The use of pigs both intact and with ileo-rectal anastomosis to estimate the apparent and true digestibility of amino acids in untreated, heat-treated and thermal-ammoniated high-tannin grain sorghum

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Received 5 December 1988; revised 7 November 1989; accepted 23 July 1990

This experiment was conducted to determine apparent and true amino acid digestibilities of untreated (BPS), heat-treated (HBPS) and thermal-ammoniated (NH_3BPS) high-tannin sorghum with pigs both intact and with an ileo-rectal anastomosis (IRA). The mean endogenous protein secretion for the surgically modified (12,1 g CP/d) and normal pigs (5,8 g CP/d) differed significantly ($P \leq 0,01$). A net synthesis of isoleucine, lysine and methionine was observed in the large intestines of normal pigs fed the sorghum diets. In general, the mean apparent and true faecal and ileal digestibilities of amino acids (AA) were the highest for NH_3BPS, followed by HBPS and BPS. Thermal ammoniation improved the true ileal digestibility (as measured with IRA pigs) of arginine (28,3%), methionine (22,9%), valine (42,8%), histidine (22,9%), isoleucine (8,8%), lysine (27,3%), phenylalanine (27,3%), threonine (24,6%), serine (17,0%) and tyrosine (6,9%). Although ammoniation improved AA digestibility, the improvements were too small to be of practical importance.

'n Eksperiment is uitgevoer om die skynbare en ware aminosuurverteerbaarheidswaardes vir onbehandelde (BPS), hittebehandelde (HBPS) en geammonifiseerde (NH_3BPS) voëlbestande graansorghum met normale en ileum–rektum-anastomose-gemodifiseerde (IRA) varke te bepaal. Die hoeveelheid endogene N uitgeskei deur normale diere (5,8 g RP/d) was hoogsbetekenisvol ($P \leq 0,01$) laer as die hoeveelheid uitgeskei deur gemodifiseerde diere (12,1 g RP/d). 'n Netto sintese van isoleusien, lisien en metionien het plaasgevind in die dikderms van die normale varke. Oor die algemeen was die skynbare en ware fekale en ileale verteerbaarheid van aminosure die hoogste met die NH_3BPS-dieet, gevolg deur die HBPS- en BPS-diëte. Termiese ammonifisering het 'n verhoging meegebring in die ware ileale verteerbaarheid (soos bepaal met die gemodifiseerde diere) van arginien (28,3%), metionien (22,9%), valien (42,8%), histidien (22,9%), isoleusien (8,8%), lisien (27,3%), fenielalanien (27,3%), treonien (24,6%), serien (17,0%) en tirosien (6,9%). Alhoewel aminosuurverteerbaarheid verhoog is, was die verbetering egter te klein om van enige praktiese belang te wees.

Keywords: Amino acids, ammonia, digestibility, endogenous excretion, heat, ileo-rectal anastomosis, ileum, nitrogen, sorghum.

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Tannins have a deleterious effect on the nutritive value of sorghum and depress growth rate and feed efficiency ratios (Kemm, Ras & Daiber, 1984; Myer & Gorbet, 1985). Rostagno, Rogler & Featherson (1973) and Cousins, Tanksley, Knabe & Zebrowska (1981) showed that there is a reduction in amino acid availability with increasing tannin content. However, ammoniation has been shown to inactivate tannins and thus to improve the nutritive value of high-tannin sorghum (Price, Butler, Featherson & Rogler, 1978; Price, Butler, Rogler & Featherson, 1979; Reichert, Flemming & Schwab, 1980), and Ford & Hewitt (1979) found an increase in methionine availability due to ammoniation (as measured with *Streptococcus zymogenes*).

