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Ileal and total tract digestibility in growing pigs fed cassava root meal and rice bran with inclusion of cassava leaves, sweet potato vine, duckweed and stylosanthes foliage

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Abstract

Four F1 (Large White x Mong Cai), crossbred pigs, surgically fitted with post-valve T-caecum (PVTC) cannulas, were used in a 4*4 Latin square arrangement to determine the nutritive value of feeds in which the foliages from sweet potato, cassava, duckweed and stylosanthes provided 30% of the dry matter of the diet, the remainder of which was a mixture (50: 50) of cassava root meal and rice bran.

The diets with fresh water spinach or fresh cassava leaves had a higher apparent digestibility of organic matter in the total digestive tract but not at the level of the ileum, when compared with the diets containing sweet potato vines or stylosanthes foliage. Apparent digestibility of crude protein was also higher on the diets with water spinach and cassava leaves but the differences were confounded by different concentrations of crude protein in the foliages, and were not significant when the digestibility coefficients were corrected by covariance for differences in protein content of the diets.

The total tract apparent digestibility of the crude fiber ranged from 44 to 51%, and did not differ among diets. On all the diets, a substantial proportion of the crude fiber (close to 40%) was digested pre-caecally.

Key words: Crude protein, fiber, caecum

Digestibilidad íleal y total de cerdos en crecimiento alimentados con harina de raiz de yuca y salvado de arroz con la inclusión de hojas de yuca, batata dulce, lemna y follaje de stylosanthes

Resumen

Cuatro cerdos F1 (Large White x Mong Cai), con canulas post-válvula T-ciego insertadas quirúrgicamente, se asignaron en un arreglo de cuadro latino 4*4 para determinar el valor nutritivo de alimentos en los cuales el follaje de batata dulce, yuca, lemna y stylosanthes suministraba el 30% de la materia seca de la dieta, el porcentaje restante fue una mezcla (50:50) de harina de raiz de yuca y salvado de arroz.

Las dietas con lemna u hojas frescas de yuca presentaron una mayor digestibilidad aparente de la materia orgánica en el total del tracto digestivo pero no a nivel del íleon, al compararlas con las dietas que contenian batata dulce o follaje de stylosanthes. La digestibilidad aparente de la proteína cruda fue también mas alta en las dietas con lemna y hojas de yuca pero las diferencias se confundieron por concentraciones diferentes de proteína cruda en los follajes, y no presentaron significancia cuando los coeficientes de digestibilidad se corrigieron mediante covarianza por las diferencias en el contenido de proteína de las dietas.

La digestibilidad aparente de la fibra cruda en el total del tracto digestivo estuvo entre 44 y 51%, y no presentó diferencia entre las dietas. En todas las dietas, una proporción importante de la fibra cruda (cerca del 40%) fue digerida antes del ciego.

Palabras clave: Proteína cruda, fibra, ciego

Introduction

In smallholdings, in remote area in Central Vietnam, many farmers have not enough money to buy the high quality protein sources such as fish meal and soybean meal but are able to produce plants the leaves of which can be relatively high in protein. Examples of these potential protein sources are the foliages from duckweed, cassava, sweet potato and stylosanthes.

Sweet potato (*Ipomoea batatas* L) is the third important crop in Vietnam after rice and maize and in 2001 occupied 245,000 ha (Statistical Yearbook 2002). The leaves have a protein content ranging from 26 to 33% in the dry matter (DM) and have been used successfully as supplementary feed for different classes of livestock (Dominguez 1992; Woolfe 1992; Moat and Dryden 1993; Ishida et al 2000; Le Van An and Lindberg 2004).

Duckweed (*Lemna* spp) is a small floating aquatic plant which grows on natural pond surfaces. They flourish in different climates and are fast growing and when adequately fertilized may contain up to 40% protein in DM (Porath et al 1979; Bui Xuan Men 1995; Skillicorn et al 1993; Leng et al 1995) Duckweed protein has a more balanced array of essential amino acidy, than most vegetable proteins and closely resembles animal protein according to Culley and Epps (1978).

Cassava (*Manihot esculenta)* is an annual crop widely grown in tropical countries. The leaves are rich in protein, carotene and minerals, and for this reason they are considered to be a potential source of animal feed in tropical countries (Gohl 1993; Preston and Leng 1987; Wanapat 1997).

Stylosanthes guianensis (Stylo) is a legume that has been introduced in many tropical countries (Mannetje and Jones 1992). It has been reported to produce between 12 and 17 tonnes of DM/ha/yr with 14 to 18 % crude protein in the DM (Satjipanon et al 1995). According to Mannetje and Jones (1992), the DM digestibility of young plant material lies between 60 to 70%, but with increasing age and lignification this may be reduced to below 40%.

The objective of the research described in this paper was to determine the nutritive value of feeds for growing pigs in which the foliages from the above plants were used as the only protein source for supplementing low-protein energy sources derived from cassava root meal and rice bran.

Materials and methods

Animals and experimental design

Four F1 (Large White x Mong Cai), crossbred pigs (two castrated males and two intact females) with an average live weight of 60 ±1.7 kg were given four diets according to a 4 x 4 Latin Square design. The energy component of the diets was a mixture (1:1) of cassava root meal and rice bran. The four test diets contained the energy component plus dried meals of either sweet potato vine (SPV), duckweed (DW), cassava leaves (CL) or Stylo foliage (SV), all of which were included at the level of 30% of total diet DM. The pigs had been vaccinated against pasteurellosis and hog cholera, and surgically fitted with post-valve T-caecum (PVTC) cannulas to allow collection of ileal digesta (Van Leeuwen et al 1991).

The four experimental diets were introduced to the pigs two weeks post-surgery. The experimental periods were for

14 d, comprising 5 d for adaptation to each diet followed by 4 d of collection of faeces, 1 d of collection of ileal digesta, 1 d of rest and finally a second day of collection of ileal digesta.

The pigs were housed individually in pens which had a floor area of 3 m^2. During digesta collection the pigs were restricted to a limited space within the pen

Diets and feeding system

Sweet potato vines (SPV) were harvested 70 days after planting, were chopped into small pieces (1-2 cm long) and then spread out on a concrete floor overnight for wilting to reduce the moisture content. They were then dried in an oven at 45°C for about 12 h. The same procedure was followed for cassava leaves (which were collected at the time of harvesting the roots), for duckweed (collected from natural ponds) and stylo foliage (harvested 60 days after planting). The dried materials from the four sources were then milled through a 1 mm screen and stored in a dry environment.

Chromium oxide was included in the diets as an indigestible marker. All diets were supplemented with a standard mixture of vitamin, minerals and trace elements formulated according to the requirements proposed by NRC (1988).

The test diets were offered to the pigs in two meals daily at 06:00 and 18:00 h). Water was freely available from nipple drinkers.

Sample collection

The samples of ileal digesta were collected for one hour every second hour during a 12 h collection period, using a soft plastic tube connected to the ileal cannula. For each experimental period there were thus 12 samples which were weighed, homogenized and immediately frozen (-18ºC) after collection. At the end of each collection period, the samples were thawed, homogenized, sub-sampled and dried at 60ºC. Faeces were collected daily and stored at 4ºC. At the end of each experimental period the samples were polled and mixed. Sub-samples were taken and dried at 60ºC. The dried samples of ileal digesta and faeces were milled through a 1 mm screen prior to chemical analysis.

Chemical analysis

The chemical composition was determined according to the methods of AOAC (1984). Dry matter (DM) content was measured by drying at 105ºC for 24 h. Nitrogen was determined by the Kieldahl method and crude protein expressed as N*6.25. For faeces and ileal digesta the nitrogen determination was done on the fresh samples. Ether extract (EE) was determined by Soxhlet extraction. Ash was the residue after ashing the samples at 600ºC. Chromium oxide in feed, faeces and digesta was determined according to the method of Fenton and Fenton (1979).

Statistical analysis

Analysis of variance was performed according to a 4 x 4 Latin Square design using the General Linear Model (GLM) procedure of the Minitab Software (Version 12) (Minitab 1998). Sources of variation were treatment, pigs, periods and error.

Results

There were major differences in the chemical composition of the four protein sources (Table 1). Crude protein was highest in duckweed, followed by cassava leaves with lowest values for sweet potato vines and stylo foliage. Crude fibre was highest in stylo and lowest in duckweed and cassava leaves with intermediate values for sweet potato vines.

Table 1. Chemical composition of feed ingredients

	Dry matter, %	Crude protein, % in DM	Crude fat, % in DM	Crude fiber, % in DM	Ash, % in DM
Rice bran	90	11.3	9.7	7.8	8.5
Cassava root	89	2.3	2.1	3.1	2.3
Duckweed	92	31.7	3.2	8.7	3.8
Sweet potato vine	84	17.0	5.4	14.2	5.6
Stylo foliage	87	17.3	2.5	20.5	5.5
Cassava leaves	85	26.5	4.7	8.5	3.4

The composition of the test diets (Table 2) reflected the differences in the composition of the protein sources, with lowest levels of crude protein and highest levels of crude fiber in the Stylo diet, with exactly the opposite trend for the DW diet.

Table 2. Proportions of ingredients and chemical composition of the diets

	DW	CL	SPV	Stylo
Ingredients, % DM basis				
Rice bran	34	34	34	34
Cassava root	34	34	34	34
Sweet potato vine	0	0	30	0
Duckweed	30	0	0	0
Cassava leaves	0	30	0	0
Stylo foliage	0	0	0	30
Mineral-vitamin mix.	1.6	1.6	1.6	1.6
Chromic oxide	0.4	0.4	0.4	0.4
#Chemical composition, % in DM				
Organic matter	95	95	94.7	94.7
Crude protein	14.0	13.3	8.18	8.42
Crude fat	5	5.4	5.6	4.8
Crude fiber	5.85	6.23	7.8	9.58
Ash	4.8	4.7	5.3	5.3

 # Derived from recorded intakes and chemical analyses of samples

The intakes of crude protein also reflected the composition of the four sources of supplementary protein, with highest values for the diet containing duckweed followed by the diet with cassava leaves and with lowest values for the stylo diet (Table 3). DM intakes were relatively low on all diets when expressed as a function of live weight (range from 2.2 to 2.5 g/kg live weight).

There were no differences among diets in ileal apparent digestibility of organic matter. The values for crude protein apparent digestibility mirrored those for crude protein intake with highest values for the duckweed diet and lowest values for the stylo diet. These differences can be explained by the decreasing proportion of endogenous N in the faeces when dietary intake of crude protein increases. Adjusting the apparent digestibility coefficients by covariance using dietary crude protein concentration as the covariate reduced the differences to the point where they were no longer significant (P=0.08). As expected the values of apparent digestibility of the crude fiber at the level of the ileum were low for all diets with no differences among them. Total tract apparent digestibility of crude fiber was higher for the duckweed and cassava leaf diets than for those with sweet potato vines or stylo foliage. Surprisingly, this difference appeared to reflect a greater proportion of the diet organic matter being digested in the large intestine and caecum in the case of the duckweed and cassava leaf diets, compared with those containing sweet potato vines or stylo foliage. On all the diets the greater part of the digestion of the crude fiber took place post-ileum., with no differences among the diets.

Diet crude fiber content was negatively related with total tract digestibility of OM (Figure 2) but not with ileal digestibility of OM (Figure 1). There were indications (P = 0.19 and 0.12) that ileal and total tract digestibility of crude protein was negatively related to the concentration of crude fiber in the diet (Figures 3 and 4). In contrast, ileal and total tract digestibility coefficients for organic matter and crude protein were positively correlated with the crude protein of the diet (Figures 5, 6, 7 and 8).

Table 3. Mean values for feed intake and apparent ileal and total tract digestibility of the experimental diets

	DW	CL	SPV	Stylo	SEM	Prob.
Mean daily intake, g/d						
Dry matter	1373	1177	1583	1422	124	0.24
Crude protein	189	157	129	120	15.4	0.068
Crude fibre	87.3	85.2	103	132	10.3	0.057
Crude protein, g/kg DM	140[a]	133[a]	81.8[b]	84.2[b]	7.9	0.003
Ileal apparent digestibility, %						
Organic matter	81.7	80.9	81.2	79.6	0.52	0.08
Crude protein	73.2[d]	69[c]	65.7[b]	60.7[a]	1.13	0.004
Crude protein#	70.4	66.9	68.3	63	2.3	0.08
Crude fat	59.8[c]	55.9[bc]	52.5[ab]	49.5[a]	1.73	0.01
Crude fiber	21.1	18.3	18.1	17.1	1.2	0.16
Total tract apparent digestibility, %						
Organic matter	87.9[b]	88.4[b]	84.8[a]	83.8[a]	0.63	0.001
Crude protein	75.7[c]	72.8[c]	68.7[b]	63.6[a]	1.1	0.004
Crude protein#	73	70.8	71.1	65.8	2.4	0.12
Crude fat	65.1[a]	62.2[a]	58.7[b]	54.3[b]	1.78	0.01
Crude fiber	49.2[a]	50.76[a]	46.4[b]	43.9[b]	1.47	0.03
Proportion of total tract apparent digestibility that occurred post-ileum, %						
Organic matter	7.05	8.54	4.25	5.01		
Crude protein	3.30	5.22	4.37	4.56		
Crude fat	8.14	8.54	4.25	5.01		
Crude fiber	57.1	63.9	61.0	61.0		

 # Corrected by covariance for differences in the crude protein content of the diets

a bc Means with different superscripts within rows are different at P<0.05

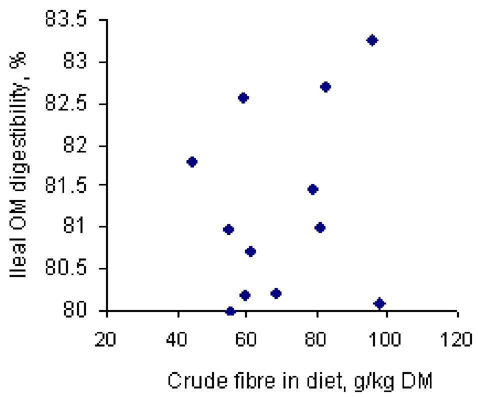

Figure 1. Relationship between crude fiber content of the diet and ileal digestibility of organic matter

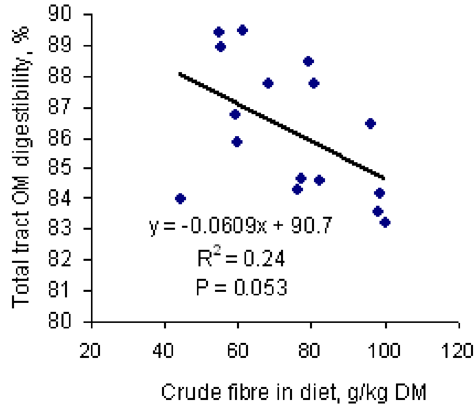

Figure 2. Relationship between crude fiber content of the diet and total tract digestibility of organic matter

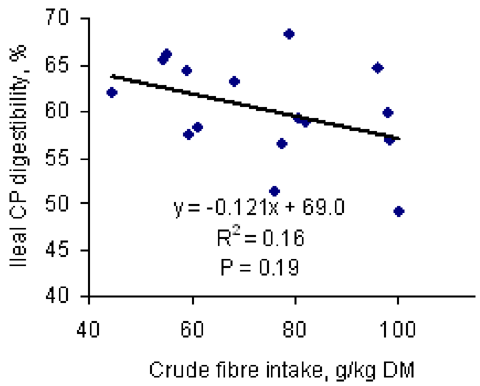

Figure 3. Relationship between crude fiber content of the diet and ileal digestibility of crude protein

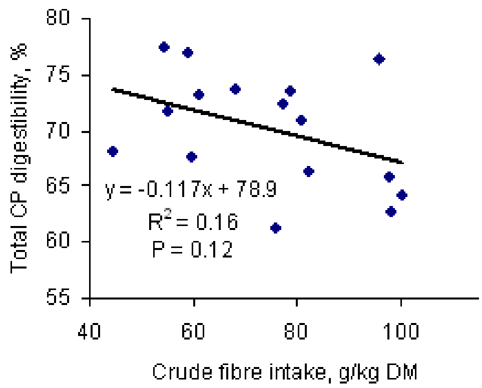

Figure 4. Relationship between crude fiber content of the diet and total tract digestibility of crude protein

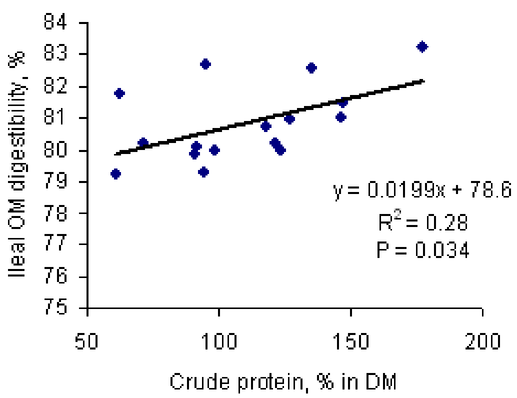

Figure 5. Relationship between crude protein content of the diet and ileal digestibility of organic matter

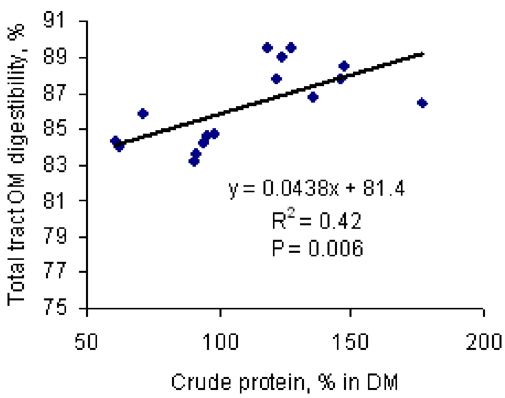

Figure 6. Relationship between crude protein content of the diet and total tract digestibility of organic matter

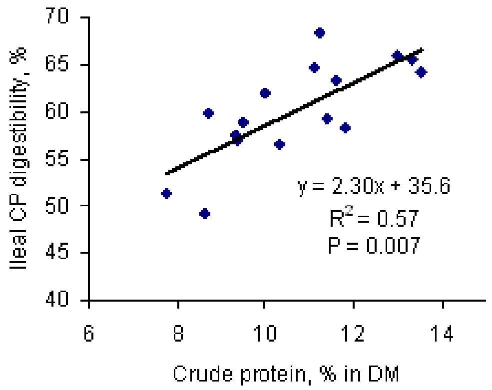

Figure 7. Relationship between crude protein content of the diet and ileal digestibility of crude protein

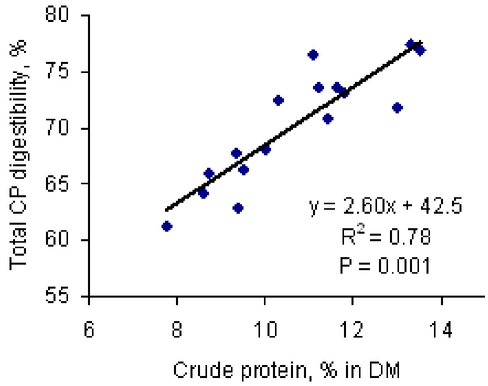

Figure 8. Relationship between crude protein content of the diet and total tract digestibility of crude protein

Discussion

Reports in the literature (Low 1982; Graham et al 1986; Fernandez and Jorgensen 1986; Graham and Aman 1987a,b) show conclusively that addition of fiber to the diet leads to lower apparent ileal digestibility of starch, crude protein, fat and minerals. According to Sauer and Ozimek (1986), the level and source of dietary fiber are the two most important factors influencing the amount of endogenous nitrogen and amino acids present in the ileal digesta. In the present experiment, comparisons among the protein sources were confounded by the major differences in intake of crude protein and crude fibre, which resulted from fixing the inclusion rate at 30% of the total diet DM for all the protein sources. It is therefore difficult to decide whether the better results for duckweed and cassava were due to the lower content of fibre or the higher content of crude protein, as both these elements were (crude protein), or tended to be (crude fiber), correlated with ileal and total tract digestibility of organic matter and crude protein.

The total tract digestibility of the crude fibre ranged from 44 to 51%, and did not differ among diets. Phuc and Lindberg (2000) reported similar values in pigs fed diets with high levels of cassava leaves, groundnut foliage and leucaena leaves.

On all the diets, a substantial proportion of the crude fiber (~40%) was digested pre-caecally, which is in agreement with earlier reports on feeding lucerne, red clover, white clover and perennial ryegrass to pigs (Lindberg et al 1995; Andersson and Lindberg 1997a,b). The absence of differences in crude fiber digestibility among the diets, at the level of both the ileum and the total tract, indicates that the nature of the fibrous component in each of the protein sources was similar. It can be concluded therefore that in the case of the four foliar sources of protein used in this experiment, that it was the quantity of fiber, rather than the quality, which contributed to the differences in digestibility of organic matter and crude protein among the four diets.

The crude protein content of the foliages, and therefore of the diets, appears to the the factor that explains most of the differences in ileal and total tract digestibility of organic matter and crude protein. Thus when the digestibility coefficients of crude protein, both at the ileum and for the total tract, were adjusted for differences in the crude protein content of the diets, the differences among the forage sources were no longer significant (Table 3). Bounhong Norachack et al (2004) found no differences in digestibility of DM and crude protein in pigs fed different proportions of stylo foliage and fresh cassava leaves supplying from 20 to 30% of the DM of a diet based on broken rice. However, in their experiment, N retention was almost three times higher when cassava leaves rather than stylo foliage were the major protein source.

Conclusions

- Inclusion of fresh water spinach or fresh cassava leaves, as the only source of supplementary protein in diets for growing pigs based on cassava root meal and rice bran, increased apparent digestibility of organic matter in the total digestive tract but not at the level of the ileum, when compared with inclusion of similar quantities either sweet potato vines or stylo foliage.

- Apparent digestibility of crude protein was higher on the diets with water spinach and cassava leaves but the differences were confounded by different concentrations of crude protein in the foliages, and were not significant when the digestibility coefficients were corrected by covariance for differences in protein content of the diets.

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