Assessment of the Potential of Sweetpotato as Livestock Feed in East Africa: Rwanda, Uganda, and Kenya

A report presented to The International Potato Center (CIP) in Nairobi

By

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Based on a study mission to Rwanda, Uganda, and Kenya

TABLE OF CONTENTS

Annexes:

1. Introduction

The use of sweetpotato as a feed source in sub-Saharan Africa has been limited thus far and its use principally consists of vines being fed to dairy cattle and goats as energy supplements. As part of the development of the sweetpotato commodity initiative, the degree to which resources should be dedicated to developing the potential use of sweetpotato as an animal feed in this region needs to be assessed. This study thus focuses on the assessment of the extent to which sweetpotato can contribute to livestock production in East Africa, principally in Rwanda, Uganda, and Kenya. The objective of the study is to examine whether sweetpotato can play a more significant role in livestock production in East Africa, under what conditions it can play such a role, where it could make the most noteworthy contribution, and what research and development activities need to be carried out to realize this potential.

The assessment examines two potential areas where sweetpotato may play a significant role. The first area is sweetpotato as smallholder livestock feed, mainly for pigs, dairy cows, and dairy goats; the second area examines the potential of sweetpotato as substitution for a portion of the current maize-based commercial feed. With these two areas of interest in mind, both smallholder livestock raisers and large factories were interviewed during a period of ten days between June 27th and July 8th 2008. Pig and dairy cow farmers in the surrounding areas of Kigali were visited and interviewed, as was SOPAB *(Société pour la Production d'Aliments pour Bétail)*, the largest feed factory in Rwanda and a small backyard type of feed manufacturer. The visit to Uganda was too short to allow visits outside of Kampala, and the most significant visit there was to Ugachick, the largest feed factory in the country. Much of the information on Uganda draws instead on five weeks of interviews with nearly 60 homesteads about their pig production systems in 1997. The visits to pig and dairy farmers in Kenya were more extensive, including farmers around Nairobi and in western Kenya (Kisii area). Both smallholder growers and contract farmers of Farmer's Choice, the largest piggery and feed factory in Kenya, were interviewed for comparative purposes.

The report is thus divided into two major sections. The first section examines the potential of sweetpotato as smallholder livestock feed. In this section, the current feeding characteristics of smallholder pig, dairy cow and dairy goat, and contract farming pig production are provided first as a basis for discussion of the potential role of sweetpotato in these production systems. This discussion includes a set of recommendations on research activities needed to render sweetpotato a more productive feed source. The second section examines the potential of sweetpotato in commercial feed production. This section is based on discussions with the large factories in each country and the comparative economic analysis of sweetpotato and the current main feed, which is maize.

2. Potential of sweetpotato as smallholder livestock feed

This assessment of the potential of sweetpotato as feed for small holder livestock growers in East Africa rests on the understanding of the current production system, particularly the feed system, in relation to the final output of milk, offspring, and meat. The first part of this section examines the current characteristics of the dairy cow, dairy goat, and meat pig production in Rwanda, Uganda, and Kenya, based on which the potential of the role of sweetpotato for smallholder livestock feed is provided in the second section.

2.1 Characteristics of livestock production

2.1.1 Dairy cows

The zero grazing policy has (in the case of Rwanda) or would have (in the case of Kenya) a greater impact on meat cattle than dairy cows, as the latter, particularly the pure breeds, are less likely to be left to open grazing for fear of picking up diseases and the need for more intense feed. Nonetheless, such a policy still has had an impact on the dairy cows because the feed prices have increased already in Rwanda: prior to the zero grazing policy, each bundle of sweetpotato vines (15-20 kg) cost 200 RWF, but now cost 250-300 RWF. Sweetpotato vines sold in the market are either for planting material or feed, and the quality of the former is higher, while the vines for feed are cut while the roots are being harvested; thus, the quality is lower. The prices differ depending on the quality, and thus the use (Table 1).

Table 1. The prices of sweetpotato vines depending on use

	Price (RWF/bundle)	Wt (kg/bdl)	Price (RWF/kg)
Planting material	500	17.5	28.6
Feed	300	18.5	16.2

As the second largest staple crop, next only to banana, large quantities of sweetpotato roots are consumed in Rwanda, and this consumption pattern generates a large amount of sweetpotato vines that are used as feed for dairy cows. As such Rwandan farmers have cheaper access to sweetpotato vines for feed (Table 2), and subsequently seem to be more familiar with the benefits of sweetpotato vines for milk production than farmers in Kenya.

Table 2. The prices of sweetpotato vines for feed in Rwanda and Kenya

	Rwanda			Kenya	
	RWF/kg	USD/kg[1]		Ksh/kg	USD/kg[2]
Before zero grazing	11	0.021	When maize is available*	5	0.08
Currently	16	0.029	Wet season	10	0.16
			Dry season	20	0.32

* During maize harvest season, maize stalks are widely available and cheap, thus offering serious competition with SP vines.

Several Rwandan dairy cow farmers interviewed independently stated that regular feeding of sweetpotato vines increases milk production by an amount that averages approximately 1.5 liters per day. Meanwhile, merely sporadic feeding of sweetpotato vines is worse than not providing this high quality feed at all. They further stated that only if a farmer can afford to feed it on a regular basis should sweetpotato vines be fed; otherwise, the productivity is even lower that not feeding it at all. This is because once the cows get used to high quality feed, she will not eat unless this quality feed is present. She will otherwise refuse to eat for a couple of days until she gets too hungry to continue resisting inferior feeds. And, skipping two to three days of eating has a serious adverse effect on milk production. She may even stop lactating while waiting for the good feed (Table 3).

Table 3. The effects of irregular feeding of sweetpotato vines

[1] RWF 545 = US$ 1
[2] Ksh 63 = US$ 1

Feeding practices	Milk production (liters/cow/day)
Feed SP vines regularly	16
Never feed SP vines	10-12
Feed SP vines sporadically	< 10

There are no data to support this claim by farmers as none of the interviewed farmers have engaged in such irregular feeding practices. Nevertheless, the feeding practices from the interviewed the farmers indicate that the regular feeding of small amounts of sweetpotato vines (5 kg/day or less) seems to have little positive effects on milk production as well (Table 4). Both milk production per cycle and per year are calculated in this table because the calving interval of each cow is variable, ranging from 12 months up to 24 months. Milk production per cycle is calculated based on the milk produced during the period after calving, and it is then divided by the length of time it takes to calve in order to calculate the milk production per year. Table 4 is sorted by milk production per year. The two farmers in Rwanda, each feeding an average of15 kg of sweetpotato vines per day achieved the highest amount of milk production per cow per year. Farmer #13 was the only Kenyan that fed significant amounts of sweetpotato vines, while all other interviewed Kenyan farmers only fed 0-5 kg per day, and sporadically at best. The pure breeds are fed 80-100 kg of fresh fodders each day, most of which is Napier grass; while the crosses and local breeds are fed an average of 60 kg and 20-30 kg of fodders, respectively.

Table 4. Milk production and feeding practices

Farmer	Breed	Milk (L/cycle)	Milk (L/yr)	Feed (kg/day/cow)
RWD 1	Pure	5,000	4,000	Napier 70, **SP vines 15**, maize stalks
RWD 2	Pure	4,875	3,900	Napier 30, maize stalks 20, **SP vines 15**, concentrate 6 -8
12	Pure	3,540	3,540	Napier 70, dairy meal 4, desmodium+calliandra+SP vines 5
7	Pure	4,200	3,360	Napier 60, Maize stalks 20, desmodium 10, SP vines, grazing
10	Pure	3,990	3,103	Napier , hay , maize bran + dairy meal mix 6 kg
2	Pure	3,060	3,060	Napier 80, grasses 25, dairy meal 3, maize stalks, calliandra
13	Pure	2,580	2,580	Napier 30**, SP 15**, tethonia+desmodium+tree fodder 15, grass 10
8	Pure	3,120	1,993	Napier 40, SP vines 2-3, Maize stalks, molasses 0.2 litre
12	Pure	3,540	1,770	Napier 70, dairy meal 4, desmodium+calliandra+SP vines 5
6	Cross	3,210	1,376	Napier 63, grasses 60, Maize stalks seasonally
3	Cross	1,200	857	Napier 30, grazing, dairy meal 2
9	Local	540	327	Napier 20, grazing, SP vine 1 kg, maize stalks
5	Cross	1,020	306	Napier 30, grasses 30, dairy meal 1
11	Local	630	242	Napier 35, grasses 10, desmodium+calliandra 2.5, SP vines <1
1	Local	330	189	Napier 20kg, grazing
4	Cross	300	150	Napier 45, grasses 20

In addition to milk, dairy cows also generate additional income from the sale of calves, whose prices often depend on the lactating rate of the cow (i.e., the higher the daily milk production of the cow, the higher the price of the calf). Nevertheless, the higher frequency of calving rate, though resulting in higher income from the sale of the calves, decreases the milk income as the length of milking period decreases accordingly. Milk prices vary between 24 to 40 Ksh per kg in different areas of central and western Kenya, so the adjusted milk income is based on the same milk price for all farmers (including the data from Rwanda) and the adjusted gross income is the sum of incomes derived from both milk and calves (Table 5). While the two Rwandan farmers who feed sweetpotato vines regularly realize the highest gross income, Kenyan farmer #13, though feeding 15 kg of sweetpotato vines per day, still achieves lower gross income, probably due to insufficient total feed (70 kg of material in total).

Table 5. Adjusted milk and gross income of per cow per year

Farmer	Breed	Adjusted milk income (KS/Y/cow)	Adjusted gross income (KS/yr/cow)	Feed (kg/day/cow)
RWD 1	Pure	120,000	157,500	Napier 70, **SP vines 15**, maize stalks
RWD 2	Pure	117,000	154,500	Napier 30, maize stalks 20, **SP vines 15,** concentrate 6 -8
7	Pure	100,800	153,300	Napier 60, Maize stalks 20, desmodium 10, SP vines, grazing
10	Pure	93,100	143,100	Napier , hay , maize bran + dairy meal mix 6 kg
12	Pure	106,200	140,575	Napier 70, dairy meal 4, desmodium+calliandra+SP vines 5
12	Pure	53,100	121,850	Napier 70, dairy meal 4, desmodium+calliandra+SP vines 5
2	Pure	91,800	106,800	Napier 80, grasses 25, dairy meal 3, maize stalks, calliandra
13	Pure	77,400	99,900	Napier 30, **SP 15,** tethonia+desmodium+tree fodder 15, grass 10
8	Pure	66,857	80,586	Napier 40, SP vines 2-3, Maize stalks, molasses 0.2 litre
6	Cross	41,271	54,605	Napier 63, grasses 60, Maize stalks seasonally
3	Cross	25,714	36,914	Napier 30, grazing, dairy meal 2
11	Local	7,269	29,669	Napier 35, grasses 10, desmodium+calliandra 2.5, SP vines <1
5	Cross	9,180	20,180	Napier 30, grasses 30, dairy meal 1
9	Local	9,818	16,818	Napier 20kg, grazing, SP vine 1 kg, maize stalks
4	Cross	4,500	13,833	Napier 45, grasses 20
1	Local	5,657	13,532	Napier 20kg, grazing

The pure breeds require higher investment, as it takes 26 tons of Napier grass-feed a year from 1.8 acres of land, but the return is also higher. The cross and local breeds require less investment and in turn offer lower returns (Table 6).

Table 6. Investment and economic return from the different breeds of dairy cows

	Pure	Cross	Local
Napier (ton/yr/cow)	26	13	9
Land needed (acre/yr/cow)	1.8	0.9	0.7
Return on cow (Ksh/yr/cow)	129,465	31,383	20,007
Return on land (Ksh/yr/acre)	70,940	34,392	30,695

2.1.2 Dairy goats

Raising dairy goats is a relatively new phenomenon as goat milk has gained popularity due to being hailed as a healing drink for HIV-AIDS patients. This popularity has pushed the prices way beyond the price of cow milk, with the price of goat milk varying between 40 and 120 Ksh/liter; the closer to Nairobi, or any major city, the higher the price. But so far there are only a small number of farmers raising dairy goats, for the following reasons:

- Goat milk is a new enterprise especially since it became the “miracle food” for HIV patients
- Lack of awareness that goats can be productive, because the local goats are not

- Lack of access to exotic breeds
    - Not enough exotic breeds available
    - Good breeds are expensive: 7,000 Ksh vs. 1,000 Ksh for a local goat

The compositions of feed for dairy goats are more varied, less uniform, and more difficult to quantify. Though Napier also plays a significant role in dairy goat diet, it is less dominant than in the cow diet. Sweetpotato vines are used by almost all farmers, and though the absolute quantities are less than that fed to cows, the relative quantities (i.e., percentage of total feed) are higher. This is largely due to the lower feed requirement for goats than cows. The two best performing pure breed diets are due to: 1) large amounts of fodder feed (8-9 kg/day) plus a protein source supplement of sunflower meal or cottonseed meal, 2) large amounts of fodder feed (12 kg/day) plus dairy meal (Table 7). Farmer #7 feeds only 6 kg of fodders, 3 kg of which are sweetpotato vines, which is only 50% of the volume of the fodders fed by farmer #2, but still achieves 93% of the milk production of farmer #2. Among the cross breeds, the two dairy goats with the highest milk production are those fed a significant amount of sweetpotato vines.

Table 7. Milk production and income in relation to feeds

Farmer	Breed	Milk (liters/yr)	Adjusted gross income (Ksh/yr/goat)	Feed (kg/day/goat)
4	Pure	1080	61,200	Napier, SP vines, desmodium, green cover crop mix 8-9 kg, grasses, sunflower meal or cottonseed meal
2	Pure	540	31,300	Napier, caliandra, SP vines, tethonia, avocado leaves 12 kg, and dairy meal 1 kg
7	Pure	504	27,580	**SP vines 3,** Calliandra 3 kg, dry mix of SP vine+calliandra+maize bran 0.25
3	Pure	480	21,600	Same as Farmer #2, but Dairy meal only 0.5 kg
10	Cross	270	18,150	Napier 7, **SP vines 3,** caliandra+tethonia+tree fodder 3
9	Cross	240	16,133	**SP vines 7**, Napier 2.5, caliandra+tethonia+avocado leaves+sesbania 3
1	Cross	240	16,400	Napier, calliandra, maize stem, tree fodder mix, and dairy meal 1 kg
8	Cross	135	10,075	Napier 10, SP vine 2, Tethonia+avocado leaves+tree fodder+caliandra 2
5	Cross	55	4,581	Napier, SP vine, fodder, Luceana mix 5 kg
6	Cross	53	3,863	Napier, dairy meal+ maize bran mix 4 kg, SP vines
8	Local	90	5,050	Napier 10, SP vine 2, Tethonia+avocado leaves+tree fodder+calliandra 2

The return on pure bred dairy goats is by far greater than that of the cross breeds or local breeds (Table 8). The investment of a pure exotic breed is high both in the goat and the feed, and the risk can also be equally high. An NGO project gave a group of self-help women pure breed dairy goat (but due to the cost of pure breed goats, only 7 out of the group of 25 were given a goat initially), and most of the goats or their offspring did not survive. The only goat operation that survived is that of a woman who is not so much a farmer as an entrepreneur who has a lucrative business of silk screening and printing of garments. It suggests that pure breeds are difficult to raise and may not be appropriate for first time raisers. It would have been better to have provided more women with local breeds for only 1,000 Ks each, vs. 7,000 Ks for a pure breed, and have them breed with the hybrid bucks in order to produce F1 off-springs.

Table 8. Milk production and income from different breeds of dairy goats

	Baby goat (Ksh)	Milk (liters/day)	Milk period (mo)	Milk income (Ksh/yr/goat)	Total income (Ksh/yr/goat)	Adjusted total income* (Ksh/yr/goat)
Pure	7,000	2.4	8	41,220	47,345	35,420
Cross	3,800	1.4	4	7,868	11,568	8,730
Local	1,000	1.0	3	4,050	5,050	5,050

*For the sake of comparison, adjusted income uses 45 Ksh/liter as the standard price of milk

The best approach seems to be the practice that many of the farmers have pursued—start with a local she-goat and breed it with a pure buck or a 75% pure buck. The cross breeds are more disease-resistant and require less feed. While the prices of pure and local bred baby goats are fairly standardized between 7,000-8,000 Ksh each and 1,000 each, respectively, the prices of cross bred babies varies between 2,800 and 6,000 Ksh each.

The optimal birthing potential of dairy goats is two births per year, but the average births among the interviewed farmers are only 1.1 births. While low breeding rate is highly related to the quality of feed, in this case, the low birth rate is also caused by the following reasons:

- Not enough bucks, farmers often have to wait a long time to find a buck to mate the goat
- Lack of know-how, as most of the farmers do not yet know the mating patterns of goats.

Dairy goats, which are much less demanding of volume of feed compared to dairy cows, offer much greater return on the land on which to grow fodder (Table 9). The return on land for the pure bred dairy goat is 181,597 vs. 70,509 Ksh/yr/acre for pure bred cows, with similar discrepancies for the cross breeds (see Table 6).

Table 9. Investment and return from the different breeds of dairy goats

	Pure	Cross	Local
Napier (tons/yr/goat)	3.7	2.9	2.9
Land needed (acres/yr/goat)	0.3	0.2	0.2
Return on goat (Ksh/yr/goat	47,345	10,545	5,050
Return on land (Ksh/yr/acre)	181,597	50,558	24,212

2.1.3 Pigs

The smallholder pig raising in Rwanda, Uganda, and Kenya share many similar characteristics, which are described below for each country. This is followed by a summary of the problems/constraints associated with this sweetpotato-pig feed system.

2.1.3.1 <u>Pig husbandry in Rwanda</u>

Pig husbandry is a new enterprise (at least around Kigali), which arose in response to increasing demand in Kigali. Pork is so popular now it is called “Benz”, as in Mercedes Benz.

Pork commands a higher price than mutton or beef in both Rwanda and Kenya as there is a shortage of supply (Table 10).

Table 10. Prices of various meats in Kenya and Rwanda

	Rwanda (RWF/kg)	Kenya (Ksh/kg)
Pork	2,500	250
Beef	1,500	150
Goat	1,000 – 1,200	200

There are still relatively few farmers who raise them, but the numbers are increasing as they become more aware of the market opportunity. Most farmers are interested in producing piglets to sell, as the Kigali consumers seem to favor piglets to accompany their evening beer drinking and for roasting whole piglets. Sweetpotato roots and vines make up the bulk of the pig diet, while sorghum alcohol residue, grasses, some cassava roots and leaves are fed as supplements. Due to a lack of knowledge about processing the vines, farmers leave most of the vines in the field after the roots have been harvested, collecting only enough vines for planting material and three days of fresh feed.

Two reasons cited by farmers for raising pigs were:

- Easier to raise than goats because goats can get stolen at night and thus must be kept inside of the house while pigs cannot get stolen because they squeal loudly
- More profitable than dairy cows

2.1.3.2 <u>Pig production in Kenya</u>

According to Farmer's Choice (FC), the largest pig and feed-producing company in Kenya, 70% of pigs in Kenya are produced within 100 km from Nairobi. Of the pigs marketed by FC, 40% is supplied by contracting farmers, to whom FC provides the pure breeds, discounted commercial feed, extension services, and guidelines for quality of pigs. The pig procurement office is one and the same as the extension office, which is the direct link to the contracting farmers. The least requirement is five pure breed sows, but would prefer the farmers have at least 10 sows, and capacity to produce 60 pigs, of 70-80 kg each, per year. Most of these contracting farmers feed commercial feed, and supplement it with sweetpotato vines, which are fed sporadically. These farmers also own land on which they grow various crops to supplement the feed. Most of the land is planted with Napier grass, either for their own dairy cows or to sell to other dairy cows. Little land is allocated to sweetpotato production due to a lack of awareness of the potential benefits of sweetpotato as pig feed.

The other 30% of pig production is scattered in central and western Kenya where sweetpotato production is high. The sweetpotato-pig feeding system among these farmers is similar to that observed in Uganda and Rwanda—sweetpotato roots and vines make up the bulk of the pig diet and they are supplemented by alcohol residue and whatever other crops are available.

According to the FC procurement/extension staff, little research has been done by KARI on pig and there is much about pig feeding, particularly farm crop based feeding, is unknown in Kenya. For example, sweetpotato-pig feeding system is basically unknown to them (though it is not unknown to sweetpotato farmers in western Kenya). Speaking on behalf of FC, he very much welcomes collaborative research on the use of fresh sweetpotato vines or vine silage as feed for their contracting farmers in order to cut feed cost and improve growth efficiency.

Pig raising is a completely new enterprise in some part of the country, such as in Kisii. There is little demand in this area because most of the population in the Kisumu/Kisii area are the Seventh Day Adventist (SDA) or Moslem and do not consume pork. A group of 26 farmers plan to start growing pigs but so far only one has started production, three years ago. His main focus is on sow production for other interested growers.

This one particular farmer, and other members in the group, would prefer to rely on commercial feed along with maize bran. But the feed supply was interrupted during the unrest and has not yet returned, so he was forced to feed Napier grass and other grasses/weeds, along with a small amount of sweetpotato roots and vines, as there is little available. Recently, he has discovered that he could have free access to leftovers from school lunches, and plans to focus on feeding Napier grass, grasses/weeds, and leftovers to his pigs, until the supply of commercial feed has returned. Until the group has a reliable source of feed, they cannot have reliable or expanded production. With such small production, they can only produce pork to be sold in local markets, which are extremely limited. Their goal is to be part of the contract farmers for FC and raise pigs for FC while purchasing commercial feed supplies from them.

2.1.3.3 Pig production in Soroti, Uganda (from 1997 assessment)

Thirty-nine of the 57 homesteads, or 63%, interviewed raised pigs, which completely coincides with the estimate of the head of the Farmers' Association of each village, which was 40%, 70%, and 80%. The percentage was much higher before an alleged African Swine Fever devastated the pig population in this area in 1995-96. Pigs and sweetpotato were perceived as ways to gain quick turnaround of cash while cattle and cassava were for the long haul. Tethered only loosely to a tree or a stump in the shade, the pigs grazed around the area most of the day and were fed twice a day in general.

Most homesteads raised only one pig and the average number of pigs per homestead was 1.83. Most farmers considered pig-raising a profitable venture, but hesitated to raise more for the following four common reasons: 1) insufficient feed during the dry season, 2) difficulty in confining the pigs, 3) fear of African Swine Fever, and 4) lack of cash to buy piglets. The homesteads that did not raise pigs stated similar reasons for not raising pigs. Managing and confining the pigs was of great concern because a steep fine was imposed if the pigs were caught grazing on neighbor's crops.

Even though the farmers considered pig-raising profitable, pig growth was grossly under achieved with an average of 90 grams of daily weight gain. Consequently, after seven to eight months of rearing, the pigs reach only 20-30 kg (similar to the pigs raised outside of Kigali, the pigs were mainly fed on sweetpotato roots and vines, supplemented with locally available feeds with low nutritional value—alcohol residues, fish bones, grass, mango, and papaya). One problem in the feeding practices that was not observed in Rwanda or Kenya was the rate of farmers feeding uncooked sweetpotato roots to pigs. A shared mistake among the Rwandan and Ugandan farmers is that the farmers tend to discard the vines upon harvest of the roots due to a lack of awareness of processing possibilities for the vines (Table 11).

Table 11. Pig feeding practices in three Ugandan villages.

Village	SP roots (kg/day)	Homestead cooks SP (%)	Homestead saves vines[a] (%)	Homestead feed peels (%)	Homestead feed *adakai*[b] (%)	Homestead feed *ting*[c] (%)
Dokolo	2.66	23	0	23	46	--
Aukot	2.41	29	0	71	57	57
Awoja	1.94	100	8	92	75	75

[a] Sweetpotato vines are normally fed to pigs during harvest period and once the harvest is over, the vines are discarded in the field.
[b] *Adakai* is the residue of alcohol brewed from millet.
[c] *Ting* is the residue from brewing *waragi*.

2.1.3.4 Shared characteristics

The following observed management (or lack there of) and feeding practices, among other factors, contributed to slow growth rate. These observations are significant in that "the major limiting factor in growth rate under most primitive conditions is a lack of protein in the diet and failure to control internal parasites (worms) and environmental stress" (Goodman 1994:75). Both feeding and management practices need to be improved to achieve higher production efficiency. Specific problems are:

- The lack of distinctions between three pig raising systems: 1) Sow/piglet production, 2) sow/piglet/meat pig production, and 3) Meat pig production.

- Sweetpotato production has problems of choice of varieties and methods of harvesting: First, varieties are selected for human consumption and thus are low-yielding, and wasteful as animal feed, and second, the method of cutting vines does not yield the highest productivity potential.

- The feeding system produces an unbalanced diet: First, there are too many kilos of sweetpotato roots (5-10 kg/day/pig) and vines (10-20 kg/day/pig) fed. Second, there is a shortage of sources of protein supplement[3]; 3) the method of separating roots from vines in feeding and separating sorghum residue from concentrate make an already unbalanced diet even less balanced[4]; and finally, the daily diet was not balanced and feeding was sporadic. Sweetpotato roots were mostly fed fresh and even when cooked, the roots were cooked too briefly to allow starch to break down. t

- Management practices were generally poor. Poorly constructed pens were likely to be hot during the day and cold at night and pigs were maintained in extremely unclean and unsanitary conditions. For example, in Uganda pigs were often tethered next to open latrines and the exposure to human feces put pigs at risk for infection (Holland et al. 1995). Moreover, pigs rooted around the trees on which they were tethered and often were infested with worms.

These factors result in slow growth rates, low fertility and high mortality

[3] The pigs lack any significant protein supplement, especially in light of the fact that sweetpotato vines, the main source of protein, were fed only during the harvest season.

[4] The vines were not chopped or cooked and whole vines were given to pigs, which ate only the leaves and left the vines untouched.

- In the group studied, the slow growth rates are shown by weight at various stages:

    - At weaning (35 days): 4 kg
    - At 6 weeks: 5-6 kg
    - At 4 months: 20 kg (this cohort no longer had access to commercial feed when they grew up)
    - At .6 months: 60 kg (commercial feed was still available when they were piglets)

- Fertility is affected by the following practices:

    - Nursing period lasts three months and longer
    - Taking after the practices for dairy cows and goats, piglets continue to nurse even after the sow has been mated and 1.5 months into the pregnancy
    - Sow must go to boar, instead of the other way around
    - Low fertility rate (one sow only had two piglets in the litter of her latest birth), reasons not known, but very likely related to poor feed
    - High mortality rate (none the piglets from the last birth of the sow mentioned above survived)

In summary, although sweetpotato is a good source of protein that addresses the most critical problem mentioned by Goodman, without a complementary action to improve management practices in swine cultivation, a feeding intervention based on sweetpotato would have limited impact.

2.2 Potential role of sweetpotato

The Rwandan dairy farmers' claim that sweetpotato vines promote increased milk production is consistent with a known link between yields and the protein and energy contents of various supplemental feeds used with Napier grass in a dairy cow feeding guide published by the International Livestock Research Institute (Lukuyu, 2007). In the guidebook, sweetpotato vines are listed as high protein and medium energy, ranked only below cottonseed meal and sunflower meal (Lukuyu, 2007). The only farmer interviewed that has used cottonseed meal or sunflower meal fed it to the dairy goats and, with this supplement, achieved the highest milk production and adjusted gross income (see Table 7).

In conclusion, there are two types of sweetpotato (dual purpose and forage varieties) that can play significant roles in animal feed improvement in the context of dairy cow, dairy goat, and pig production in Rwanda, Kenya, and Uganda. The issue is to promote the right variety and the management system appropriate to its use. The dual-purpose sweetpotato is better suited for smallholder pig production while the forage varieties have excellent potential to contribute to the improvement of dairy cow, dairy goat production, and pig production. This latter use would target the large FC contracting farmers, who feed vines to supplement the commercial based feed.

In addition to varietal selection, we have already identified feed processing as another area that will have a major impact for all livestock operations. Processing options include cutting, drying, ensiling, and feeding methods that need to be paired to their prospective use.

2.2.1 Forage sweetpotato selection for vine production

In this section, we deal with two issues: 1) the suitability of sweetpotato as a replacement of Napier grass in feed rations and 2) alternative production systems that can be used. Dairy cows and dairy goats, particularly the former, consume large volumes of Napier grass that require a large amount of land to produce (see Tables 6 & 9). Meanwhile, it is believed that sweetpotato can produce a larger amount of fresh fodder, or dry matter, and particularly protein on the same area. Table 12 compares Napier grass with available information on sweetpotato vines grown in Kenya, Rwanda and Uganda.

Table 12. Comparison between fresh yield, dry matter yield, and protein yield of Napier grass and sweetpotato vines

	Napier		**Sweetpotato vines**		
	Flat land	**Rocky soil**	**Uganda**	**Kenya**	**Rwanda**
Fresh yield (ton/ha/yr)	35	17.5	70	90	70
DMC (%)	14	15	13	13	13
DMY (ton/ha/yr)	4.9	2.6	9.1	11.70	9.10
Protein yield (ton/ha/yr)	0.44	0.24	1.82	2.34	1.82

Napier grass yields 13-15 ton/acre/yr on the flatland in western Kenya while yielding 7-8 ton/acre/yr on rocky soils. Forage sweetpotato has not yet been well tested in this area, and as a very site-specific crop, its potential yields can only be conservatively estimated here. The estimates of Kenyan, Rwandan, and Ugandan sweetpotato vine yields are based on the results of sweetpotato varietal trials in these three countries These were dual-purpose varieties, as there is limited information on forage variety potential. In other words, the fresh vine yields of the forage varieties can be expected to significantly exceed the data presented in Table 12. In fact, the CIP sweetpotato breeder estimates that some advanced forage sweetpotato can yield up to 60 ton per season, or 120 ton/yr. The dry matter content (DMC) and protein content of the vines were not included in the presentation; thus, the average DMC and protein content of sweetpotato vines are applied here.

Kariuki et al. (1999) tested the use of sweetpotato as a protein supplement in a trial that consisted of four treatments of protein supplements:

1. Basal diet + project dairy meal (2 kg/cow/day)
2. Basal diet + home-made* meal (2 kg/cow/day)
3. Basal diet + sweet potato vines (10 kg/cow/day)
4. Basal diet + farmers' dairy meal (2 kg/cow/day)

The basal diet consisted of 60 kg of Napier grass and maize stalks.
The findings showed that 10 kg/day of sweetpotato can be an effective equivalent to farmers' dairy meal and slightly under the commercial dairy meal (Table 13).

Table 13. The effects of various types of feed supplements on milk production

Supplement	**Milk production (liters/day)**
Project dairy meal	6.83
Home-made meal	6.77
Sweet potato vines	6.42
Farmers' dairy meal	6.42
LSD (P=0.05)	0.586

Source: presentation at Harvest Plus meeting in Kigali in 2006
Given the competitive sweetpotato vine production versus Napier grass production, as shown in Table 12, sweetpotato should be viewed as a replacement for part of the Napier grass, not just as an energy supplement.

Kariuki et al. state that trials have been conducted to feed 100% of sweetpotato vines to dairy cows. However, the results indicated that such diet was not ideal for calving. While it was suggested that 50/50 combinations of Napier grass and sweetpotato vines may be the best combination of basal feed, contingent upon further feeding trials, there is an unconfirmed claim that 50% of sweetpotato vine feed gives the milk a taste that is not well liked in the market. Thus, it is essential that trials be conducted to test the marketability of the milk in relation to the percentage of sweetpotato vine in the diet.

Using the conservative estimate of 70 ton/ha/yr of sweetpotato vine production, the return on land is considerably higher than growing Napier grass as the basal feed (Table 14). This does not yet include the additional advantage of the higher protein yield. As mentioned above, 100% replacement of Napier grass is not suitable, but 50% replacement would yield an economic return on land of 261,000 Ksh/yr/acre for dairy cows, or 674,000 Ksh/yr/acre for dairy goat production.

Table 14. Comparison of the economic return on land of growing Napier grass vs. sweetpotato vine as dairy feed

	Napier feed		Sweetpotato vine feed	
	Cow	**Goat**	**Cow**	**Goat**
Fodder (ton/yr/cow or goat)	26	3.7	26	3.7
Land (acres/yr)	0.7	0.1	0.37	0.05
Income (Ksh/y/cow or goat)	128,679	47,345	128,679	47,345
Return on land (Ksh/yr/acre)	176,273	453,993	346,443	895,716

The steps to be taken to use sweetpotato vines as partial replacement for Napier grass include the following:

- