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Sweet potato Root Silage for Efficient and Labor-saving Pig Raising in Vietnam

On-farm trials were conducted in the Red River Delta area near Hanoi, Vietnam, to test the nutritional value, as pig feed, of sweet potato roots ensiled with various other materials and to study the feeding efficiency and labor-saving potential of using sweet potato silage as pig feed (with the permission of Livestock Research for Rural Development).

Abstract
 - On-farm trials were conducted in the Red River Delta area near Hanoi, Vietnam, to test the nutritional value, as pig feed, of sweet potato roots ensiled with various other materials and to study the feeding efficiency and labor-saving potential of using sweet potato silage as pig feed. Sliced or grated sweet potato roots were ensiled with varying proportions of cassava leaf meal, rice bran, sun-dried chicken manure and salt, and nutritional values (pH, crude protein, ash) were measured after 14, 30, 60 and 90 days of ensiling. Nutritional value did not differ significantly over time. Silage with chicken manure and cassava leaf meal had significantly higher crude protein content ($P<0.001$) than did rice bran silage, but only treatments with chicken manure had higher dry matter and ash contents than the other silage products. Method of root preparation (chopping or grating) had no effect. None of the preparations with chicken manure contained aflatoxin or Salmonella. E. coli was present in the original samples but disappeared after 14 - 21 days of ensiling.A three-month pig-feeding trial compared three feeds: cooked fresh sweet potato roots (T1), uncooked roots silage with rice bran (T2), and uncooked roots silage with sun-dried chicken manure (T3). Daily weight gain was 552 g for T1, 605 g for T2 and 640 g for T3. These differences were not statistically significant because of a small sample size (only 42 pigs) and large standard deviations that resulted from large variations amongst the practices of the participating farm households, the types of pigs used and their variable taste for silage feed. The most important finding was that the reasonable growth rates could be achieved with uncooked feed. Cooking is labor intensive and fuel demanding (cooking pig feed on rice husks normally takes 2-3 hours a day). This was the result of decreased trypsin inhibitor in the ensiled roots which appeared to allow farmers subsequently to triple the number of pigs raised per cycle of 3 - 4 months. Another pig-feeding trial examined how much sweet potato root silage should be incorporated in the diet to maximize growth and economic efficiency. A regime of using sweet potato silage to make up 30 per cent of the total dry matter of diet in the first month, and reducing this proportion to 20 per cent in the second month and to 10 per cent in the third month seemed to give the greatest efficiency.

INTRODUCTION

About 43
per cent
 of the world's annual sweet potato production is used as animal feed (International Potato Center, 1998). Feeding sweet potato roots to pigs and other livestock is a common practice in many countries, including China (Scott, 1991), north and central Vietnam, some eastern islands of Indonesia (Bali and West Papua), Philippines, Papua New Guinea, Cuba and Uganda. The roots are used fresh, sun-dried or as silage to feed livestock in subsistence farming systems, often to supplement other cereal feed ingredients, particularly corn (Yeh and Bouwkamp, 1985).

Sweet potato roots have several shortcomings as an animal feed. They contain little protein - crude protein content commonly ranges from 1.3 - 4
per cent

, though could run as high as 10 *per cent*, of dry matter (Li, 1974; Purcell *et al*., 1976; Walter *et al*., 1984), and up to 40 *per cent* of the total nitrogen in sweet potato is non-protein nitrogen (Purcell *et al*., 1976). Farmers overcome this constraint by supplementing a sweet potato-based diet with rice bran, fish meal, soy beans or residue, sweet potato and cassava leaves and, to a lesser extent, commercial supplement when these are available and affordable. This shortcoming is made worse by the presence of trypsin inhibitors which reduce protein digestibility in uncooked roots (Chien and Lee, 1980; Yeh and Bouwkamp, 1985). Different levels of trypsin inhibitor activity (TIA) in sweetpotato cultivars have been reported (Bradbury *et al*., 1985; Dickey *et al*., 1984; Lin and Chen, 1980) although cooking the roots may eliminate these. Farmers in China and Vietnam do cook sweet potato-based feed daily, but the labor and fuel costs of this processing are high. In other parts of the world, where labor or fuel are in short supply (such as Uganda and West Papua), farmers are not able to cook their feed. Another constraint is the lack of available starch. Sweet potato roots contain plenty of starch (a potential energy source for livestock), but its digestibility is poor (Yeh and Bouwkamp, 1985; Tsou and Hong, 1989). Starch digestibility can be improved by cooking the sweet potato roots but, as already mentioned, this option is expensive or not feasible. For farmers who are not able to cook their feed, animal growth and economic returns on investment are poor.

