AMINO ACIDS DIGESTIBILITY TO PIGS IN VARIOUS FIBER SOURCES : 1. APPARENT DIGESTIBILITY OF AMINO ACIDS IN ILEAL DIGESTA AND FECES

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Summary

Four fibrous feedstuffs from alfalfa meal (AFM), cassava leaf meal (CLM), rubber seed meal (RSM) and leucaena meal (LM) were included in semi purified diets for growing pig (45 kg body wt.) at 20%, to investigate the effects of these fiber sources and fractions on amino acid digestibility. Cellulose (C), a purified fiber source was included in another diet at 5% level for comparison. The barrows fitted with ileal T-cannula were used in the digestion trials with latin square design. The digestibilities of amino acids were measured at both terminal ileum and fecal level. NDF and hemicellulose content were the highest in AFM-diet whereas LM-diet had the highest ADF and lignin content. RSM-diet contained the highest crude fiber and cellulose content. The digestibilities of amino acids at ileal level were found the highest with CLM-diet, while LM-diet was the least. At fecal level, control diet and CLM-diet were the highest in amino acid digestibility while AFM-diet was the least. The digestibility of amino acids was higher at ileal than fecal level. The digestibility of arginine was not affected with fiber fractions but was found to be the most disestible across all diets. The most depressed amino acid was methionine at both levels; proline and glycine, in the dispensable amino acid group, were depressed at ileal and fecal level, respectively. Lignin did not depress amino acid digestibility in general but specifically depressed methionine, histidine, isoleucine and threonine digestibility. Cellulose content did not affect amino acid digestibility but undesirable factors might be responsible.

(**Key Words**: Dietary Fiber, Alfalfa Meal, Cassava Leaf Meal, Rubber Seed Meal, Leucaena Meal, Apparent Amino Acid Digestibility, Cannulated Pigs).

Introduction

The chemical composition in fibrous feedstuffs are varied among the sources and species and these constituents are reported to affect the utilization of nutrients, including protein. Digestibility of amino acid using fecal collection is not difficult in technique but there are fundamental objections to this approach. Fecal amino acids are a mixture of undigested residues, endogenous secretions and bacteria (Mason and Just, 1976). Apparent digestibility values for amino acids measured in feces may be similar in many cases to the result of ileal analysis, but error could occur with feedstuff with low or moderate digestibility (Low, 1982). Different fiber sources depress digestibility to varying degree depending on their fiber fractions (Fernandez and Jorgensen, 1986), rate of passage (Low, 1985) and their physical characteristics. Crude fiber represents only part of real fiber intake of animal (Van Soest and McQueen, 1973) whereas content of cellulose, hemicellulose, lignin are also the components of dietary fiber. The present work was undertaken to determine the apparent digestibility of individual amino acid in fibrous feedstuffs as affected by fibrous constituents.

Materials and Methods

Diets

Fiber sources used in this study were alfalfa meal (AFM); cassava leaf meal (CLM), collected from 2-3 sundried mature leaves of *Manihot esculenta*; rubber seed meal (RSM), a decorticated kernel of rubber tree fruit (*Hevea brasilensis*); leucaena meal (RSM), a decorticated kernel of rubber tree fruit (*Hevea brasilensis*); leucaena meal

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(LM), dried leaves of browse leguminosae (*Leucaena leucocephala*) and cellulose. All meals were ground through 1 mm screen by Wiley mill and then included in semi-purified diet at 20% level. Cellulose was included in one of the diet at 5% level for comparison. Isolated soy protein was added at 15% level as main protein source, corn starch and oil were included as major energy source in the diet to meet NRC (1988) requirements. Glucose was added at 20% to improve palatability. Other dietary ingredients and chromic oxide were added as shown in table 1.

