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Chemical composition of plantain foliage (*Musa paradisiaca*) and the effect of its inclusion in the diet on nutrient digestibility in pig

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ABSTRACT

Plantain foliage (PF) meal contained, on dry basis, 626.9 g/kg NDF, 445.3 g/kg ADF, 86.5 g/kg lignin, 123.0 g/kg N x 6.25, 148.6 g/kg ash, 16.90 MJ/kg DM gross energy. The effect of feeding PF on nutrient digestibility in the pig was investigated in either ileorectostomized or intact pigs fed graded levels of PF 0, 100 and 200 g/kg in the diet, respectively). PF significantly decreased ileal and faecal digestibility of most nutrients. The contribution of the large intestine to the digestion of diets ranged from 13.0 to 22.5% of energy disappearance in the gastrointestinal tract. Estimated ileal and faecal crude protein digestibility of PF meal was 34.7 and 50.8% whereas *in vitro* crude protein digestibility of PF meal accounted for 42.0%, thus indicating a rather low availability of crude protein in the biomass. Daily ileal and faecal output of both short chain fatty acids (SCFA) and ammonia showed a trend to be proportional to the level of PF in the diet. It is suggested that PF meal should be used at low levels of inclusion in the pig's diet if a negative effect on nutrient digestibility is to be avoided.

KEY WORDS: pigs, plantain foliage meal, digestibility, fermentation

INTRODUCTION

Although it has long been recognized that feeding of pigs with either banana or plantain foliage (PF) residues is a common practice in the tropics (e.g. Nitis, 1968; Falvey and Visitpanich, 1979), there are very few reports concerning the nutritive value of this type of biomass for pigs as compared to other species such as ruminants (Ffoulkes et al., 1978; Hagemeister and Ahrens, 1986) or rabbits (Carew et al., 1989).

On the other hand, PF has been claimed to contain protein levels as high as 14.2% (Carew et al., 1989) or 16.1% (Devendra, 1979), but its digestibility has not been well established in non-herbivorous, monogastric animals that are capable of only otherwise constrained to perform a relatively limited utilisation of the protein fraction of crop residues due to the its high proportion of cell wall constituents in the residues (Low, 1985). However, preliminary studies conducted with young pigs indicated that low levels of PF meal in the diet did not impair neither performance traits nor digestibility of nutrients (Garcia and Ly, 1994; 1995).

The aim of the study was to determine the composition of PF and to study the effect of graded levels of PF in the diet on the nutrient digestibility in pigs.

MATERIAL AND METHODS

Plantain foliage preparation

The PF was from a variety (*Musa paradisiaca*) common in Havana province, Cuba, collected during fruit harvesting. The leaves and about one third of the pseudo-stem were ground then sun-dried and milled. The resulting batch of PF meal was used for approximate chemical analysis and in digestion trials on pigs.

Digestion studies

A basal diet (PFO) consisting of maize and soyabean meal was partially replaced by graded levels of PF meal in digestion studies with pigs. The composition of the experimental diets and their chemical characteristics are shown in Table 1.

Two separate trials (Experiments 1 and 2) for ileal and faecal digestibility measurements were conducted with YLD castrated male pigs with a mean live weight of approximately 50 kg.

Experiment 1. The ileal digestibility study was conducted on three pigs that were prepared with an end-to-end ileo-rectal anastomosis according to Green et al. (1987). Each pig was randomly assigned to one of the three dietary treatments in a 3 x 3 Latin square design. The animals were maintained in adjustable metabolism crates. The temperature of the room was not controlled and was about 28°C. The average daily feed supply was 0.08 kg DM per kg $W^{0.75}$ and the

TABLE 1

Composition of the diets

Indices	Diets		
	PF0	PF10	PF20
Ingredients, g/kg			
maize meal	747	670	596
soyabean oilmeal	223	201	178
plantain foliage meal	–	100	200
$CaHPO_4 \cdot 2H_2O$	10	10	10
$CaCO_3$	5	5	4
NaCl	5	5	4
vitamins and trace elements	10	9	8
Chemical composition, g/kg			
Dry matter	921.5	923.3	925.0
In dry matter:			
ash	34.3	45.8	57.1
organic matter	965.7	954.2	942.9
crude protein	165.6	161.3	156.3
crude fibre	37.1	69.3	101.5
NDF	114.9	166.9	217.3
Gross energy, MJ/kg DM	18.0	17.9	17.8

[1] supplied per kg diet: 27 mg $FeSO_4 \cdot 7H_2O$, 10 mg $MnSO_4 \cdot 4H_2O$, 15 mg $CuSO_4 \cdot 5H_2O$, 85 mg $MgSO_4 \cdot 7H_2O$, 0.3 mg $CoSO_4 \cdot 7H_2O$, 0.1 mg KI, 0.02 mg Na_2SeO_3, 1600 I.U. vitamin A, 300 I.U. vitamin D_3, 2 mg thiamine, 3 mg riboflavine, 300 mg choline, 15 mg niacin, 5 mg panthotenic acid, 15 mg pyridoxine, 0.5 mg folic acid, 25 mg cyanocobalamine

animals were weighed weekly for the purpose of adjusting feed allowance. The diets were offered twice daily at two equal meals at 9:00 and 15:00 h. Drinking water was given *ad libitum*.

Continuous collection of digesta for 2 consecutive days was preceded by 5 days of adaptation to the experimental diet. The procedure for collection of digesta and samples preparation was described by Ly et al. (1995).

Experiment 2. Faecal digestibility measurements were performed by the indirect indicator method (AIA), on six intact pigs which were allocated to the treatments according to a double 3 x 3 Latin square design. After a 7 day adaptation period in individual pens, a grab samples were taken. The level of feeding was adjusted to the initial live weight and was maintained constant during each sampling period. The level of feed intake was as described in Experiment 1.

In addition to the *in vivo* digestibility studies, the *in vitro* crude protein digestibility of PF meal was assayed by the technique of Dierick et al. (1985)

Chemical analyses

Chemical composition of feeds and faeces was determined according to AOAC methods (1990) and gross energy in an adiabatic bomb calorimeter. Composition of cell wall constituents was estimated as outlined by Van Soest and Wine (1967). Lignin was measured by 72% sulphuric acid digestion of acid detergent fibre (ADF) according to van Soest (1963), and detergent tannins according to Conklin et al. (1987) methods.

All amino acids, except tryptophan and sulphur amino acids, were determined in defatted samples after acid hydrolysis by the standard technique as described by Coto et al. (1981) on Carlo Erba automatic amino acid analyser.

Ileal samples were thoroughly mixed and a fresh aliquot was used to determine N (AOAC,1990), pH by a glass electrode, and fermentation indices. Total short chain fatty acids (SCFA) were estimated by titration after steam distillation according to Ly (1986), and ammonia was determined by microdifusion analysis (Conway, 1962). Another sample of ileal material was oven dried (C) and ground to pass a 1 mm sieve.

Acid insoluble ash was estimated according to the method of Van Keulen and Young (1977).

Statistical analyses

The differences between digestibility values were examined by analysis of variance (Steel and Torrie, 1980), with means compared by Duncan's new multiple range test.

RESULTS AND DISCUSSION

Chemical composition of plantain foliage meal

The results shown in Table 2 indicate that PF meal was characterized by a its high cell wall content. Cellulose (ADF – detergent lignin) was the main cell wall constituent and the cellulose : hemicllulose ratio was approximately 2. In contrast, Garcia et al. (1973) and Pezo and Fanola (1980) found a cellulose : hemicellulose ratio of 1 for both banana leaves and stalks, respectively. This discrepancy is difficult to explain, although differences in the examined species of *Musa* could partially account for it. On the other hand, detergent tannins accounted for 83.7 g/kg DM, a value equivalent to that of detergent lignin.

An important characteristic of the PF meal was its that of the relatively low level of crude protein (123.0 g/kg). However, more than 60% of nitrogen was

TABLE 2

Composition of plantain foliage meal, g/kg DM

Dry matter	939.2
In dry matter:	
ash	148.6
crude protein (N x 6.25)	123.0
ether extract	64.0
crude fibre	359.4
N-free extractives	304.8
NDF	626.9
ADF	445.3
cellulose	358.8
detergent lignin	86.5
detergent tannins	83.7
Gross energy, MJ/kg DM	16.9

TABLE 3

Amino acid composition of plantain foliage meal

	g/kg DM	g/16 g N
Amino acids:		
aspartic acid	6.60	6.08
threonine	2.87	2.64
serine	2.87	2.64
glutamic acid	8.41	7.74
proline	2.66	2.45
glycine	4.90	4.51
alanine	4.26	3.92
valine	4.47	4.12
isoleucine	3.51	3.23
leucine	5.43	5.00
tyrosine	6.50	5.99
phenylalanine	2.70	2.49
histidine	1.34	1.23
lysine	2.34	2.16
arginine	2.13	1.96

[1] cystine, methionine and tryptophan were not determined

present in the form of amino acids. The amino acid composition of PF meal is shown in Table 3.

Ileal and faecal digestibility of plantain foliage meal

A low level of feed intake such as that used in the present study did not allow feed refusals in any circumstance, in spite of the bulking properties of the diets.

TABLE 4

Ileal and faecal flow of digesta and water

Indices	Diets			SE
	PF0	PF10	PF20	
Experiment 1				
Ileal flow, g/day per kg DM intake				
fresh digesta	2136[a]	2623[b]	2940[b]	237*
water	1882[a]	2322[ab]	2616[b]	210*
Ileal DM, %	11.92[a]	11.47[ab]	11.00[b]	0.10*
Experiment 2				
Faecal flow, g/day per kg DM intake				
fresh faeces	319[a]	501[ab]	993[b]	130*
water	217[a]	364[ab]	713[b]	103*
Faecal DM, %	31.93	27.36	28.26	0.92+

+ $P<0.10$
* $P<0.05$
a, b <0.05

On the other hand, post-mortem examination of gastrointestinal tract showed no abnormalities in the ileorectostomized pigs.

A significant effect ($P<0.05$) of the diet was found on daily ileal and faecal fresh output and water flow (Table 4). On the other hand, the introduction of graded levels of PF meal appeared to be associated with a decrease in DM concentration in both sites of measurements. These results are in accordance with other observations where ileal and faecal flow of either fresh material or water were associated with an increase in the proportion of cell wall constituents in the diet (Sandoval et al.,1987; Cherbut et al.,1988; Longland and Low,1989).

Substitution of the basal diet with an increasing proportion of PF meal resulted in a reduction of both ileal and faecal digestibility of nutrients (Table 5). This effect achieved a higher significance ($P<0.01$) on ileal crude fibre and NDF digestibility. However, ileal ash and energy digestibility appeared not to be influenced by the type of diet given to the pigs. Ileal digestibility of some fractions of fibre has been documented after feeding a variety of diets (Vervaeke et al., 1991; Shi and Noblet, 1993). In this connection Graham (1988) has suggested that some dietary fibres can be degraded in the small intestine thus facilitating a more complete pre-caecal digestion of other nutrients. Faecal digestibility of most nutrients and energy in the diet with the highest level of PF was significantly different ($P<0.05$) from the basal diet (PFO).

The contribution of the large intestine to the digestion of diets ranged from 13.0 to 22.5% of energy disappearance in the gastrointestinal tract. These data

TABLE 5

Ileal and faecal digestibility of nutrients and energy, %

Indices	Diets			SE
	PF0	PF10	PF20	
Ileal digestibility				
dry matter	74.5[a]	69.9[ab]	67.6[b]	1.1*
ash	38.4	39.5	44.0	1.4
organic matter	77.5[a]	73.0[ab]	70.2[b]	1.1*
nitrogen	69.2[a]	67.3[ab]	60.7[b]	1.8*
crude fibre	21.5[a]	11.3[b]	5.0	8**
NDF	45.6[a]	33.5[b]	22.2	9**
energy	73.7	69.5	68.8	1.4
Faecal digestibility				
dry matter	90.8[a]	87.9[a]	78.2[b]	1.2*
ash	58.8[a]	64.0[a]	47.4[b]	1.3*
organic matter	91.9[a]	89.1[a]	80.1[b]	1.2*
nitrogen	86.6[a]	83.2[ab]	80.8[b]	1.8*
crude fibre	72.4[a]	66.5[ab]	49.1[b]	3.7*
NDF	75.4[a]	66.7[ab]	58.8[b]	2.5*
energy	91.3[a]	89.7[a]	79.1[b]	1.4

* $P<0.05$; ** $P<0.01$

[a, b, c] <0.05

are in accordance with those of Shi and Noblet (1993) who reported that the large intestine contributed 16 and 25% of total DE in growing pigs and sows, respectively. A similar range was obtained for N digested in the large intestine (19.1-24.8%, respectively). On the other hand, in agreement with other previous studies (Chesson et al., 1985; Shi and Noblet, 1993) the present experiments showed that a large proportion of different fibre fractions was extensively digested in the caecum and colon. Since cellulose is generally considered to be the predominant cell wall constituent in crude fibre, then it could be assumed that cellulose degradation in the large intestine was substantial.

In vitro crude protein digestibility revealed a rather low value for PF meal (Table 6). Ileal and faecal crude protein digestibility estimated by difference were low too (34.7 and 50.8%, respectively). Low crude protein digestibility estimated *in vitro* has been reported also in grass meal (Dierick et al.,1985). Therefore, it is very probable that a great proportion of protein is linked to the fibre fraction of the foliage of plantains, and due to it enzymatic breakdown of those polypeptides must be inhibited.

A significant increase ($P<0.05$) in ileal SCFA concentration with the increase of PF meal in the diet was observed (Table 7). A similar trend was found in faecal

TABLE 6

Contribution of the large intestine in digestion of diets

Indices	Diets		
	PF0	PF10	PF20
Digestibility, %			
dry matter	16.3	18.0	10.6
ash	20.4	24.5	3.4
organic matter	14.4	16.1	9.9
nitrogen	17.4	15.9	20.1
crude fibre	50.9	55.2	44.1
NDF	29.8	33.2	36.6
energy	17.6	20.2	10.3
Contribution to overall digestion, %			
dry matter	18.0	20.5	13.6
ash	34.7	38.3	7.2
organic matter	15.7	18.1	12.4
nitrogen	20.1	19.1	24.8
crude fibre	70.3	83.0	89.8
NDF	39.5	49.8	62.2
energy	19.3	22.5	13.0

TABLE 7

In vivo and *in vitro* crude protein digestibility, %

	Casein	PF meal
In vivo digestibility[1]		
ileal	–	34.7 ± 3.2
faecal	–	50.8 ± 9.4
In vitro digestibility	96.4 ± 1.11	42.0 ± 8.7

[1] calculated by difference (see text)

SCFA concentration ($P<0.10$). In contrast, NH_3 concentration in both ileal digesta and faeces appeared not to be influenced by the diet. On the other hand, the pH showed a trendency to decrease ($P<0.10$) in the content of the ileum or to increase ($P<0.05$) in faeces. Daily faecal flow of end-products of fermentative activity showed a significant augmentation ($P<0.01$) with the increased introduction of graded levels of PF meal in the diet. This same effect was weaker ($P<0.10$) for daily ileal flow of SCFA. In this connection, a highly significant ($P<0.001$) interdependence between daily flow of SCFA and organic matter digestibility was noted in both sites of measurements and were in agreement with previous observations made by Jentsch et al. (1990) and Ly et al. (1995).

TABLE 8

Ileal and faecal indices of fermentation in pigs

Indices	Diets			SE
	PF0	PF10	PF20	
Experiment 1				
Ileal concentration, mmol/100 g DM				
SCFA	53.24[a]	88.87[b]	101.25	8.21*
NH_3	9.98	7.28	10.94	2.10
Ileal pH	6.60	6.47	6.20	0.15[1]
Daily ileal flow, mmol/kg DM intake				
SCFA	194.37	410.99	662.22	218.35⁺
NH_3	25.36	22.13	34.86	3.47
Experiment 2				
Faecal concentration, mmol/100 g DM				
SCFA	55.45	68.71	67.95	15.20
NH_3	15.43	19.26	17.00	0.89
Faecal pH	5.76[a]	5.86[ab]	6.06[b]	0.05*
Daily faecal flow, mmol/kg DM intake				
SCFA	6.32[a]	93.38[b]	189.12	5.54**
NH_3	14.26	23.16[b]	36.96	1.60**

$^{+}$ $P<0.10$; * $P<0.05$; ** $P<0.01$

[a, b, c] – $P<0.05$

CONCLUSIONS

It can be concluded from the results of this study that both ileal and faecal digestibility of nutrients in the pig is reduced with increasing amounts of a tropical fibre source such as a foliage of plantain in the diet. Thus, a greater understanding of the physiological influences of fibre requires more information on the chemical composition of the cell wall of this feed. Moreover, methods to improve either crude protein or fibre digestibility in the pig would be of great utility in this type of biomass that is of great availability in the tropical environment.

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STRESZCZENIE

Skład chemiczny liści i łodyg bananowca (PF) i wpływ mączki PF na strawność składników pokarmowych diety u świń

Skład suchej masy PF jest następujący (g/kg): białko ogólne 123,0; popiół 148,6; NDF 626,9; ADF 445,3; lignina 86,5, oraz 16,9 MJ energii brutto/kg. Udział PF w dawkach dla świń z przetokami i nieprzetokowanych wynosił 0,100 i 200 g/kg. Dodatek PF istotnie obniżył strawność większości składników pokarmowych. Udział procesów trawiennych w jelicie grubym w stosunku do strawności w całym przewodzie pokarmowym wyrażony ubytkiem energii wynosił 13,0 do 22,5%. Strawność białka PF oznaczona do końca jelita cienkiego i do końca przewodu pokarmowego wynosiła 34,7 i 50,8% odpowiednio, podczas gdy oznaczona *in vitro* 42,0%. Dzienne wydzielanie krótkołańcuchowych kwasów tłuszczowych i amoniaku w jelicie cienkim i kale było proporcjonalne do udziału PF w diecie.

Wyniki wskazują, że mączka PF może być stosowana w małych ilościach w żywieniu świń, jeżeli da się uniknąć ujemnego jej wpływu na strawność składników pokarmowych.