Storage is another constraint facing sweet potato farmers in the sub-tropical and tropical zones. Chinese farmers can store roots for up to six months because their sweet potato is grown in a temperate climate and harvested at the beginning of the winter; but tropical farmers cannot store the roots for long without major losses to weevils, rats and rotting. To minimize their losses farmers often feed large quantities of roots to pigs during the two months after harvest, but this practice is wasteful of nutrients and does not achieve growth in proportion with the large quantity of feed used.

In an attempt to help farmers overcome these constraints, without using extra, scarce or expensive inputs, we investigated the processing of sweet potato roots into silage, and the efficiency of use of this silage as pig feed. This paper reports the results of three trials:

1. Twelve methods of ensiling sweet potato roots were tested to determine which would yield the highest protein level at the lowest cost
2. Pigs were fed fresh sweet potato roots and two combinations of root silage to determine the method would yield the best growth at the lowest cost
3. Pigs were fed silage at three rates to determine which would yield the best growth at the lowest cost.

MATERIALS AND METHODS

Sweet potato root silage trial (Experiment 1,

E1)

The silage trial, conducted on-farm in a village in Thai Nguyen Province in the Red River Delta between 18 March and 18 June 2000, tested 12 treatments - six based on sliced sweet potato roots and six on grated roots, with various mixtures of locally available and affordable rice bran, cassava leaf meal, sun-dried chicken manure and salt: the compositions of the 12 treatments (E1T1 - E1T12) are shown in Table 1. All materials were prepared (weighed, sliced, or grated, mixed and put into two layers of labelled plastic bags) on-farm by the farmers. For each treatment there were three replications for each scheduled chemical analysis - at 14, 30, 60 and 90 days after the ensiling process was started (hence there were 12 samples for each treatment, 144 samples in total). The samples remained on farm until the scheduled date for analysis (i.e., 14, 30, 60 and 90 days after ensiling) when they were transported to the laboratory of the National Institute of Animal Veterinarian or of the National Institute of Animal Husbandry in Hanoi. Analyses were carried out according to Vietnamese (TCVN) and ISO standards: dry-matter content based on TCVN 4326-86 and IS0-6496; total ash based on TCVN-4327-86 and ISO-5984; crude fibre based on TCVN-4329-86 and ISO-5498; crude protein based on TCVN-4328-86 and ISO- 5983 (Kjeldahl method); and ether extract based on TCVN-4327-86 and ISO- 5986. The pH of the samples was determined by electrode method.

Treatments	*Per cent* composition by weight of dried ingredients in total mixture		
Rice bran	Cassava leaf meal	Sun-dried chicken manure	
Based on chopped sweet potato root			
E1T1	20		
E1T2		20	
E1T3			20
E1T4	10		10
E1T5		10	10
E1T6	10	10	
Based on grated sweet potato root			
E1T7	20		

E1T8		20	
E1T9			20
E1T10	10		10
E1T11		10	10
E1T12	10	10	

1 All treatments contained 79.5 *per cent* sweet potato root (fresh weight basis) and 0.5 *per cent* salt

To assess feed and food safety aspects, silage prepared with chicken manure was tested for aflatoxin (by thin-layer chromatography) and for *Salmonella* and *E.coli* (by enterobacteria diagnosis).

Three samples of each of the grated dried sweetpotato roots and grated sweetpotato roots ensiled with rice bran were tested for trypsin inhibitor in the laboratory of the International Potato Center (CIP) as this procedure was not available in Vietnam. Sending fresh root samples was not possible; therefore only dried roots were used as comparison with the ensiled samples. Trypsin inhibitor activity, expressed in Trypsin units inhibited (TUI) per milligram of dry sample, was analyzed using the method prescribed in Zhang *et al*. (1988).

Costs of the feed ingredients were calculated to determine the economic efficiency of inputs (feed) and outputs (growth).

Silage combination feeding trial (Experiment 2, E2)

A pig-feeding trial was conducted on-farm in the same village from 20 August to 18 November 2000. Seven households participated, each with six pigs. . All 42 trial pigs were F1 crosses between the local *Mong Cai* sow and the introduced *Large White* boar. Efforts were made to ensure there was no significant difference in the weight (E2T1: 21.75 kg, E2T2: 22.96 kg, and E2T3: 21.89 kg) of the piglets in each treatment at the start of the feeding trial in order not to bias the results (P = 0.628). The sex ratio was also evenly distributed, with seven female and seven male pigs assigned to each treatment.

For 10 days before the trial the piglets were fed an increasing amount of ensiled sweetpotato roots each day to habituate them to the new diet. During the trial all pigs received a basal feed of corn meal, cassava meal, rice bran, cassava leaf meal, fishmeal, and soybean. The mix of these ingredients was based on the weight of the pigs: the bigger the pig, the lower percentage of protein and higher percentage of starch feed (Table 2).

20-30 kg	30-60 kg	61-90 kg	
Corn meal	44	40	36
Cassava meal	13	17	22
Rice bran	15	13	10
Cassava leaf meal	8	10	12
Fish meal	10	10	10
Soy bean	10	10	10
CP (*per cent*)	15.55	15.32	15.19
ME (kcal/kg)	2,916	2,927	2,948

1 Estimated according to the methods of National Institute of Animal Husbandry (1995), pp 108, 114, 120, 124, 128, 134)

2 Each composition of basal feed contained approximately 88 *per cent* of DM.

In addition to the basal feed composition, 0.5 kg of sweet potato vines were fed each day to all pigs during the three-month trial period. The recommended daily ration of this basal feed also varied according to pig weight, with the bigger pigs receiving more than the smaller ones (Table 3). The participating farmers were given the instructions of the precise amount of daily feed depending on the specific weight of the pigs, the daily rations in the table are the range of feed given within each weight category. Water was added to the mixed feed before it was given to the pigs.

20-30 kg	31-40 kg	41-50 kg	51-60 kg	>60 kg		
E2T1, T2 and T3	Basal feed	1-1.5	1.5-1.8	1.8-2	2-2.3	2.3-3
Fresh sweet potato vine	0.5	0.5	0.5	0.5	0.5	
E2T1	Cooked sweet potato root	0.8-1.4	1.2-1.4	1.4-1.8	1.6-2.0	1.8-2.2

E2T2	Uncooked sweet potato root ensiled with rice bran	0.8-1.2	1.0-1.4	1.3-1.7	1.4-1.8	1.6-2.0
E2T3	Uncooked sweet potato root ensiled with chicken manure	0.8-1.2	1.0-1.4	1.3-1.7	1.4-1.8	1.6-2.0

In addition to the basal feed, in each household two piglets were assigned to each of the following three feeding treatments (i.e., two replications per treatment per household):

- Treatment 1 (E2T1): fresh sweet potato roots, cooked
- Treatment 2 (E2T2): grated sweet potato roots ensiled with 20 *per cent* of rice bran and 0.5 *per cent* of salt, uncooked
- Treatment 3 (E2T3): grated sweet potato roots ensiled with 20 *per cent* of chicken manure and 0.5 *per cent* of salt, uncooked

The pigs were weighed four times during the trial: on the first day, after one month, after two months, and on the last day of the third month. The amount and the market price of feed were recorded to calculate the costs of total feed and per kilo of weight gain.

ANOVA one-way classification by Minitab 12.21 was performed to analyze the variance and determine the P value; the Tukey test was used to test the mean differences among categories. Variance of conditions of the participating farming households and piglet quality were not taken into consideration in the analysis.

Silage proportion feeding trial (Experiment 3, E3)

The follow-up feeding trial was conducted in the same village from 2 February to 5 May 2001. Only six households participated, each with six pigs. All 36 trial pigs were also F1 pigs. Average weight of the piglets at the start of the trial was 16 - 17 kg, with no significant difference among the piglets in each treatment (P = 0.678). The sex ratio was also evenly distributed, with six female and six male pigs in each treatment.

The silage for this trial was prepared with grated sweet potato roots (79.5 *per cent*), rice bran (20 *per cent*) and salt (0.5 *per cent*). From 25 January to 2 February the piglets were fed increasing amount of silage feed each day to help them adjust to the new diet. The basal feed for the trial contained corn meal, cassava meal, rice bran, fishmeal and soybean; the composition is given in Table 4.

20-30 kg	30-60 kg	61-90 kg	
Corn meal	47	46	44
Cassava meal	13	18	23
Rice bran	15	14	13
Fish meal	10	10	10
Soybean	15	12	10
CP (*per cent*)	16.05	14.85	13.93
ME (kcal/kg)	2,916	2,927	2,948

1 Estimated according to the methods of National Institute of Animal Husbandry (1995), pp 108, 114, 120, 124, 128, 134)

2 Each composition of basal feed contained approximately 88.4 *per cent* of DM

The three treatments were:

- Treatment 1 (E3T1). Feed comprising 90 *per cent* (DM basis) of basal feed plus 10 *per cent* (DM basis) of sweet potato silage
- Treatment 2 (E3T2). Feed comprising 80 *per cent* (DM basis) of basal feed plus 20 *per cent* (DM basis) of sweet potato silage
- Treatment 3 (E3T3). Feed comprising 70 *per cent* (DM basis) of basal feed plus 30 *per cent* (DM basis) of sweet potato silage

The daily feeding ration is shown in Table 5.

20-30 kg	31-40 kg	41-50 kg	51-60 kg	>60 kg		
E3T1	Basal feed	1.1-1.6	1.7-2.0	2.1-2.3	2.4-2.6	2.7-3.4
Silage feed	0.4-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.2	

E3T2	Basal feed	1.0-1.4	1.5-1.8	1.9-2.0	2.1-2.3	2.4-3.0
Silage feed	0.8-1.1	1.1-1.4	1.5-1.6	1.7-1.8	1.9-2.4	
E3T3	Basal feed	0.9-1.3	1.3-1.6	1.6-1.8	1.9-2.0	2.1-2.7
Silage feed	1.1-1.7	1.8-2.1	2.2-2.4	2.5-2.7	2.8-3.5	

The weighing schedule, calculation of cost and benefits, and statistical analysis procedure were identical to those used in the previous feeding trial.

Sweet potato root silage trial (E1)

Within each treatment, dry matter, crude protein, ether extract, crude fiber and ash contents did not differ significantly over time (at 14, 30, 60 and 90 days of silage). Also, the method of preparing the sweet potato roots (slicing or grating) had no effect on these parameters. However, some parameters did differ amongst treatments, as summarized in Table 6. In particular, silage made with 20 *per cent* of chicken manure or 20 *per cent* of cassava leaf meal, or with a combination of the two (10 *per cent* each), had the highest crude protein contents, and the pH and dry-matter and ash contents of the silage containing 20 *per cent* of cassava leaf meal were different to those of the silage made with 20 *per cent* of chicken manure. Silage made with chicken manure has the lowest cost per kilo, and so has the highest potential as a pig feed, particularly as many farmers will have an immediate source of manure from their own chickens.

	pH	Dry matter (*per cent*)	Crude protein (*per cent* of dry matter)	Ash (*per cent* of dry matter)
1 Sweet potato roots ensiled with 20 *per cent* rice bran	3.28 e	27.63 c	9.18 c	9.13 c

2 Sweet potato roots ensiled with 20 *per cent* cassava leaf meal	3.31 e	28.85 bc	16.62 a	8.42 dc
3 Sweet potato roots ensiled with 20 *per cent* chicken manure	4.09 a	30.48 a	16.59 a	16.50 a
4 Sweet potato roots ensiled with 10 *per cent* rice bran and 10 *per cent* chicken manure	3.69 c	29.30 ab	13.35 b	13.15 b
5 Sweet potato roots ensiled with 10 *per cent* cassava leaf meal and 10 *per cent* chicken manure	3.81 b	30.75 a	17.10 a	12.39 b
6 Sweet potato roots ensiled with 10 *per cent* rice bran and 10 *per cent* cassava leaf meal	3.48 d	28.51 bc	13.17 b	8.63 dc
P	<0.001	<0.001	<0.001	<0.001
With chicken manure	3.91	30.00	15.14	14.79
With cassava leaf meal	3.38	29.09	14.93	8.47

1 Treatments were based on 79.5 *per cent* sweet potato roots (either sliced or grated) and 0.5

per cent
salt.

Within columns, means followed by the same letter do not differ significantly at P<0.05 by ANOVA and Tukey.

The average of trypsin units inhibited (TUI) of the dried root samples, on dry matter basis, was 15.33 TUI/mg while the average of the three ensiled samples was 11.75 TUI/mg, indicating 30.5 *per cent* decrease. It is expected that the decrease from fresh roots would be more significant.

Silage combination feeding trial (E2)

The average daily weight gains of the pigs over the 89 days of the trial showed no significant difference amongst the three treatments (Table 7), because of the large standard deviation that resulted from the highly variable households, varied piglet quality and growth potential, and varied palatability for silage feed. Even so the differences are quite substantial. The cost of E2T2 (Treatment 2) was considerably higher than the other two, and most uneconomical.

Mean	SD	Mean	SD	Mean	SD		
Initial weight (kg)	21.75	4.78	22.96	2.86	21.89	2.86	0.628
Final weight (kg)	70.96	13.31	76.82	12.19	78.93	10.58	0.208
Total weight gain (kg)	49.21	9.92	53.86	10.04	57.04	8.73	0.108
Daily weight gain (g/d)	552	186	605	158	640	145	0.283
Rate of weight gain (%)	226		234		261		
Feed cost (VND/kg weight gain)	6,724		7,354		6,767		

The most important finding was that uncooked sweet potato root silage could achieve pig growth comparable with that achieved with cooked sweet potato roots, but at much lower cost in labor time and fuel. Instead of eliminated through cooking, more than 30 *per cent* of trypsin inhibitor was reduced through ensiling, which appeared to be enough to remove the need of cooking. Moreover, silage can be stored for at least five months, so ensiling also effectively resolves the storage problem.

Having been freed from the expense and effort of cooking their pig feed, and having discovered the potential of cassava leaves as feed, the participating farmers using sweet potato root silage now raised three times as many pigs as before. And many non-participating farmers adopted this technology from their neighbors. Even commune leaders from the neighboring province came to ask about the technology, and would even like to extend the technology to potato silage for feed.

Silage proportion feeding trial (E3)

Total weight gain and daily weight gain (539 g) for E3T1 were significantly higher than those for E3T3; gains for Treatment 2 were similar to those of the other two treatments (Table 8). E3T1 was the most cost-effective and E3T3 the least. Nevertheless, at the time of the trial, pigs could be sold for 9,100 vnd/kg liveweight, therefore, all three treatments were profitable. This would suggest that adding as little as 10 *per cent* of sweet potato root silage to the feed is an effective option since farmers' traditional practices are often not profitable.