Design

Barrows with an average body wt. of 45 kg and fitted with ileal T-cannula were used in the digestion trial of 6 × 6 latin square design. They were raised in individual cages with raised slatted floor. Each trial period was 7 d long and separated by 4 d adjusted period. Each day's feed supply was divided into two equal meals of 800 g at 7:00 and 19:00 and was mixed with 1½ *l* of water to form a gruel. All pigs were provided with fresh water at all time. Ileal samples were collected by double-layer plastic bag fastened with

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF THE DIETS USED IN THE EXPERIMENT[1]

Components (%)	C diet	AFM diet	CLM diet	RSM diet	LM diet
Ingredients					
Isolated soy protein	15	15	15	15	15
Cellulose	5	0	0	0	0
Alfalfa meal	0	20	0	0	0
Cassava leaf meal	0	0	20	0	0
Rubber seed meal	0	0	0	20	0
Leucaena leaf meal	0	0	0	0	20
Corn oil	3	3	3	3	3
Corn starch	53	38	38	38	38
Glucose	20	20	20	20	20
Chromic oxide	0.5	0.5	0.5	0.5	0.5
Vit.-min. premix[2]	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Ca-carbonate	0	0.5	0.5	1.0	1.0
Monosodium-PO_4	0.5	2.0	2.0	1.5	1.5
Dicalcium-PO_4	2.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0
Chemical analysis					
Crude protein	12.56	16.27	17.11	18.94	15.36
Ether extract	4.36	6.04	5.81	5.48	4.33
Crude fiber	4.6	4.71	4.20	4.70	4.55
Crude ash	4.51	6.61	7.47	5.22	7.24
NFE	73.97	66.37	65.41	65.66	68.52
Calcium	1.08	1.40	1.18	1.21	1.44
Phosphorus	0.23	0.54	0.50	0.44	0.58
DE (kcal/kg)[3]	3153	3204	3146	3206	3204

[1]Abbreviated: C, control; AFM, alfalfa meal; CLM, cassava leaf meal; REM, rubber seed meal; LM, leucaena meal;

[2]Contributed the following nutrients per kg of diet: Zn, 100 mg; Cu, 10 mg; Mn, 20 mg; Fe, 150 mg; Se, 1 mg; Vitamin A 4,000,000 IU; Vitamin D_3, 800,000IU; Vitamin E, 6,000IU; Vitamin K_3, 1,400 mg; thiamin, 800 mg; riboflavin, 2,000 mg; pyridoxine, 800 mg; cobalamine, 6,500 mg; Ca-pantothenate, 6,000 mg; niacin, 10,000 mg; folacin, 400 mg and ethoxyquine, 500 mg.

[3]Calculated value.

rubber band to cannula. The collection carried out for 12 hr on two days, started from 9:00 on d6 and from 7:00 on d7 by 2 hr interval which was similar to procedure used by Jorgensen et al. (1984). After each 2 hr of collection, the bags were removed and frozen. Fecal collection was made from 7:00 of d3 to 19:00 of d4 of each period. The collections for individual animal in each period were pooled, dried in an air-forced oven and ground through 1 mm screen.

Chemical analyses

The fiber sources, diets and collected samples were analyzed for proximate compositions by standard method (AOAC, 1984). The fiber fractions, including neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose and lignin were analyzed by Goering and Van Soest (1970) procedure. Chromic oxide in all samples was analyzed for the concentration by the method of Fenton and Fenton (1979). For amino acid analysis, the samples of 30-50 mg were hydrolyzed at 110℃ for 16 hr with 3 ml 6 N HCl and determined using amino acid analyzer (LKB model 4150 alpha).

Statistical analyses

The digestibility of amino acids was calculated according to Austreng (1978). The data were subjected to analysis of variance and the treatment means compared by Duncan's New Multiple Range Test using the Proc Anova of SAS (1985) procedure.

TABLE 2. PROXIMATE AND AMINO ACID COMPOSITION OF FIBER SOURCE USED IN EXPERIMENT

Component (%)	Fiber sources[1]			
	AFM	CLM	RSM	LM
Crude protein	23.55	25.20	28.20	15.80
Crude fiber	20.20	19.62	29.90	24.70
NDF	36.0	39.20	48.03	49.67
ADF	29.0	35.16	26.63	43.01
Hemicellulose	7.0	4.04	21.40	6.60
Cellulose	21.0	12.12	19.88	21.54
Lignin	7.0	7.97	5.47	8.78
Indispensable amino acids				
Arginine	0.32	3.47	1.04	0.54
Histidine	0.50	0.98	1.14	0.45
Isoleucine	0.34	0.54	0.58	0.88
Leucine	0.76	1.32	1.23	0.80
Lysine	0.50	0.84	0.61	0.60
Methionine	0.16	0.32	0.34	0.16
Phenylalanine	0.51	0.79	1.10	0.52
Threonine	0.49	0.83	0.74	0.49
Valine	0.45	0.61	0.94	0.39
Dispensable amino acids				
Alanine	0.58	1.06	1.00	0.57
Aspartic acid	1.49	2.10	2.25	1.72
Glutamic acid	1.26	2.19	3.58	1.33
Glycine	0.50	0.88	0.90	0.54
Proline	0.79	1.00	1.26	0.70
Serine	0.60	0.80	1.38	0.58
Tyrosine	0.28	0.55	0.55	0.33

[1]Abbreviated. AFM, alfalfa meal; CLM, cassava leaf meal; RSM, rubber seed meal; LM, leucaena meal.

Results and Discussion

Fiber source composition

The contents of proximate composition, fiber fraction and amino acids in the fiber sources used are presented in table 2. Rubber seed meal had the higher content of crude fiber and hemicellulose than the others while contained the lowest lignin content. Leucaena meal contained the highest fiber fractions, including NDF, ADF, cellulose and lignin content. Cassava leaf meal seems to have the lowest crude fiber content and moderate content of other fiber fractions. Alfalfa meal also had moderate fiber fraction contents and contained cellulose content similar to cassava leaf meal.

Most of indispensable amino acid contents were found higher in cassava leaf meal than other fiber sources, especially arginine and lysine. These were similar to the results reported by Nwokolo (1987). Rubber seed meal had better amino acid profile and high in histidine, methionine and glutamine content. These were similar to those reported by Toh and Chia (1977) but differed from those of other researchers (Babatunde and Pond, 1987; Narahari and Kotharadaman, 1983). This could be due to lack of uniformity of the products used, extraction process and presence of 'shell'. Methionine content were found to be the lowest in all fiber sources.

Crude protein in the diets ranged from 12.56 to 18.94% (RSM-diet) as shown in table 1 while ether extract ranged from 4.33 to 6.04%. Crude fiber and ash content ranged from 4.20 to 4.70 and 4.51 to 7.47%, respectively. NDF and hemicellulose content were the highest in AFM-diet whereas ADF and lignin found to be

TABLE 3. FIBER FRACTION AND AMINO ACID CONTENTS OF THE EXPERIMENTAL DIET

Components (%)	Dietary treatments[1]				
	C	AFM	CLM	RSM	LM
Crude fiber	4.60	4.71	4.20	4.70	4.55
NDF	4.75	9.30	8.60	8.19	7.23
ADF	1.12	6.67	6.14	5.90	9.55
Cellulose	0.97	2.15	2.82	4.65	4.53
Hemicellulose	0.63	2.63	2.46	2.29	2.32
Lignin	0.17	0.99	1.31	0.89	1.66
Dietary indispensable amino acids					
Arginine	0.92	0.72	1.40	1.27	0.99
Histidine	0.46	0.49	0.73	0.68	0.59
Isoleucine	0.40	0.36	0.64	0.54	0.55
Leucine	0.95	0.83	1.53	1.23	1.03
Lysine	0.81	0.62	1.19	0.97	0.81
Methionine	0.18	0.15	0.31	0.23	0.22
Phenylalanine	0.62	0.53	0.97	0.77	0.66
Threonine	0.48	0.44	0.82	0.82	0.56
Valine	0.38	0.40	0.68	0.55	0.47
Dietary dispensable amino acid					
Alanine	0.55	0.52	0.96	0.75	0.61
Aspartic acid	1.48	1.39	2.39	1.97	1.60
Glutamic acid	2.93	2.14	4.16	3.80	2.94
Glycine	0.54	0.47	0.90	0.74	0.60
Proline	0.75	0.72	1.20	1.02	0.91
Serine	0.72	0.84	1.10	0.96	0.79
Tyrosine	0.31	0.33	0.55	0.42	0.40

