively low levels of fibre. The digestion of feedstuffs rich in fibre may, however, vary according to the different classes of pigs. Boyd et al. (1976) found that the DMD and DE content of lucerne meal was lower for growing gilts than for sows. The extent of digestion of crude fibre has been shown by Horszczaruk and Sljivovacki (1971) to be greater in mature pigs than in growers. Sows also tend to digest more cellulose than gilts (Boyd et al. 1976).

Feedstuffs, particularly those rich in fibre, would be expected to be digested to a greater extent in sows because the retention time is usually longer in sows than in growers (Castle and Castle 1956). The other factor that may be responsible for the greater digestibility of high fibre feedstuffs by mature animals is that these animals are usually given the high fibre diet over a longer period, allowing the digestive system to alter and become more accustomed to the high fibre diet. Both Pollman et al. (1979) and Nuzback et al. (1982) have found that the digestion of high fibre diets increased over the gestation period of the sow. In particular, hemicellulose digestion increased which suggested that a population of hemicellulytic microbes that had a greater capacity to utilize the cell-wall constituents, had developed over a two or three month adaptation period (Pollman et al. 1979). In contrast, the digestibility of lower fibre diets did not alter over the gestation period of the sow (Elsley et al. 1966; Pollman et al. 1979).

CONCLUSION

The digestibility of low fibre diets by sows is similar to that by growers. However, the digestion of feedstuffs rich in fibre appears to be greater in mature animals. This may be attributable to the longer retention time of diets in the alimentary tract of mature animals and the longer acclimatization period of the digestive tract to the diet. Consequently the microbial population in the intestine of mature animals may change allowing a greater digestion of the fibre fraction of the diet.

SUMMARY

JANE LEIBHOLZ

The present papers review a number of aspects of digestion in the pig with particular emphasis on the development of digestion of the pig and on the digestion of protein.

The size of the stomach of pigs shows a positive relation with live weight, but the secretion of acid and proteolytic enzymes increased from birth to 42 days of age and possibly beyond this age, This results in little hydrolysis of protein in the stomach of young pigs but more than 80% of the dietary protein is hydrolysed in the stomach of the young pig. The major sites of N absorption is the lower two-thirds of the small intestine in both young and growing pigs.

Some dietary N is absorbed from the hind gut but most of this N is of little nutritional value. Hence, comparisons between protein concentrates should normally be made from ileal digestibility data, although faecal figures may be used for diets of high digestibility. For these diets the values are similar for growing pigs and sows but differences do occur with high fibre diets.

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