E3T1		E3T2		E3T3			
Mean	SD	Mean	SD	Mean	SD		
Initial weight (kg)	17.86	2.81	17.47	2.40	16.97	2.16	0.678
Final weight (kg)	67.50 a	8.18	63.46 ab	8.55	58.75 b	9.31	0.041
Total weight gain (kg)	49.64 a	6.77	45.99 ab	7.38	41.78 b	8.94	0.049
Daily weight gain (g/d)	539 a	73.6	500 ab	80.3	454 b	97.2	0.049
Rate of weight gain (%)	278		263		246		
Feed cost (VND/kg weight gain)	8,182		8,335		8,693		

Across rows, means followed by the same letter do not differ significantly at P<0.05 by ANOVA and Tukey tests.

However, closer examination of the data for daily weight gain and feed cost in each month of the study suggested that there might be a better alternative. As shown in Table 9, within each month of the trial, there was no significant difference between the daily weight gains for all three treatments, but the feeds costs were different. Feed costs were lowest for:

- Treatment 3 in the first month
- Treatment 2 in the second month
- Treatment 1 in the third month

Mean	SD	Mean	SD	Mean	SD			

Month 1	Weight gain (kg/m)	15.53	4.37	13.50	2.33	12.85	3.75	0.178
Daily weight gain (g/d)	518	145.6	450	77.7	428	124.8	0.178	
Feed cost (VND/kg weight gain)	7,702		7,540		***6,664***			
Month 2	Weight gain (kg/m)	17.12	3.97	17.45	3.57	14.89	3.94	0.221
Daily weight gain (g/d)	552	128.0	563	115.3	480	127.0	0.221	
Feed cost (VND/kg weight gain)	8,245		***7,897***		9,048			
Month 3	Weight gain (kg/m)	17.00	3.79	15.04	4.64	14.04	4.78	0.264
Daily weight gain (g/d)	548	122.3	485	149.6	453	154.3	0.264	
Feed cost (VND/kg weight gain)	***8,852***		9,558		10,172			

These results suggest that a varying feeding regime would require the lowest input to achieve the same growth as feeding the same amount of silage during the three months period. So varying the amount of sweet potato root silage in the feed, from 30 *per cent* (dry matter basis) in the first month, to 20 *per cent* in the second month and to only 10 *per cent* in the third month, may achieve better growth and economic efficiency than feeding 10 *per cent* silage through the three-month period. It is reasonable to hypothesize that the profit would increase by using this feeding scenario.

CONCLUSIONS

Feeding sweet potato roots to pigs offers a good opportunity to convert an undesirable and often unmarketable crop into a high-value commodity - pork. But sweet potato roots have low starch digestibility and protein content, and contain trypsin inhibitors which reduce protein uptake, and the traditional way to overcome these constraints is to cook the feed, which is expensive of labor and fuel. Moreover, sweet potato roots do not store well, so feed must be prepared fresh every day. Ensiling sweet potato roots with rice bran, cassava leaf meal or chicken manure, offers an alternative solution to some of these constraints. In addition to reducing the level of trypsin inhibitor, silage can be stored for five months without spoilage if it is stored carefully in tightly packed plastic bags under anaerobic condition.

Silage based on uncooked sweet potato roots was found to achieve pig growth rates comparable with those achieved with cooked sweet potato roots, at no increase in cost and with considerably lower labor requirements. Lowering trypsin inhibitor levels through the ensiling process decreased the need for cooking. Participating farmers stated that the heavy labor requirement for cooking was one of the major obstacles to increasing production, and indeed, when freed from this chore, farmers were able to increase their production three-fold. On their own initiative, the farmers have been using rice bran to ensile sweet potato roots because they find it to be most convenient. Some farmers expressed interest in extending sweet potato root silage to chickens, ducks, and even dogs.

When used with other feed materials, even small amounts of sweet potato silage (10 *per cent* of the total feed, on a dry-matter basis) can achieve good growth. But it seems that it may be more cost-effective to feed a higher amount (30 *per cent* of total feed) in the first month, and then reducing this proportion in subsequent months. The effects of this feeding regime need to be verified by a trial specifically designed to test this hypothesis.

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Yes