[1]Abbreviated: C, control; AFM, alfalfa meal; CLM, cassava leaf meal; RSM, rubber seed meal; LM, leucaena meal.

the highest in LM-diet table 3. Crude fiber and cellulose content were the highest in RSM-diet. The amino acid contents of the diets are also shown in table 3. Because isolated soy protein was the main protein source used, any difference in the concentration of amino acid in the diets were due to fiber source added. Since all diet included natural fiber sources, there were relatively low in sulfur amino aicd, not in lysine, which was also compatible with the finding by Nwokolo (1987).

The amino acid digestibility at terminal ileum

Inclusion of cassava leaf meal in the diets pronounced sound effect on amino acid digestibility as shown in table 4. The lowest values among diets in all digestibility values occurred for LM-diet and in proline for AFM-diet. Arginine tended to be the most digestible essential amino acid among all diets. This agreed well with the findings of Knabe et al. (1989). Proline was found to be the least digestible. The control diet containing cellulose as fiber source was relatively similar in amino acids digestibility to AFM-diet and RSM-diet. This indicated that cellulose content had no effect on amino acid digestibility as these diets varied in cellulose content. Lignin also seemed to have no deterious effect on amino acid digestibility in general, and contrasted to the reports by Shah et al. (1982), Nomani and Stansburry (1982). These were shown by different lignin content in CLM-diet (1.31%), AFM-diet (0.99%) and RSM- diet (0.89%), but CLM-diet had higher amino acids digestibility than the others. However, lignin might bind with individual amino acid, for instance, methionine and histidine (Howard et al., 1986). Moderately low values in phenylalanine, threonine and tyrosine digestibility

TABLE 4. EFFECT OF FIBER SOURCES ON APPARENT DIGESTIBILITY OF DRY MATTER, PROTEIN AND AMINO ACIDS MEASURED AT THE TERMINAL ILEUM OF GROWING PIGS

Components (%)	Dietary treatments[1]				
	C	AFM	CLM	RSM	LM
Dry matter	84.61	83.75	92.82	87.65	76.19
Crude protein	86.97	87.63	93.84	80.58	83.75
Dietary indispensable amino acids[2]					
Arginine	93.99^{bc}	92.94^{c}	98.05^{a}	96.34^{ab}	83.54^{d}
Histidine	80.81^{b}	83.97^{b}	93.84^{a}	84.99^{b}	56.72^{c}
Isoleucine	80.79^{b}	88.05^{ab}	93.79^{a}	86.65^{ab}	59.80^{c}
Leucine	87.14^{b}	91.22^{ab}	94.72^{a}	91.82^{ab}	66.38^{c}
Lysine	89.76^{b}	86.41^{b}	94.73^{a}	92.29^{ab}	70.77^{c}
Methionine	83.88^{b}	86.41^{ab}	94.57^{a}	89.69^{ab}	47.77^{c}
Phenylalanine	80.20^{b}	88.63^{a}	94.85^{a}	90.40^{a}	65.52^{c}
Threonine	81.42^{ab}	71.80^{bc}	93.76^{a}	87.04^{ab}	58.94^{c}
Valine	74.68^{b}	86.21^{a}	93.00^{a}	85.90^{a}	57.77^{c}
Dietary dispensable amino acids					
Alanine	81.96^{b}	88.07^{ab}	94.51^{a}	88.88^{ab}	53.11^{c}
Aspartic acid	91.06^{b}	91.57^{ab}	96.44^{a}	91.30^{b}	76.78^{c}
Glutamine	92.64^{a}	91.55^{a}	87.00^{a}	94.57^{a}	79.95^{a}
Glycine	72.37^{c}	80.73^{bc}	93.33^{a}	84.57^{ab}	52.06^{d}
Proline	82.40^{b}	21.48^{d}	93.96^{a}	89.24^{ab}	71.13^{c}
Serine	91.39^{b}	93.39^{a}	96.65^{a}	92.76^{ab}	78.20^{c}
Tyrosine	79.51^{b}	92.21^{a}	94.17^{a}	90.10^{a}	65.65^{c}
Mean	84.43	83.58	94.23	89.76	65.25