The most commonly used procedure for determining amino acid digestibilities for pigs has been the faecal index method. Digestibility, as determined at the end of the small intestine, is a more accurate index of the availability of amino acids to the pig (Just, Jorgensen & Fernandez, 1981). In order to measure this, the technique of collecting digesta from a cannula at the terminal ileum was developed. However, several difficulties and short-comings are associated with obtaining representative samples (Sauer & Ozimek, 1986). These problems were largely overcome by the new technique (ileo-rectal anastomosis = IRA) suggested by Fuller & Livingstone (1982), which provided a way to allow the simple estimation of ileal digestibility. Picard, Bertrand, Genin & Mailard (1984) found that amino acid digestibility data obtained from IRA pigs were similar to data derived from classical methods. Hennig, Noel, Hermann, Wünche & Mehnert (1986) confirmed from biochemical and morphological studies that animals with an IRA were suitable for the determination of nutrient digestibility in the small intestine. Their results were confirmed by Schumann, Souffrant & Gebhard (1986), Green, Bertrand, Duron & Maillard (1987), Green, Bertrand, Duron & Maillard (1988) and Brand, Badenhorst, Siebrits & Hayes (1989a), who applied the technique successfully.

This experiment was conducted to determine the effect of thermal ammoniation and heat treatment of high-tannin grain sorghum on (i) apparent and true amino acid digestibility across the entire digestive tract as measured with intact pigs and (ii) the apparent and true amino acid digestibility up to the terminal ileum as measured with IRA pigs.

Experimental Procedures

High-tannin grain sorghum, with a 1,24% polyphenol content, was used in this study. The polyphenol content was determined by the modified Jerumanis procedure as described by Daiber (1975). The sorghum was treated as follows:

1. Bird-proof sorghum (BPS), no treatment applied.
2. BPS thermally ammoniated in a commercial An-Stra-Verter® oven (NH_3BPS) at a level of 15 g NH_3/kg dry matter (DM) (Brand, Hayes, Erasmus & Siebrits, 1989b).
3. BPS heated in an An-Stra-Verter® oven, but with no ammonia in the chamber (HBPS).

An amino acid free diet (PFD), consisting of a combination of maize starch and wheat straw calculated to contain the same crude fibre content as the experimental sources, was used to correct the amino acid digestibility values for endogenous protein contribution. True amino acid digestibility was determined by subtracting the daily endogenous secretions, derived when the animals were fed the PFD diet, from the daily amino acids excreted on the three dietary treatments.

Sixteen Large White boars with a mean live mass of 40 kg were used as experimental animals. Eight of the boars were modified surgically according to the IRA technique as suggested by Fuller & Livingstone (1982). The surgical procedures were described in detail by Brand *et al.* (1989a). Pigs were randomly allotted to the different treatments (BPS, HBPS, NH_3BPS and the PFD). Four, 4 × 4 latin-square designs were used. Pigs were subjected to a 14-day trial period which consisted of a 7-day preliminary period and a 7-day collection period, during which time faeces were collected, while pigs were housed in metabolism crates. Between each 14-day trial period, the pigs received a 16% protein, balanced diet for 7 days. Pigs had free access to water at all times. A daily amount of 1 500 g air-dry meal was fed to each pig in equal portions at 08h00 and 13h00. The procedures followed in collection and analyses of faeces samples were as described in detail by Kemm & Ras (1971).

Dietary ingredients fed, as well as faeces samples, were chemically analysed for DM and nitrogen by standard AOAC methods (AOAC, 1984). Amino acid composition of feeds and samples, after acid hydrolysis in a sealed tube, was analysed using a Beckmann Model 6300 amino acid analyser.

Differences between treatment means of the modified and normal pigs were tested for significance by analysis of variance (Snedecor & Cochran, 1980).

Results and Discussion

The crude protein (CP) and amino acid (AA) composition of the differently treated high-tannin sorghum samples are summarized in Table 1. Heat treatment and thermal ammoniation reduced the tannin content of BPS from 1,24 to 1,14 and 0,55% respectively, while the CP content was increased from 11,5 to 11,8 and 13,5%, respectively. It was assumed that the increase in CP was due to retained ammonia, which, being non-protein nitrogen (NPN), was excreted as urea and was thus of no further use to the pig. Heat as well as ammonia treatment had no effect on the AA composition of the grain. Digestibility coefficients for CP in diets were adjusted to exclude the ammonia intake. As a result, slightly lower coefficients than expected were obtained for the thermal-ammoniated grain. The apparent and true faecal digestibility of CP was lower for NH_3BPS than for HBPS. This could possibly be attributed to NPN in the faeces of pigs fed the NH_3BPS diet, since higher DM digestibility values were obtained with the NH_3-treated diet. Relatively large differences in AA digestibilities were found between individual pigs (Tables 2 & 3) in different treatments, especially in the case of the ileo-rectal anastomosed pigs. These differences were possibly due to factors such as the low food intake, variation in food intake, the relatively high and variable moisture content of digesta and the possible influence of tannin in the diets on AA digestibility.

Table 1 Protein content and amino acid composition of untreated, heat-treated and thermal-ammoniated high-tannin grain sorghum samples (dry-matter basis)

	Experimental diets		
Item	BPS	HBPS	NH_3BPS
Crude protein (%)	11,5	11,8	13,5
Tannin (%)	1,24	1,14	0,55
Indispensable amino acids (%)			
Arginine	0,31	0,32	0,25
Histidine	0,19	0,19	0,17
Isoleucine	0,34	0,33	0,32
Leucine	1,26	1,28	1,15
Lysine	0,17	0,19	0,15
Methionine	0,13	0,14	0,15
Phenylalanine	0,47	0,48	0,43
Threonine	0,29	0,30	0,27
Valine	0,41	0,41	0,39
Dispensable amino acids (%)			
Alanine	0,85	0,87	0,78
Aspartic acid	0,61	0,63	0,56
Cystine	0,23	0,23	0,21
Glutamic acid	1,92	1,96	1,94
Glycine	0,27	0,28	0,24
Proline	0,73	0,75	0,67
Serine	0,42	0,44	0,37
Tyrosine	0,38	0,39	0,26

The apparent and true faecal digestibilities for AA for the differently treated grain sorghum are summarized in Table 2. The apparent and true faecal digestibilities of AA for thermal-ammoniated BPS were higher than the corresponding digestibilities for BPS and HBPS, while HBPS digestibility values, in turn, were higher than values for BPS. The only exceptions were serine, tyrosine and valine. The improvements in AA digestibilities were endorsed by improvements in DM and CP digestibilities. Apparent lysine digestibility was significantly ($P \leq 0,01$) improved from –8,1% to 28,9% by heat *per se* and from –8,1% to 38,2% by thermal ammoniation. The low lysine digestibility for untreated high-tannin sorghum might have resulted from increased endogenous lysine losses. Apparent methionine

Table 2 Apparent and true faecal disgestibilities of amino acids (AA) in the test components

Item	Apparent digestibility			True digestibility		
	BPS	HBPS	NH_3BPS	BPS	HBPS	NH_3BPS
Crude protein (%)*	54,6^{1} ± 4,3	67,0^{2} ± 6,4	65,4^{2} ± 5,5	58,4^{1} ± 4,4	70,9^{2} ± 6,2	69,1^{2} ± 5,5
Dry matter (%)	81,9^{a1} ± 2,0	84,2^{b} ± 1,7	86,9^{2} ± 1,6	81,9^{a1} ± 2,0	84,2^{b} ± 1,7	86,9^{2} ± 1,6
Indispensable AA (%)						
Arginine	48,3^{a1} ± 10,8	62,6^{b} ± 3,3	67,3^{2} ± 4,8	52,2^{a1} ± 10,9	66,4^{b} ± 3,3	72,1^{2} ± 4,8
Histidine	28,8^{a1} ± 13,3	41,0^{b} ± 2,9	51,9^{c2} ± 6,4	34,2^{a1} ± 13,4	46,6^{b} ± 3,0	57,9^{c2} ± 6,5
Isoleucine	47,2^{a1} ± 11,7	59,5^{b} ± 5,9	66,7^{2} ± 5,8	51,1^{a1} ± 11,8	63,6^{b} ± 5,8	70,8^{2} ± 5,8
Lysine	−8,1^{1} ± 21,1	28,9^{2} ± 13,6	38,2^{2} ± 8,5	2,0^{1} ± 21,2	38,1^{2} ± 13,5	49,2^{2} ± 8,5
Methionine	64,9^{a1} ± 9,8	75,2^{b} ± 3,8	82,6^{2} ± 3,9	65,9^{a1} ± 9,9	76,1^{b} ± 3,8	83,4^{2} ± 3,9
Phenylalanine	60,2^{a1} ± 9,2	71,3^{b} ± 3,0	76,2^{2} ± 5,9	63,0^{a1} ± 9,3	74,0^{b} ± 3,0	79,2^{2} ± 5,9
Threonine	59,3 ± 21,6	61,2 ± 3,5	69,2 ± 5,2	63,5 ± 21,6	65,3 ± 3,5	74,0 ± 5,1
Valine	61,3 ± 23,4	55,3 ± 4,4	64,4 ± 5,8	65,6 ± 23,4	59,6 ± 4,4	68,8 ± 5,8
Dispensable AA (%)						
Serine	73,0 ± 15,0	80,0 ± 9,9	78,9 ± 4,7	75,5 ± 15,0	82,5 ± 9,9	81,9 ± 4,7
Tyrosine	64,9 ± 8,6	74,2 ± 2,8	67,5 ± 6,1	67,4 ± 8,6	76,5 ± 2,9	71,0 ± 6,1

a—c Denote significant ($P \leq 0,05$) differences in apparent or true digestibilities in rows.

1,2 Denote highly significant ($P \leq 0,01$) differences in apparent or true digestibilities in rows.

* Dietary crude protein corrected (to 11,5% for all test components) for increased nitrogen due to ammoniation.

Daily DM intakes respectively 1 317 ± 22, 1 328 ± 23 and 1 340 ± 15 g/d for the BPS, HBPS and NH_3BPS diets.

digestibillty was significantly ($P \leq 0,05$) improved by 15,9% with heat *per se* and by 27,3% with thermal ammoniation ($P \leq 0,05$). Thermal ammoniation highly significantly ($P \leq 0,01$) improved the true faecal digestibility of lysine (47,2%) and methionine (17,5%) as well as the digestibilities of arginine, histidine, isoleucine and phenylalanine. Heat *per se* significantly improved the true faecal digestibillty of lysine by 36,1% ($P \leq 0,01$) and methionine by 10,2% ($P \leq 0,05$), and of arginine, histidine, isoleucine and phenylalanine ($P \leq 0,05$).

The apparent and true ileal AA digestibility values are summarized in Table 3. The AA digestibilities measured for NH_3BPS were higher than the AA digestibilities for HBPS which, in turn, were higher than values measured for BPS. The only exceptions were for tyrosine, histidine and iso-

Table 3 Apparent and true ileal disgestibilities of amino acids (AA) in the test components

Item	Apparent digestibility			True digestibility		
	BPS	HBPS	NH_3BPS	BPS	HBPS	NH_3BPS
Dry matter (%)	66,6^{a1} ± 9,8	73,9^{b} ± 6,8	79,1^{2} ± 4,4	66,6^{a1} ± 9,8	73,9^{b} ± 6,8	89,0^{1} ± 4,4
Crude protein (%)*	42,2 ± 12,7	51,1 ± 11,7	58,4 ± 4,1	53,4 ± 13,6	60,1 ± 11,9	67,2 ± 4,9
Indispensable AA (%)						
Arginine	47,7^{a} ± 11,9	56,6 ± 6,3	63,7^{b} ± 3,3	57,2^{a} ± 13,5	64,2 ± 6,9	73,4^{b} ± 3,7
Histidine	18,4 ± 19,4	20,1 ± 12,8	28,8 ± 8,7	41,0 ± 23,4	40,0 ± 13,5	50,4 ± 10,7
Isoleucine	60,5 ± 9,1	56,3 ± 9,0	67,4 ± 4,2	68,9 ± 8,2	63,8 ± 9,8	75,0 ± 4,9
Lysine	21,0 ± 15,1	31,7 ± 11,4	34,5 ± 8,2	43,3 ± 20,1	48,8 ± 12,8	55,1 ± 9,6
Methionine	65,3^{a} ± 12,8	73,3 ± 6,6	81,7^{b} ± 3,3	68,0^{a} ± 12,9	75,4 ± 6,8	83,6^{b} ± 3,3
Phenylalanine	58,7 ± 15,7	66,6 ± 7,2	73,9 ± 3,7	64,2 ± 16,7	71,2 ± 7,7	79,0 ± 4,0
Threonine	47,7 ± 14,4	57,8 ± 6,9	63,2 ± 5,8	59,8 ± 14,7	67,7 ± 7,7	74,5 ± 5,8
Valine	39,3^{a} ± 19,0	48,9 ± 10,0	61,4^{b} ± 4,7	48,8^{a} ± 19,7	56,9 ± 10,9	69,7^{b} ± 5,4
Dispensable AA (%)						
Serine	62,5 ± 11,6	70,7 ± 5,5	74,5 ± 4,2	69,4 ± 12,2	76,3 ± 6,1	81,2 ± 4,2
Tyrosine	63,1 ± 11,7	69,8 ± 6,1	66,6 ± 5,2	68,3 ± 12,3	74,1 ± 6,6	73,0 ± 5,1

a,b Denote significant ($P \leq 0,05$) differences in apparent or true digestibilities in rows.

1,2 Denote highly significant ($P \leq 0,01$) differences in apparent or true digestibilities in rows.

* Dietary crude protein corrected (to 11,5% for all test components) for increased nitrogen.

Daily DM intakes respectively 1 036 ± 290, 1 152 ± 200 and 1 144 ± 150 g/d for the BPS, HBPS and NH_3BPS diets.

leucine. Thermal ammoniation had a significant ($P \leq 0,05$) influence on the true digestibility of arginine, methionine and valine and their digestibilities were improved by 28,3, 22,9 and 42,8%, respectively. The true digestibilities of the other indispensable amino acids, namely histidine, isoleucine, lysine, phenylalanine and threonine were improved by 22,9, 8,8, 27,3, 27,3 and 24,6%, while for the dispensable amino acids, serine and tyrosine, digestibilities were improved by 17,0 and 6,9%, respectively. Heat treatment *per se* resulted in an improvement in the true ileal digestibilities of arginine (12,2%), lysine (12,9%), methionine (10,9%), phenylalanine (10,9%), threonine (13,2%), valine (16,6%), serine (9,9%) and tyrosine (8,5%). Improvements were large although not significant, owing to the great variation between individual pigs, for reasons already stated.

The apparent faecal and ileal digestibility values of proteins and amino acids for high-tannin sorghum found in the present study were considerably lower than values found by Cousins *et al.* (1981). They reported an apparent faecal N digestibility of 72,0% and amino acid digestibility values which ranged between 55,5—78,6%, with a mean value of 74,3% for essential amino acids and 71,3% for non-essential amino acids. The apparent ileal N digestibility was found to be 68,7%, with amino acid digestibility values ranging between 40,5—80%. Mean apparent ileal amino acid digestibilities of 71,8% for the essential amino acids and 65,1% for the non-essential amino acids were reported. The levels of amino acids found in the present study were, however, in agreement with values found by Rostagno *et al.* (1973) in studies with roosters. They reported mean apparent amino acid digestibility values of 25,6% and 22,2% for high-tannin grain sorghum. The corresponding true amino acid digestibilities were 35,9% and 26,2%.

The endogenous secretions of protein and amino acids by intact and IRA pigs on the PFD diet, which was used to calculate the true faecal and ileal digestibility of amino acids, are presented in Table 4. The mean daily feed consumption of the normal and IRA pigs was 963 ± 178 and 1 198 ± 80 g DM/d, respectively. The value for metabolic faecal protein of 6,01 g CP/kg DM consumed was slightly lower than the values of 7,87 (Tullis & Whittemore, 1986) and 6,31 (Sauer, Stothers & Parker, 1977) obtained with pigs which had slightly higher intake rates. The mean endogenous protein secretion of the IRA pigs was 12,1 g/d. The difference of 6,32 g CP/d between the normal and surgically modified pigs (which represents the amount of endogenous protein secreted in the small intestine, and which is subsequently absorbed and/or degraded to nitrogen in the caecum and colon) was highly significant ($P \leq 0,01$).

The endogenous secretions of arginine, histidine, lysine, threonine, alanine and glycine by the IRA pigs were highly significantly ($P \leq 0,01$) higher, while the endogenous secretions of isoleucine, leucine, metheonine, phenylalanine, valine and tyrosine were significantly ($P \leq 0,05$) higher than the endogenous secretions of these amino acids by the normal pigs. This is in contrast with results obtained by other researchers, e.g. Sauer *et al.* (1977) and Holmes, Bayley, Leadbeater & Horney (1974) who used ileo-caecal re-entrant and ileal re-entrant cannulas respectively.

Table 4 Endogenous secretions* of proteins and amino acids (AA) by ileo-rectal anastomosed and intact pigs on the amino acid free diet

Item	Protein-free diet		
	Intact pigs	Ileo-rectal anastomosed pigs	Difference**
Crude protein (g/d)	5,79 ± 1,64	12,11 ± 2,52	6,32[1]
Indispensable AA (g/d)			
Arginine	0,20 ± 0,06	0,34 ± 0,07	0,14[1]
Histidine	0,17 ± 0,04	0,51 ± 0,13	0,34[1]
Isoleucine	0,22 ± 0,07	0,34 ± 0,10	0,12•
Leucine	0,37 ± 0,12	0,59 ± 0,18	0,22•
Lysine	0,28 ± 0,11	0,44 ± 0,11	0,16[1]
Methionine	0,02 ± 0,01	0,04 ± 0,02	0,02•
Phenylalanine	0,21 ± 0,06	0,30 ± 0,08	0,09•
Threonine	0,20 ± 0,07	0,41 ± 0,08	0,21[1]
Valine	0,28 ± 0,10	0,45 ± 0,12	0,17•
Dispensable AA (g/d)			
Alanine	0,16 ± 0,06	0,30 ± 0,08	0,14[1]
Glycine	0,25 ± 0,11	0,61 ± 0,19	0,36[1]
Serine	0,18 ± 0,06	0,34 ± 0,06	0,16
Tyrosine	0,15 ± 0,05	0,23 ± 0,06	0,08•

* On DM basis.

** Difference obtained by subtracting faecal endogenous excretion from ileal endogenous secretion.

• Denote significant ($P \leq 0,05$) differences.

[1] Denote highly significant ($P \leq 0,01$) differences.

Daily feed intake 963 ± 178 and 1 198 ± 80 g DM/d for ileo-rectal anastomosed and intact pigs.

However, in these studies ileal digesta was collected, while in this study, the digesta obtained with the IRA pigs consisted of ileal digesta plus secretions from the caecum and colon. It can be assumed that the large intestine, although bypassed by anastomosis, would proceed with secretions up to the rectum, but possibly at a lower rate. The amount of amino acids excreted in the faeces of intact pigs, was generally slightly lower than the amounts found by Sauer *et al.* (1977). Similarly lower endogenous protein excretion was found in the present study. The extent of excretion of endogenous amino acids, however, was similar to that found by Sauer *et al.* (1977), except fot the excretion of methionine, alanine, glycine and serine which was found to be considerably lower.

Table 5 shows the difference between small intestinal (as estimated with IRA pigs) and total tract digestibilities calculated by subtracting small intestinal values from total tract digestibilities. A positive value in the difference of apparent digestibility indicates the amount of disappearance and extent of digestion in the large intestine (in percentage units), whereas a negative value indicates a synthesis of amino acids in the large intestine. In most instances, when considering apparent digestibility, N and amino acids disappeared from the large intestine which is consistent with data reported by others (Tanksley & Knabe, 1984). The greatest disappearance in the large intestine occurred, in

Table 5 Differences in faecal and ileal disgestibilities of nitrogen and amino acids (AA)

Item	Apparent digestibility			True digestibility		
	BPS	HBPS	NH_3BPS	BPS	HBPS	NH_3BPS
Difference* in:						
Nitrogen digestibility	12,4	15,9[a]	7,0	5,0	10,8	1,9
DM digestibility	15,3[1]	10,3[1]	7,8[a]	15,3[1]	10,3[1]	7,8[a]
Difference* in indispensable AA						
Arginine	0,6	6,0	3,6	–5,0	2,2	–1,3
Histidine	10,4	20,9[1]	23,1[1]	–6,8	6,6	7,5
Isoleucine	–13,3[a]	3,2	–0,7	–17,8[1]	–0,2	–4,2
Lysine	–29,1[1]	–2,8	3,7	–41,3[1]	–10,7	–5,9
Methionine	–0,4	1,9	0,9	–2,1	0,7	–0,2
Phenylalanine	1,5	4,7	2,3	–1,2	2,8	0,2
Threonine	11,6	3,4	6,0	3,7	–2,4	–0,5
Valine	22,0[a]	6,4	3,0	16,8	2,7	–0,9
Difference in dispensible AA						
Serine	10,5	9,3	4,4	6,1	6,2	0,0
Tyrosine	1,8	4,4	0,9	–0,9	2,4	–2,0

* Differences expressed as percentage units.

[a] Denote significant ($P \leq 0,05$) differences between normal and ileo-rectal anastomosed pigs.

[1] Denote highly significant ($P \leq 0,01$) differences between normal and ileo-rectal anastomosed pigs.

general, for amino acids with low digestibilities in the small intestine. When referring to the difference in apparent amino acid digestibilities, only the concentrations of isoleucine, lysine and methionine were higher at the terminal ileum than in the faeces, which points to a net synthesis of these amino acids in the caecum and colon. These results agree with data reported by others, who found a net synthesis of lysine and methionine (Sauer, Just, Jorgensen, Fekadu & Eggum, 1980; Tanksley & Knabe, 1984), lysine and isoleucine (Sauer *et al.* 1977) and lysine, methionine and phenylalanine (Lin, Knabe & Tanksley, 1987) in the large intestine of the pig.

According to differences in true amino acid digestibilities between normal and IRA pigs for BPS, lysine and isoleucine were excreted at considerably higher rates ($P \leq 0,01$) in the faeces than in the ileal digesta. With the exception of threonine, valine and serine, all the other amino acids were excreted in larger amounts in the faeces than in the ileal digesta for pigs fed the BPS diet. Pigs fed the HBPS diet excreted more isoleucine, lysine and threonine in the faeces, while the excretion of arginine, isoleucine, lysine, methionine, threonine, valine and tyrosine in the faeces of pigs fed the NH_3BPS diet exceded the amount excreted in ileal digesta. This phenomenon suggests that the endogenous contribution was underestimated. Although expected, it is clear that the traditional technique of estimating endogenous contribution, using a PFD diet, underestimates the endogenous secretion (Krawlelitzki, Volker, Smulikowska, Bock & Wünsche, 1977; Gebhardt, Souffrant, Liebert, Kohler, Matkowitz & Schmandke, 1981). The larger differences found with the high-tannin diet may be attributed to a higher endogenous secretion when these diets were fed. Glick & Joslyn (1970) noted an increased excretion of protein in the faeces of rats fed 2% or more tannic acid in the diet. They demonstrated that the proteolytic activity of the intestinal contents of rats fed 5% tannic acid was three times that of the control rats, and concluded that protein of endogenous origin accounted for most of the protein excreted. Rostagno *et al.* (1973) found that, when 1,41% tannic acid was added to a PFD diet, a significant increase occurred in the excretion of amino acids per unit of diet. The increased amino acid excretion ranged from 3,2 times for cystine to 6,6 times for histidine, with an overall mean increase of 4 times that of chicks fed the PFD without added tannic acid.

Conclusions

Thermal ammoniation had an advantageous effect on the digestibility of all the amino acids determined. Lysine and histidine were the least digestible of the indispensable amino acids by either method of determination. However, a pig with an intake of 1600 g sorghum per day would have 3,36 and 3,04 g/d histidine and lysine available for uptake, respectively. If true ileal digestibility values are used to calculate actual uptake, the untreated grain would supply 1,36 and 1,32 g histidine and lysine, while the corresponding figures for the thermal-ammoniated grain would be 1,69 and 1,67 g, respectively. This represents an increase of 0,33 and 0,35 g/d. When considering that the requirement for lysine and histidine in the growing pig is 14,4 and 3,2 g/d, respectively, the improvements following treatments are too small to have any practical application. This is especially so since treatment involves heating up to 90°C, which may cause denaturation and heat damage to some of the amino acids. It is thus concluded that thermal ammoniation of high-tannin sorghum, as used in this study, is too costly and is not recommended as a method to improve the nutritive value of BPS for pigs.

Acknowledgements

Thanks are due to Mrs J. Behrens and Messrs A.C. Adams and D. Hauptfleisch for the chemical analyses and amino acid determinations. Thanks to Dr E.H. Kemm for his valuable guidance with the planning and criticism of the experiment and to Mr M.N. Ras for his assistance with the digestion trial. The authors also thank Newtech Manufacturers for the treatment of the grain and Prof. J.G. van der Walt for the surgical preparation of the pigs. Messrs Z. Thwala and T. Modungwana are thanked for taking care of the animals.

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