Ensiling of Sweet Potato Leaves (*Ipomoea batatas* (L.) Lam) and the Nutritive Value of Sweet Potato Leaf Silage for Growing Pigs

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ABSTRACT : The effect of adding carbohydrate-rich feedstuffs to sweet potato leaves (SPL) on silage quality was studied using a total of 180 laboratory silos. Silage quality was assessed by changes of pH, dry matter (DM), crude protein (CP) and ammonia nitrogen (NH_3-N). Pre-wilted SPL was mixed with cassava root meal (CRM), sweet potato root meal (SPM) or sugar cane molasses (Mo) at levels of 0, 30, 60 and 90 g kg^{-1} (air-dry weight of additives to pre-wilted weight of SPL). Samples for assessing silage quality were collected after mixing the SPL with the additive and thereafter at 7, 14, 28 and 56 days of ensiling. There was a marked decrease in pH after 7 days and the pH remained low and stable until day 56. Addition of 60 and 90 g kg^{-1} resulted in a lower pH ($p<0.05$) than the other treatments. The DM content of the silage increased ($p<0.05$) with increasing levels of additive, while there were no differences in DM with time of ensiling. The CP content of the silage decreased ($p<0.05$) with increasing levels of additive. The CP content did not change up to 28 days, but was lower ($p<0.05$) after 56 days in all treatments. The NH_3-N levels were increasing ($p<0.05$) with time of ensiling, and were lower ($p<0.05$) with additive levels of 60 g kg^{-1} or higher. Also, the additive source affected the NH_3-N values, with the lowest values found for Mo. Castrated male pigs (Large White×Mongcai) were used in 4×4 Latin square design to study the total tract digestibility and nitrogen (N) utilisation of diets with inclusion of ensiled SPL. The diets were based on cassava root meal with inclusion of protein from either fish meal (C) or SPL ensiled with CRM (D1), SPL ensiled with SPM (D2) and SPL ensiled with Mo (D3). The digestibility of DM, organic matter (OM) and CP were higher ($p<0.05$), and the digestibility of crude fibre (CF) was lower ($p<0.05$), in diet C than in diets D1, D2 and D3. However, there were no differences ($p>0.05$) in digestibility of dietary components between diets D1, D2 and D3. Also, the excretion of N in faeces was higher ($p<0.05$) and the N retention was lower ($p<0.05$) in diets D1, D2 and D3 than in diet C. It can be concluded from the present experiments, that a good quality silage can be produced from pre-wilted SPL by addition of 60 g kg^{-1} of either CRM, SPM or Mo. Diets with inclusion of 450 g ensiled SPL kg^{-1} DM showed a high digestibility of dietary components and thus ensiled SPL should be considered as a potential feed resource for growing pigs. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 4 : 497-503)***

Key Words : Sweet Potato Leaves, Silage, Additive, Cassava Root Meal, Sweet Potato Root Meal, Sugarcane Molasses, Digestibility, Growing Pigs

INTRODUCTION

Sweet potato is one of the main crops after rice and maize and is planted in different ecological zones of Vietnam, as well as in many other tropical countries. It has been used as a food crop when rice was insufficient. However, since rice production has improved, sweet potato is more commonly being used as feed for livestock. Sweet potato-pig production systems are popular and play an important role for farmers to provide cash income and manure for cropping.

The economic development in Vietnam has led to an increasing demand for meat for human consumption. However, meat production is often constrained by the shortage of feed or costly feed imports. For many years, new forage varieties have been introduced to Vietnam, as well as to other developing countries in South-East Asia, with the aim of improving feed quantity and quality. Despite this, there are only a few examples of successful implementation at farm level, mainly because these plants often require different cultivation techniques than those used in traditional farming. Thus, the exploitation and use of local feed resources may be a better way of improving the feed supply to farm animals. In this context, sweet potato is one of the local feed resources that is available at farm level in Vietnam.

