Feeding of sweet potato to monogastrics

by P.L. Domínguez

INTRODUCTION

The starchy roots and tubers produced in many tropical areas constitute an important energy source for human and animal feeding. Traditionally sweet potatoes have been cultivated in the tropical countries of Latin America and the Caribbean almost exclusively for tuber production to be used for human consumption, while its foliage has always been considered as a residue. The productive potential of certain varieties of sweet potato can reach from 24 to 36 t/ha/ crop of roots (Morales, 1980) and the foliage production can vary from 4.3 to 6.0 t dry matter/ha/crop (Ruiz *et al.*, 1980).

CHEMICAL COMPOSITION

Sweet potato is one of the world's most important food crops. Its main nutritional importance has been its starch content. However, sweet potato can also be a source of other nutritionally important dietary factors, such as, vitamin A, ascorbic acid, thiamin, riboflavin and niacin.

The chemical composition of sweet potato roots and vines are shown in Table 1. Low protein, fat and fibre levels were found in the roots, but the high nitrogen-free-extract fraction in this tuber is indicative of their main potential value as an energy source. Vines have a lower carbohydrate content but are higher in fibre and protein and so their principal nutritive value is as a source of vitamins and protein.

Carbohydrates generally make up between 80 to 90 % of the dry weight of sweet potato roots, however the uncooked starch of the sweet potatoes is very resistant to the hydrolysis by amylase. When cooked, their susceptibility to the enzyme increases. Thus after cooking the easily hydrolysable starch fraction of sweet potato increases from 4% to 55% (Cerning-Beroard and Le Dividich, 1976).

TABLE 1.
Chemical composition of sweet potato roots and vines (% dry matter)

	Roots		Vines	
	Noblet *et al.*, 1990	Dominguez, 1990	Godoy and Elliot, 1981	Dominguez, 1990
Dry matter	=	29.2	15.0	14.2
N x 6.25	4.4	6.4	18.2	18.5
Ash	3.1	5.3	17.7	12.5
ADF	4.2	5.5	22.3	23.5
NDF	6.9	=	26.2	=
Lignine	0.7	=	5.7	=
Ether extract	0.6	=	=	=
Gross energy MJ/kg DM	17.1	16.5	=	14.4

Because the structure of sweet potato starch does not differ from that of cereals and mandioca (Szylit *et al.*, 1978) the difficulty with its digestion could very well relate to the larger size of the starch molecule (25 μm) compared to the latter's (12 μm).

The protein content and quality of sweet potato roots and vines are two of the most important factors that deserve attention when sweet potato is used as a feed. Several environmental factors have been shown to influence protein content in sweet potatoes.

The effects of genotype on crude protein content are well described (Purcell *et al.*, 1972, Edmond and Ammerman, 1971) as are those of cultural management and growth duration (Purcell *et al.*, 1976).

Amino acid analysis of sweet potato roots and vines (Table 2) shows them to be of good nutritional quality but deficient in total sulfur aminoacids and lysine in terms of the ideal protein (Fuller and Chamberlain, 1982).

TABLE 2. **Amino acid content of sweet potato roots and vines**[1]

		Roots		Vines
	Ideal Protein[2]	Purcell *et al.*, 1972	Li, 1982	Walter *et al.*, 1978
Isoleucine	3.8	4.2-10.1	3.9-5.1	4.9
Leucine	7.0	7.8-9.2	6.2-7.9	9.6
Total sulphur	3.5	2.8-3.8	3.0-3.9	2.8
Phenylalanine[3]	6.7	11.9-13.6	7.2-10.1	10.6
Threonine	4.2	5.5-6.3	5.1-6.1	5.3
Trytophan	1.0	0.8-1.2	=	=
Valine	4.9	6.8-8.3	4.9-8.2	6.3
Lysine	7.0	4.2-7.2	4.3-4.9	6.2
Chemical score Total sulphur	100	80-109	85-110	80
Lysine	100	60-103	61-70	88

[1] *g/100g protein*
[2] *Fuller and Chamberlain, 1982*
[3] *Phenylalanine + Tyrosine*

TABLE 3. **Inhibition of trypsine, %**

Raw soybean	89.5
Soybean meal	33.7
Raw sweet potato	78.8
Cooked sweet potato	16.7
Fresh vines	26.1
Vine meal	16.7

Source: Diana Martinez and P.L. Dominguez 1990 unpublished

The presence of trypsin inhibitors in the raw sweet potato roots could decrease the protein digestibility in mixed feed. The vines do not produce this effect because they do not contain great quantities of inhibitors. This trypsin inhibitor can be destroyed or reduced by preheating the raw sweet potato roots (Table 3).