[1]Abbreviated: C, control; AFM, alfalfa meal; CLM, cassava leaf meal; RSM, rubber seed meal; LM, leucaena meal.

[2]Means with the different superscripts within the same row were significant difference ($p < 0.05$).

in the present study also agrees with the investigation by Bergner et al. (1981). An adverse effect on amino acid digestibility was observed with RSM-diet and AFM-diet suggested that the content of NDF and/or ADF responsible for the lowering digestibility.

The amino acid digestibility measured over the total tract

The digestibility of all amino acids in control diet and CLM-diet was the highest, and significance difference between treatments were found (table 5). The low DM digestibility of AFM-diet and RSM-diet obtained from non-digested material might depress the protein and amino acid digestibility as increased endogenous losses caused by mechanical erosion. Digestibility of almost all amino acids was found lower at fecal than ileal level, except for control and LM-diet. Higher content of fiber fractions increase the rate of endogenous loss of protein or carbohydrate from the intestinal wall and serve as substrates for microbial activity as suggested by Laplace et al. (1989). The LM-diet which was higher in fiber fraction contents than other diets might explain this finding. Methionine and/or histidine as well as glycine were found to be the least digestible among the diets whereas arginine was the most digestible.

Comparison of digestibility values measured at the terminal ileum and over the total tract.

The difference between ileal and fecal values of apparent amino acid digestibilities presented in table 6. Some ileal values were less than fecal but most ileal values were greater. Except for control and LM-diet, almost all amino acid digestibilities had higher values at ileal level

TABLE 5. EFFECT OF FIBER SOURCES ON APPARENT DIGESTIBILITY OF DRY MATTER, PROTEIN AND AMINO ACIDS MEASURED BY THE TOTAL TRACT OF GROWING PIGS

Components (%)	Dietary treatments[1]				
	C	AFM	CLM	RSM	LM
Dry matter	91.22	57.27	80.17	46.42	63.55
Crude protein	93.43	54.53	78.90	55.53	73.97
Dietary indispensable amino acids[2]					
Arginine	98.02^{a}	83.54^{c}	92.35^{ab}	84.37^{bc}	89.33^{bc}
Histidine	91.07^{a}	56.72^{bc}	81.99^{ab}	47.68^{c}	74.21^{ab}
Isoleucine	94.58^{a}	59.80^{c}	85.68^{a}	63.51^{bc}	77.91^{bc}
Leucine	95.76^{a}	66.88^{c}	88.05^{ab}	75.52^{bc}	78.90^{bc}
Lysine	95.75^{a}	70.77^{c}	90.24^{ab}	81.01^{b}	83.39^{b}
Methionine	92.94^{a}	47.77^{c}	82.88^{ab}	65.28^{bc}	73.17^{c}
Phenylalanine	95.49^{a}	65.52^{c}	87.97^{ab}	75.43^{bc}	78.90^{b}
Threonine	95.28^{a}	58.94^{d}	88.25^{ab}	72.67^{cd}	77.69^{bc}
Valine	93.56^{a}	57.77^{c}	88.15^{ab}	62.88^{c}	72.20^{bc}
Dietary dispensable amino acids					
Alanine	94.19^{a}	53.11^{c}	84.64^{ab}	67.44^{bc}	72.43^{b}
Aspartic acid	91.60^{a}	76.78^{b}	92.26^{a}	83.54^{ab}	86.83^{a}
Glutamine	96.73^{a}	79.95^{d}	95.10^{ab}	86.94^{c}	89.82^{bc}
Glycine	95.01^{a}	52.73^{d}	85.82^{ab}	66.99^{cd}	74.38^{bc}
Proline	97.14^{a}	71.62^{b}	89.50^{a}	71.71^{b}	81.13^{ab}
Serine	96.86^{a}	78.20^{c}	91.10^{ab}	80.04^{c}	82.66^{bc}
Tyrosine	93.26^{a}	65.65^{c}	84.89^{ab}	75.42^{bc}	79.76^{ab}
Mean	94.82	65.23	88.01	72.40	79.48

[1]Abbreviated: C, control; AFM, alfalfa meal; CLM, cassava leaf meal; RSM, rubber seed meal; LM, leucaena meal.

[2]Means with the different superscripts within the same row were significant difference ($p < 0.05$).

than fecal level. These result are contrasted to the experiments done by Mitaru et al. (1984). Glutamine, glycine and proline in some diets were higher at fecal than ileal level. Taverner and Farell (1981) reported that amino acids which disappeared in the large intestine were glycine, proline, serine and threonine; these amino acids are high in mucin protein (Horowitz, 1967) and endogenous ileal digesta (Taverner et al., 1981a), which might explain this finding. Methionine shows the greatest difference among the natural-fiber source diets. The average difference between ileal and fecal level was more than 10% (positive and negative), except for the CLM-diet (6.16%). These findings indicate that ileal analysis is more accurate for determining the digestibility of amino acids, particulay with high fiber diets.

In conclusion, the apparent digestibility of amino acids at ileal level was the highest in CLM diet while at fecal level control and CLM-diet were higher than the others. LM-diet was the least digestible at ileal level while at fecal level was AFM-diet. The digestibilities of amino acids at ileal were higher than fecal level except control and LM-diet. Arginine digestibility was the least affected by fiber fractions at both levels while methionine and/or histidine were the greatest affected at ileal and fecal level, respectively. Cellulose content did not affect the amino acid digestibility while lignin specified on some amino acids. On the basic of this finding, it appears that cassava leaf meal is an acceptable source of feedstuff for pigs as it is utilized efficiently despite its fiber content.

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TABLE 6. COMPARISON ON THE APPARENT DIGESTIBILITIES OF DRY MATTER, PROTEIN AND AMINO ACID MEASURED AT THE TERMINAL ILEUM AND THE TOTAL TRACT

Components (%)	Dietary treatments[1]				
	C	AFM	CLM	RSM	LM
Dry matter	−6.61	26.48	12.65	57.99	12.64
Crude protein	−6.46	33.10	14.94	35.88	9.78
Dietary indispensable amino acids					
Arginine	−4.03	9.40	5.70	11.47	−5.79
Histidine	−10.26	27.25	11.85	37.31	−17.49
Isoleucine	−13.79	28.25	8.11	23.14	−18.11
Leucine	−8.62	24.34	6.67	16.30	−12.52
Lysine	−5.99	15.64	4.49	11.28	−12.62
Methionine	−9.26	38.64	11.69	24.41	−25.40
Phenylalanine	−15.29	23.11	6.88	14.97	−13.38
Threonine	−13.86	12.86	5.51	14.37	−18.75
Valine	−18.88	28.44	4.85	23.02	−14.43
Dietary dispensable amino acids					
Alanine	−12.23	34.96	9.87	21.44	−19.32
Aspartic acid	−0.54	14.79	4.18	7.76	−10.05
Glutamine	−4.09	11.60	−8.10	4.63	−9.87
Glycine	−22.64	28.00	7.51	17.58	−22.32
Proline	−14.74	−50.14	4.46	17.53	−10.00
Serine	−5.47	15.19	5.55	2.72	−4.46
Tyrosine	−13.75	25.56	9.28	14.68	−11.11
Mean	−10.83	18.06	6.16	16.41	−14.10

[1]Abbreviated: C, control; AFM, alfalfa meal; CLM, cassava leaf meal; RSM, rubber seed meal; LM, leucaena meal.

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