Sweet potato is an ideal livestock feed, as the roots can provide a source of energy and the leaves can provide protein (Woolfe, 1992). Similar to cassava leaves, sweet potato leaves are high in crude protein and amino acids and cassava leaves as well as sweet potato wines have been shown to have comparable nutritional properties when fed to rats (Phuc, 2000). The digestibility of sweet potato vines is low in pigs due to its high fibre content (Domínguez and Ly, 1997). In contrast, sweet potato leaves are low in fibre and high in crude protein content (Ishida et al., 2000; An et al., 2003) and should have the potential to improve the nutritional properties of the diet.

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Table 1. Dry matter content (%) and chemical composition (% of DM) of sweet potato leaves and the ingredients used as silage additives

	Sweet potato leaves (SPL)	Cassava root meal (CRM)	Sweet potato root meal (SPM)	Sugar cane molasses (Mo)
Dry matter	15.60*	86.70	87.40	77.00
Crude protein	26.55	2.82	5.20	1.90
Crude fibre	12.83	2.95	2.20	-
Essential amino acids				
Lysine	1.08	0.73	0.42	-
Methionine	0.54	0.20	0.15	-
Threonine	1.32	0.41	0.42	-
Tryptophan	0.38	0.11	0.08	-
Phenyalanine	1.37	0.52	0.46	-

* DM content was analysed in fresh matter after harvest

Traditionally, sweet potatoes leaves are used fresh or sundried in diets for pigs. Sweet potatoes can be planted at different times of the year, but the biomass yields are different according to the seasons and varieties (An et al., 2003). During the rainy season, sweet potato leaves can be harvested at 20 to 30 day intervals, and produce a high biomass yield. However, due to regular rainfall and high humidity during this season there is a need to develop suitable techniques to preserve this feed resource in order to make full use of its potential. The ensiling technique has been shown to be an appropriate methodology for the preservation of animal feed resources and the technique is extensively used worldwide (McDonald et al., 1991). Silage quality depends on a number of factors, of which moisture content and feed composition are the most important (McDonald et al., 1991). In order to improve the silage quality, grains or sugar cane molasses can be added to provide conditions for an efficient fermentation process and also to reduce effluent production (Sibanda et al., 1997; O'Doherty et al., 1998; Jaurena and Pichard, 2001).

The purpose of the present study was to identify an appropriate inclusion level of cassava root meal, sweet potato root meal and sugar cane molasses for the ensiling of sweet potato leaves, and to determine the nutritive value of the most promising silage in growing pigs.

MATERIALS AND METHODS

Ensiling of sweet potato leaves

Sweet potato (local variety) leaves were harvested at 60 days after planting. The vines were manually separated into leaf and stem parts, and only the leaf part was used for ensiling. Leaves were chopped into small pieces of 2-3 cm and spread out on the floor overnight for wilting to reduce the moisture content. Cassava root meal (CRM), sweet potato root meal (SPM) and sugar cane molasses (Mo) were used as additives in making silage of sweet potato leaves (SPL). The chemical composition of these materials is shown in Table 1. CRM, SPM and Mo were added at 0, 30, 60 and 90 g kg^{-1} (air-dry weight of additive to pre-wilted weight of SPL).

One hundred and eighty laboratory silos were used according a factorial design with 3 additives and 4 treatments (one control without additive and three additive levels), with 6 measuring times and 3 replicates per treatment. The laboratory silos were cylindrical plastic cans of 2,000 cm^3 capacity. A valve was fixed on the cover of the can to release high air-pressure during ensiling. The mixtures of sweet potato leaves and additives were pressed to remove air and covered. The contents of each silo weighed approximately 1,500 g. The silos were kept at room temperature, from April to August 2001, with an average temperature of 26 to 29°C.

Assessment of nutritive value

Four castrated male pigs (Large White×Mongcai) were used to study the total tract digestibility and nitrogen (N) utilisation of diets with inclusion of ensiled SPL. The pigs were from the same litter and had an average initial body weight of 31.8±0.7 kg. The experiment was conducted as a 4×4 Latin square, with a total length of 40 days, comprising four periods of 5 days adaptation to the diets and 5 days of quantitative collection of faeces and urine.

The diets were based on cassava root meal with inclusion of protein from either fish meal (C) or SPL ensiled with either CRM (D1), SPM (D2) or Mo (D3) (Table 6). The leaves were ensiled with 60 g kg^{-1} pre-wilted weight of sweet potato leaves of either CRM, SPM or Mo.

Chemical analysis

The pH value of the silage was recorded on fresh samples by a pH electrode. Samples for chemical analysis were dried at 60°C for 24 h and ground through a 1 mm screen. The dry matter (DM) was determined by drying at 105°C for 24 h to constant weight. The CP (N*6.25), crude fat (EE), crude fibre (CF) and ash were determined according to the AOAC (1990). The ammonium nitrogen (NH_3-N) in the sample was distilled with water and MgO, and collected by 0.3% H_2BO_3 and then titrated with standard 0.1 N H_2SO_4.

Table 2. Effect of additive level on pH value in ensiled sweet potato leaves*

Treatment	Days					SE	P
	0	7	14	28	56		
Control	6.08[a]	4.35[bx]	4.23[bx]	4.05[b]	4.21[bx]	0.061	0.001
CRM30	6.02[a]	4.15[bxy]	4.05[bxy]	4.03[b]	4.11[bxy]	0.065	0.001
CRM60	6.10[a]	3.98[by]	3.92[by]	3.95[b]	4.02[by]	0.048	0.001
CRM90	6.08[a]	4.05[by]	3.90[by]	3.88[b]	3.87[byz]	0.059	0.001
P**	0.881	0.01	0.01	0.365	0.001		
SPM30	6.03[a]	4.18[bxy]	4.15[bxy]	4.13[b]	4.13[bxy]	0.041	0.001
SPM60	5.95[a]	3.93[bz]	3.93[bxy]	3.93[b]	3.90[bz]	0.063	0.001
SPM90	5.98[a]	4.06[byz]	3.90[by]	3.90[b]	3.95[byz]	0.068	0.001
P**	0.642	0.001	0.05	0.068	0.01		
Mo30	5.93[a]	4.21[bx]	3.90[by]	4.03[b]	4.17[bx]	0.048	0.001
Mo60	5.95[a]	3.98[by]	3.93[by]	3.88[b]	3.97[by]	0.054	0.001
Mo90	5.98[a]	3.83[by]	3.83[by]	3.82[b]	3.92[by]	0.051	0.001
P**	0.541	0.001	0.001	0.05	0.01		

* CRM=cassava root meal, SPM=sweet potato meal, Mo=sugar cane molasses; 30, 60 and 90=g kg^{-1} air-dry weight of additive to pre-wilted weight of sweet potato leaves. [a, b, c]: Values in the same row with different superscript letters differ (p<0.05).
[x, y, z] Values in the same column with different superscript letters differ (p<0.05). ** P value of comparison between control and different additive levels.

Table 3. Effect of additive level on dry matter content (%) in ensiled sweet potato leaves*

Treatment	Days					SE	P
	0	7	14	28	56		
Control	29.28	29.64[c]	29.23	28.79	28.23[b]	0.224	0.011
CRM30	31.34	32.05	31.84	31.93	31.45	0.225	0.212
CRM60	34.40	34.83	34.59	34.29	34.03	0.233	0.230
CRM90	36.57	36.96	36.58	36.23	35.95	0.397	0.478
P**	0.001	0.001	0.001	0.001	0.001		
SPM30	31.88	31.09	32.01	31.68	31.45	0.395	0.809
SPM60	34.81	34.87	34.88	34.47	34.21	0.300	0.456
SPM90	37.16	37.44	37.51	37.19	36.93	0.337	0.753
P**	0.001	0.001	0.001	0.001	0.001		
Mo30	30.56	30.64[a]	30.41	30.16	29.81[b]	0.175	0.042
Mo60	32.86	32.95	32.78	32.62	32.48	0.154	0.263
Mo90	34.21	34.33	34.44	34.23	34.20	0.070	0.143
P**	0.001	0.001	0.001	0.001	0.001		

* For abbreviations see Table 2. [a, b, c] Values in the same row with different superscript letters differ (p<0.05).
[x, y, z] Values in the same column with different superscript letters differ (p<0.05). ** P value of comparison between control and different additive levels.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) by using the General Linear Model (GLM) procedure of Minitab (1998). When the F test was significant (p<0.05) the Tukey's test for paired comparisons was used to compare means.

RESULTS

Effect of additive source and level of inclusion

The level of CRM, SPM and Mo added affected the silage composition and the changes with time of ensiling of pH, DM, CP and NH_3-N are shown in Table 2, 3, 4 and 5. Generally, the pH decreased rapidly during the first week (p<0.01) and then remained stable until 8 weeks at all levels of additive addition. Increasing level of additive decreased pH and the levels of 60 and 90 g kg^{-1} resulted in the lowest pH at all times. There were no significant differences in DM contents of the silages with time (p>0.05), except for the control, which showed a reduction in DM content. Increasing levels of CRM, SPM and Mo increased the DM content (p<0.01). The CP content was lower at day 56 than at the start in all treatments (p<0.05). Increasing the inclusion of CRM, SPM and Mo decreased the CP content (p<0.05) of the silage. The NH_3-N increased with time of ensiling (p<0.05) and was higher in the control treatment at day 28 and 56, when 60 g kg^{-1} of CRM or more was added. In contrast, with addition of Mo the NH_3-N content was lower (p<0.05) than in the control treatment already at day 7 when 30 g kg^{-1} of Mo or more was added. For SPM the change in NH_3-N content was more erratic, with lower values (p<0.05) than the control at day 7 to 28 when 30 g

Table 4. Effect of additive level on crude protein content (% in DM) in ensiled sweet potato leaves*

Treatment	Days					SE	P
	0	7	14	28	56		
Control	24.52	24.68^{a}	24.68^{a}	24.25	23.82^{b}	0.174	0.027
CRM30	23.53	23.60	23.90^{a}	23.85	22.84^{b}	0.151	0.004
CRM60	23.07	23.47	23.84^{a}	23.15^{b}	22.59^{b}	0.196	0.013
CRM90	22.70	22.68	22.89	23.03	21.96	0.282	0.147
P**	0.01	0.01	0.001	0.001	0.001		
SPM30	23.67^{ay}	23.75^{ay}	23.91^{ay}	23.58^{ay}	22.50^{by}	0.124	0.001
SPM60	23.56^{ay}	23.75^{ay}	23.76^{ay}	23.96^{ay}	22.41^{by}	0.135	0.001
SPM90	22.78^{z}	22.98^{z}	23.45^{z}	23.52^{az}	22.12^{bz}	0.235	0.011
P**	0.001	0.001	0.001	0.001	0.001		
Mo30	23.85^{ay}	24.04^{ax}	24.09^{axy}	23.59^{abxy}	22.48^{bxy}	0.280	0.013
Mo60	23.39^{y}	23.97^{y}	24.13^{ay}	23.44^{y}	22.58^{by}	0.312	0.040
Mo90	22.07^{z}	22.56^{z}	23.03^{az}	21.95^{z}	21.55^{bz}	0.291	0.038
P**	0.001	0.001	0.001	0.001	0.001		

* For abbreviations see Table 2. a, b, c: Values in the same row with different superscript letters differ ($p<0.05$).
x, y, z: Values in the same column with different superscript letters differ ($p<0.05$). ** P value of comparison between control and different additive levels.

Table 5. Effect of additive ratio on ammonia N (% of total N) in ensiled sweet potato leaves*

Treatment	Days					SE	P
	0	7	14	28	56		
Control	1.16^{a}	3.45^{b}	4.00^{b}	4.94^{c}	5.72^{d}	0.108	0.001
CRM30	1.27^{a}	2.97^{b}	3.11^{b}	3.93^{c}	4.62^{d}	0.129	0.001
CRM60	0.96^{a}	3.40^{b}	3.31^{b}	3.62^{b}	3.45^{c}	0.172	0.001
CRM90	1.47^{a}	3.72^{b}	3.95^{b}	4.01^{b}	4.83^{c}	0.130	0.001
P**	0.077	0.238	0.001	0.001	0.001		
SPM30	1.47^{x}	2.68^{y}	3.01^{y}	3.94^{y}	4.56	0.054	0.001
SPM60	1.13^{x}	2.78^{y}	2.85^{y}	4.11^{y}	4.82	0.079	0.001
SPM90	0.55^{y}	3.01^{xy}	3.52^{z}	3.32^{z}	5.02	0.068	0.001
P**	0.01	0.001	0.001	0.001	0.001		
Mo30	1.13^{a}	2.05^{by}	2.67^{by}	2.79^{by}	3.80^{cy}	0.083	0.001
Mo60	0.88	$2.00I^{y}$	2.88^{ay}	3.15^{abz}	3.51^{by}	0.109	0.001
Mo90	0.92^{a}	1.93^{by}	2.19^{bz}	2.94^{cy}	3.09^{cz}	0.056	0.001
P**	0.283	0.001	0.001	0.001	0.001		

* For abbreviations see Table 2. a, b, c Values in the same row with different superscript letters differ ($p<0.05$).
x, y, z Values in the same column with different superscript letters differ ($p<0.05$). ** P value of comparison between control and different additive levels.

kg^{-1} of SPM or more was added while at day 56 there were no differences in NH_3-N content between control and addition of SPM.

Apparent digestibility and N-utilization

The daily intake of CF was higher in diets D1, D2 and D3 than in diet C ($p<0.05$), while there were no differences in the daily intakes of DM, CP and organic matter (OM) (Table 6). The total tract apparent digestibility (TTAD) of DM, OM, CP and CF did not differ between the ensiled SPL diets ($p>0.05$). The TTAD of CF was lower in diet C than in diets D1, D2 and D3 ($p<0.05$), while the TTAD of DM, OM and CP were higher ($p<0.05$) for diet C compared with the other diets (Table 7).

The N retention for the fish meal diet was 16.5 g day^{-1}, or 56% of N digested, which was significantly higher ($p<0.05$) than for ensiled SPL. There were no significant differences in N retention between the ensiled SPL diets, which ranged from 11.6 g day^{-1} to 13.4 g day^{-1} (Table 7).

DISCUSSION

The characteristics of an ideal crop for preservation as silage are that it should contain an adequate level of fermentable substrate in the form of water soluble carbohydrates (WSC) and a DM content above 200 g kg^{-1} (McDonald et al., 1991).

The results from present study show that pre-wilted sweet potato leaves can be successfully preserved as silage. However, without additives the fermentation processes were too slow, resulting in a high pH during the first and second weeks of ensiling compared to the other treatments. This can be explained by the low level of WSC in sweet potato leaves. Woolfe (1992) reported that sweet potato leaves contain about 78 g sugars and 34 g starch kg^{-1} DM. Also, McDonald et al., (1991) reported that the WSC contents of

Table 6. Diet ingredients (g kg^{-1} DM), composition (%) and daily intake (g day^{-1}) in pigs

	Diets*				SE/P**
	Control	D1	D2	D3	
Ingredient					
Cassava root meal	795	545	545	545	
Fishmeal	200	-	-	-	
SPL ensiled with CRM	-	450	-	-	
SPL ensiled with SPM	-	-	450	-	
SPL ensiled with Mo	-	-	-	450	
Premix	5	5	5	5	
Chemical composition					
Crude protein	12.0	12.0	12.3	12.1	
Crude fibre	2.6	7.5	7.4	7.1	
Ether extract	2.2	3.7	3.7	3.8	
Total ash	7.2	5.4	5.3	5.8	
Daily intake					
Dry matter	1,810	1,590	1,580	1,640	66.7/0.105
Organic matter	1,670	1,500	1,500	1,530	62.3/0.203
Crude protein	245	215	219	225	9.15/0.164
Crude fibre	60[a]	130[b]	128[b]	128[b]	4.54/0.001

* D1, Sweet potato leaves ensiled with cassava root meal; D2, Sweet potato leaves ensiled with sweet potato root meal; D3, Sweet potato leaves ensiled with sugar cane molasses. ** SE=standard error; P=P value of comparison between treatments.

Table 7. Total tract apparent digestibility (%) of dietary components, nitrogen metabolism (g day^{-1}) and utilization (g retained kg^{-1} digested) in diets with inclusion of sweet potato leaves ensiled with different additives in cassava-based diets

	Diets*				SE**	P***
	Control	D1	D2	D3		
Digestibility						
Dry matter	85.0[a]	80.0[b]	78.5[b]	80.7[b]	0.68	0.001
Organic matter	89.5[a]	84.5[b]	83.5[b]	83.0[b]	0.78	0.001
Crude protein	73.9[a]	69.8[ab]	68.7[b]	71.5[ab]	1.01	0.017
Crude fibre	47.5[a]	57.5[b]	59.0[b]	59.7[b]	1.16	0.001
Nitrogen metabolism						
Intake	48.5	43.0	43.1	44.6	1.56	0.092
Fecal excretion	9.7[a]	11.0[ab]	10.9[ab]	11.4[b]	0.35	0.033
Urinary excretion	12.0	12.8	12.9	12.9	0.38	0.323
Retention	16.5[a]	11.3[b]	11.6[b]	13.4[ab]	0.988	0.011
Nitrogen utilization	567[a]	472[b]	477[b]	519[ab]	17.59	0.008

* D1, Sweet potato leaves ensiled with cassava root meal; D2, Sweet potato leaves ensiled with sweet potato root meal; D3, Sweet potato leaves ensiled with sugar cane molasses. ** SE = standard error, *** P value of comparison between treatments.

tropical forage species are generally considered to be lower than those of temperature species. It should also be noted that the sweet potato leaves were pre-wilted, which increased the DM content from 156 to 293 g kg^{-1} and should have contributed to creating conditions for an efficient fermentation process.

Cassava root meal, sweet potato root meal and sugar cane molasses are locally available feedstuffs in Vietnam. They are rich in easily available carbohydrates in the form of sugars and starch that can provide a source of potentially available energy for growth of the lactic acid bacteria (McDonald et al., 1991). The rapid drop in pH at day 7 when additives were used in the present study supports the contention that they provided easily available substrates that supported the fermentation. This finding is in accordance with a number of earlier studies where carbohydrate-rich materials have been used as additives in an attempt to improve both the fermentation process and the nutritional value of silage (McDonald et al., 1991; Sibanda et al., 1997; Jaurena and Pichard, 2001).

Increasing level of additive to the pre-wilted SPL increased the DM content, in accordance with earlier findings where molasses and cereal grains have been used as silage additives (Abou-Raya et al., 1973; Moseley and Ramanathan, 1989; Lättemäe et al., 1996; Sibanda et al., 1997). The increase in DM content in the SPL silage can be explained by the added DM from CRM, SPM and Mo, and may be of significance for improving the fermentation process in forages low in WSC (McDonald et al., 1991).

The CP content was highest in the untreated silage, but decreased with increasing inclusion of the additives. This should be expected as CRM, SPM and Mo only contain 20 to 30 g CP kg^{-1} DM. The CP content of the silage did not change during the first 2-3 weeks of ensiling, but there were

Table 8. Comparison of the essential amino acid contents in sweet potato leaves with the ideal protein (g $16g^{-1}$ N) for pigs

Amino acids	Ideal protein [a]	Sweet potato leaf [b]	Sweet potato leaf [c]
Histidine	2.3	2.1	2.3
Threonine	4.2	5.1	3.7
Valine	4.9	5.7	7.1
Methionine+cystine	3.5	4.2	3.7
Phenyalanine+tyrosine	6.7	7.0	9.4
Isoleucine	3.8	3.7	5.8
Leucine	7.0	8.5	9.9
Lysine	7.0	4.3	4.0
Tryptophan	1.0	ND	1.1
Non-essential amino acids	59.6	38.7	ND

[a] Agricultural Research Council, 1981. [b] An et al., 2003
[c] Woolfe, 1992; ND: no determination.

significant decreases at day 56 in all treatments. If good fermentation conditions are provided, only minor effects on the silage protein content should be expected (McDonald et al., 1991). The drop in CP content at day 56 could have been due to nitrogen losses from protein decomposition, as a result of microbial instability in the silage. An ideal silage fermentation process is dominated by lactic acid bacteria, which have limited capacity for amino acid synthesis and a low ability to ferment amino acids (McDonald et al., 1991). The low content of NH_3-N content in this experiment, less than 60 g kg^{-1} N in all treatments, was comparable to grass silage produced in England and Wales (Haigh, 1996a,b). However, despite this there was an increase in the NH_3-N content in the silages with time, which may have been responsible for the drop in CP content.

The replacement of CP from fish meal with CP from ensiled sweet potato leaves in the diets for pigs reduced the digestibility of DM, OM and CP, demonstrating a lower nutritive value of the diets with ensiled sweet potato leaves than with fish meal. However, as the dietary inclusion of ensiled SPL was high (450 g kg^{-1}) the nutritional properties of the diets were still good considering the limited reduction in digestibility of both OM (-50 to -65 g kg^{-1}) and CP (-24 to -52 g kg^{-1}). The lower digestibility of OM and CP with inclusion of ensiled sweet potato leaves was probably due to the higher crude fibre (CF) content of these diets. The dietary fibre influences the intestinal morphology and rate of intestinal cell turnover in pig, which ultimately can effect nutrient digestion, absorption and metabolism. Also, a high fibre content in the diet may increase the peristaltic action of the gut and therefore increase the transit time of digesta in the small intestine (Wenk, 2001).

The reduction in digestibility of OM and CP in the present study was in general agreement with earlier studies in growing pigs fed diets with inclusions of various forages (lucerne leaf meal, Lindberg and Cortova, 1995; lucerne, white cover, red clover and perennial ryegrass meal, Lindberg and Andersson, 1998; leucaena meal, Ly et al., 1998; cassava leaves, Phuc et al., 2000; Echeverría et al., 2002). In the present study, the reduction in OM digestibility was from -1.02 to -1.48% units for each percent unit increase of dietary CF content. This was of a similar magnitude as that found with dietary inclusion of lucerne, white clover, red clover and ryegrass (Lindberg and Andersson, 1998) and of cassava leaves, leucaena and groundnut leaves (Phuc and Lindberg, 2000).

The replacement of CP from fish meal with CP from ensiled sweet potato leaves resulted in a marked reduction in the daily N accretion (-4.4 g day^{-1} or –27%), partly due to the lower digestibility of the CP, and of OM, in sweet potato leaves. In addition, the CP in sweet potato leaves is low in lysine (Woolfe, 1992; An et al., 2003), when compared with the ideal amino acid pattern for growing pigs (Table 8). This was clearly reflected in the reduced utilization of digested N (-12.5%), when CP from sweet potato leaves replaced CP from fish meal. The N balance data suggest that the CP of sweet potato leaves ensiled with sugar cane molasses was better utilized, measured as a higher daily N retention (14.4 vs. 12.8 g day^{-1}) and had a better utilization of digested N (51.9 vs. 47.5% of N digested), than the CP of sweet potato leaves ensiled with either cassava root meal or sweet potato root meal. Interestingly, the silage produced with sugar cane molasses as additive had the lowest NH_3-N content, suggesting that less protein had been decomposed with this additive during the ensiling process. Thus, the choice of carbohydrate source for the ensiling of sweet potato leaves could be of significance for production of a silage with a high protein value and merits future studies.

IMPLICATIONS

It can be concluded from the present experiments, that a good quality silage can be produced from pre-wilted sweet potato leaves by addition of 60 g kg^{-1} of either cassava root meal, sweet potato root meal or sugar cane molasses. Diets with inclusion of 450 g ensiled sweet potato leaves kg^{-1} DM showed a high digestibility of dietary components and thus ensiled sweet potato leaves should be considered as a potential feed resource for growing pigs.

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