Cooking sweet potato is therefore necessary on account of two factors, i.e. starch digestibility and the presence of trypsin inhibitors.

THE USE OF SWEET POTATO IN POULTRY FEEDING

Sweet potato tuber and foliage products have been evaluated as a feed for poultry. Turner *et al.* (1976) examined various diets consisting of cooked sweet potato and a protein supplement for poultry feeding. Chicks fed on a starter feed reached slaughter weight sooner than when fed on sweet potato diets, however, with the latter the broilers had a higher dressing out percentage. The results of the organoleptic evaluation of birds slaughtered at 13 weeks of age showed that meat from chickens fed a diet, where 75% of the corn was replaced by sweet potato, had the best flavour (Mohamed *et al.*, 1974).

Yoshida and Morimoto (1958) reported that the carbohydrate fraction in sweet potato to be about 90 % digestible in chicks, while Fetuga and Oluyemi (1976) obtained a coefficient of metabolizable energy of 90,9 or 87,2 in diets where the tuber replaced 25 or 40% of the glucose in a basal diet; at both levels, rate and efficiency of gain were best for the sweet potato diets. These results suggest that, as an energy source, and at these levels of substitution the tuber is as efficiently used as maize by chicks.

The performace of two-week old birds fed rations containing sweet potato root meal replacing 0, 50, 75 and 100% of corn in the rations up to 6 weeks of age was studied (Table 4) (Gerpacio *et al.*, 1978). The comparison was carried out on the basis feed intake, weight gain, feed efficiency, dressing percentage and digestibility or availability of the major nutrients (dry matter, fibre, protein, energy). Performance of birds fed the sweet potato and especially at the higher levels, was less satisfactory compared with corn, suggesting that for the tuber, only 50 % or, at the most, 75 % replacement of the corn is advisable.

TABLE 4.
Evaluation of sweet potato roots as energy sources for broilers

	Level of replacement of corn			
	Control	50	75	100
Initial weight 2 weeks, g	200	235	219	220
Feed consumption 2-6 weeks, g	2070	2141	2017	1937
Weight gain 2-6 weeks, g	775	764	719	676
Feed/gain	2.50	2.51	2.81	2.99
Dry matter digestibility, %	72.0	64.3	69.2	70.1
Crude fibre digestibility, %	59.5	40.4	34.0	50.2
Metabolizable nitrogen, %	72.6	61.8	70.8	65.6
Metabolizable energy, %	82.6	64.3	73.0	73.7

Source: Gerpacio et al, 1978

The presence of non-identified factors which inhibit the digestive and metabolic processes are suggested in sweet potato-based rations. These factors caused low dry matter digestibility and low metabolizable protein and energy values, even when the rations contained adequate and high-quality proteins (Gerpacio *et al.*, 1978).

Studies with dehydrated sweet potato vine meal (Garlich *et al.*, 1974) have shown that this material can be used in poultry rations both as a source of protein and of xanthophyll pigment. The xantophyll of sweet potato vines is a good pigmentation agent for egg yolks and broiler skins.

DIGESTIBLE NUTRIENTS OF SWEET POTATOES FOR PIGS

Raw or cooked, peeled or unpeeled, sweet potato tubers have been evaluated in digestibility trials (Oyenuga and Fetuga, 1975). Peeling significantly increased digestibility of crude protein, ether extract and crude fibre but had no effect on digestible and metabolizable energy nor on total digestible nutrients. Cooking did not significantly affect the utilization of energy, but increased the digestibility of the nutrients.

Table 5 summarizes several of the main digestibility evaluation trials carried out on sweet potato.

Canope *et al.* (1977) found that cooking improved digestibility of all nutrients, but especially of nitrogen.

In a metabolism trial using village pigs (Rose and White, 1980) the animals received raw sweet potato tubers the digestible energy values (15.8 MJ/kg DM) were very high. This could have been be due to the low intakes in this experiment. For this reason a depression in apparent digestibility might be expected as the level of intake increased. However, there seems to be some indication of a difference between breeds in their ability to digest raw sweet potato.

Tomita *et al.* (1985) evaluated ensiled sweet potato. The high digestible energy value obtained was related to the high gross energy value of the silage and the poor nitrogen digestibility was probably due to antitryptic factors, which though low, are not totally eliminated by means of this method of conservation (Lin *et al.*, 1988).

The digestible energy, metabolizable energy and net energy of sweet potato for pigs have been estimated by Wu (1980) and Noblet *et al.* (1990). The different results obtained varied considerably; while Wu (1980) found that the NE of sweet potato (8.5 MJ/kg DM) was only 79% of that of corn, Noblet *et al.* (1990) showed that NE of sweet potato and corn were equivalent (12.3 MJ/kg DM).

TABLE 5. **Digestibility of sweet potato tuber (%)**

	Canope *et al.*, 1977		Rose and White, 1980	Tomita *et al.*, 1985	Noblet *et al.*, 1990
	Raw	Cooked	Raw	Silage	Chips
Dry matter	90.4	93.5	95.3	91	=
Energy	89.3	93.0	94.2	89	89.3
Organic matter	92.1	94.5	96.1	91	91.8
Nitrogen	27.6	52.8	49.8	32	52.3
DE, MJ/kg DM	14.1	14.5	15.8	16.3	15.3

TABLE 6. Digestibility of sweet potato vine and root diets

Digestibility %	Sugar (65.1%)	CSP (72.8%)	CSP + SPV (65.8 + 10.0%)
Dry matter	94.5	85.5	81.8
Nitrogen	89.6	76.0	73.3
Energy	93.5	89.2	85.6
Crude fibre	76.6	81.4	67.6
DE, MJ/kg DM	15.8	14.7	14.0

CSP - Cooked sweet potato soybean meal as source of protein
SPV - Sweet potato vines
DE - Digestible energy
Source: P.L. Dominguez, 1990 unpublished

Table 6 shows the digestibility of cooked sweet potato diets (18 % DM), in which 10 % of fresh foliage was, or was not, included (12-15 % DM), compared with a sugar based control, using soybean meal as a protein source (P.L. Domlnguez *et al.*, 1991, unpublished data).

From the above results it is clear that the digestibilities of energy and fibre in sweet potato diets are high, though the nitrogen digestibility is somewhat low because of the poor digestibility of sweet potato protein, even when cooked. The inclusion of foliage lowered the digestibility of all nutrients due to the increases in the fibre content of the diet. Nevertheless, the digestible energy values are acceptable and even higher than expected when compared with the values reported by Takahashi *et al*. (1968) for DE of foliage (4.1 MJ/kg DM). On the other hand, although the nitrogen retention is low in these diets, it is adequate, and it even increases when foliage is added (14.1 vs 16.4 g/day). All this confirms that foliage is an acceptable protein source for pigs when included at moderate levels in the diet.

SWEET POTATOES AS A DIET FOR PIGS

Experiments carried out using sweet potato for fattening pigs indicate that the best use of the nutrients is obtained when they are cooked (Corring and Rettagliati, 1969).

Watt (1973) summarized the results of feeding sweet potato to pigs. These conclude that cooking sweet potato increased live-weight gain when compared with raw sweet potato and that pigs grazing sweet potatoes require a protein supplement of 500 g concentrate per pig per day for optimal growth.

On the other hand, as raw sweet potato progressively replaces cereals in the diet (Table 7) daily weight gains tend to decrease, together with feed intake, without significant changes in feed conversion (Marrero, 1975).

TABLE 7. **Raw sweet potato as energy source for fattening pigs**

Corn (% DM)	88.2	46.8	22.4	8.5
RSP (% DM)	=	42.2	69.5	84.3
Intake kg GM/day	2.29	2.05	1.91	1.92
Liveweight gain, kg/day	0.74	0.65	0.58	0.57
Feed conversion kg DM/kg gain	3.16	3.23	3.31	3.37

Pigs 32-90 kg
RSP: Raw sweet potato
Source: Marrero, 1975

Due to its antitryptic factor content, raw sweet potato, used as a feed for growing-finishing pigs, needs more added soybean meal or some other protein supplement than cooked or dried sweet potato chips to acheive satisfactory performances. This fact indicates that the utilization of cooked or sun-dried chips is more economical than the use of raw sweet potatoes.

Several results (Lee and Lee 1979; Lee and Yang, 1979; Cornelio *et al*., 1988; Manfredini *et al*., 1990) have confirmed that the performance of pigs fed diets containing dried sweet potato chips is not comparable to that of pigs fed corn diets (Table 8), but daily gain and feed/gain ratio were acceptable when the pigs were fed diets where sweet potato chips replaced half of the corn in the diet.

TABLE 8. Sweet potato chips as an energy source for fattening pigs

Sweet potato chips % in diet	Daily gain, kg	Feed/gain kg DM/kg	Source
0	0.56	3.14	Lee and Lee (1979)
35-41	0.49	3.71	
69-81	0.48	3.80	
0	0.54	3.29	Lee and Yang (1979)
25	0.50	3.44	
50	0.48	3.52	
75	0.47	3.39	
100	0.50	3.23	
0	0.84	2.92	Cornelio *et al.* (1988)
15	0.74	3.23	
31	0.76	3.17	
46	0.72	3.38	
0	0.64	3.79	Manfredini *et al.* (1990)
20	0.62	3.94	
40	0.60	4.01	

TABLE 9. Utilization of differents sources of protein for pigs fed cooked sweet potato

	Protein contribution to the diet[2]				
Soybean meal	50.9[1]	62.9	=	=	=
Torula yeast	=	=	62.9	40.9	19.1
Meat and bone pastes	=	=	=	26.5	52.8
Intake kg DM/day	2.30	2.71	2.36	2.30	2.33
Liveweight gain, kg/day	0.77	0.77	0.78	0.78	0.70
Feed conversion kg DM/kg gain	3.01	3.51	3.03	2.95	3.33

[1] *Corn control diet; Pigs 29-90 kg*
[2] *% of total protein*
Source: Dominguez, 1990

In Cuba, intensive and specialized pig production units use liquid feeds which are mechanically distributed through pipes to the troughs (Domlnguez, 1990). The greatest part of the Cuban experiments carried out up to date using this equipment have utilised mashed cooked sweet potato tuber (18-20 % DM).

Table 9 shows the performance of pigs fed cooked sweet potato diets compared with a maize soybean-diet (Domlnguez, 1990). The protein sources used were soybean meal and torula yeast and the latter was partially substituted by 35 and 70 % respectively of meat and bone pastes.

In all treatments, daily gains and feed conversions were similar or very close to those obtained with the maize-soybean diet. However, it is clear that the protein source used influences the performance of pigs consuming sweet potato. As a result even if the pigs fed the sweet potato-soybean showed the same weight gains as those on maize-soybean, the former needed a higher feed consumption and then had poorer feed conversions. On the other hand, both weight gain and conversion of pigs fed diets supplemented with torula yeast, as the only or major protein source, were equal to those fed the cereal diet; this may be due to its high content of lysine.

Considering, these results, it is evident that cooked and mashed sweet potato may totally replace maize for fattening pigs provided an adequate protein supplementation is used.

However, the total substitution of maize by sweet potato supplemented with torula yeast for weaned piglets from 7 to 15 kg live weight decreased daily gains from 329 to 284 g/day and increased feed conversion from 1.95 to 2.48 kg/kg (Mora *et al.*, 1990).

The supplementation of standard diets with sweet potato foliage did not improve the performance of pigs (Malynicz and Nad, 1973). Kohn *et al.*, (1976) substituted part of a maize-soybean ration for 26 to 90 kg pigs with sweet potato foliage and obtained a decrease of daily gain and an increase of feed conversion.

TABLE 10.
Sweet potato foliage as a source of protein for pigs fed the tuber

	Protein contribution[2]			
Soybean meal	62.9	47.7	32.3	50.9[1]
Fresh SPV	0	18.8	37.9	0
Intake (kg DM/day)	2.71	2.46	2.46	2.30
Liveweight gain, kg/day	0.77	0.69	0.64	0.77
Feed conversion, kg DM/kg gain	3.51	3.55	3.81	3.01
Fresh intake/gain, kg/kg Corn	=	=	=	2.80
Soybean meal	0.72	0.54	0.39	0.54
CSP	9.50	8.60	8.10	=
SPV	=	2.40	5.10	=

[1] Corn control diet
Pigs 29-90 kg
[2] % of total protein
Source: Dominguez, 1990

SPV - Sweet Potato Vines
CSP - Cooked Sweet Potato

Table 10 shows the results of partially replacing 25 and 50 % of soybean meal as a protein source with fresh foliage in sweet potato-soybean diets (Domlnguez, 1990). The use of fresh foliage at both levels decreased the intake of dry matter; probably due to the bulkiness of this feed (12-15 % DM). The high level use also resulted in poorer gains and feed conversion. However, with low level of substitution of soybean meal, feed conversions similar to those obtained with sweet potato-soybean diets were acheived.

When carrying out an economic analysis of the use of sweet potato forrage in pig feeding, it is important to note that the inclusion of the forrage in sweet potato-soybean diets results in a lower feed need per unit of gain so that when substituting 25 % of soybean, the intake of this protein source is similar to that used in the maize-soybean diet.

Fresh foliage has been used for weaned piglets (6 to 12 kg) to replace 10 % of the cereal concentrate. Animal performance was satisfactory both from the point of view of weight gain (186 vs 202 g/day), feed conversion (2.8 vs 2.5 kg/kg) and also with regard to mortality and herd culling (Mora *et al.*, 1991).

On the other hand, the use of sweet potatoes does not affect carcass composition, lean meat content nor meat quality in the heavy pig (156 kg); however, the dressing out percentage was better for the control group (Manfredini *et al.*, 1990).

SOME ECONOMIC ASPECTS

A simple economic analysis of the productivity of corn-soybean meal and sweet-potato-soybean meal diets was carried out (Table 11) considering the world yield of these crops (FAO, 1989) and the pigs performance shown in Table 10.

The productivity of the tuber diet was similar to that of corn and soybean meal, whilst when vines are also used as a protein source the productivity increased 1.37 times with respectto the corn diet. Calculations were carried out considering only one annual harvest, though the sweet potato can actually be harvested two or more times in a year. Also the remaining vines can always be used in other species.

It is possible to assert that sweet potato crop, with the integration of vines as a protein source for pigs, can compete advantageously and surpass corn as a diet for swine in Cuban conditions.

TABLE 11. **Sweet potato crop as a source of feed for pig production**

	Corn SBM	CSP SBM	CSP SBM SPV[1]	CSP SBM SPV[2]
Productivity, ha/t liveweight	1.06	1.05	0.89	0.77
Liveweight yield t/ha	0.94	0.95	1.12	1.29

[1] *15% of DM* *SBM - Soybean Meal* *CSP - Cooked Sweet Potato*
[2] *30% of DM* *SPV - Sweet Potato Vines* *Crops yield FAO (1989)*

CONCLUSIONS

The presence of antitryptic factors and low starch digestibiliy necesitate the prior treatment of sweet potato (dehydration or cooking) in order that it can be used efficiently in the diets of monogastric animals. Dehydrated sweet potato can substitute up to 50 % of maize in diets for poultry and pigs with satisfactory results. When cooked sweet potato totally replaces maize in fattening pig diets an adequate protein supplement is always needed. Fresh foliage is very palatable for pigs and can economically be used in order to replace part of the protein of the diet. The inclusion of high levels of sweet potato in the diet does not affect carcass nor meat quality of pigs. It can be asserted that the sweet potato crop, with the integration of vines as a protein source, can compete advantageously and surpass corn as a diet for swine in Cuban conditions.

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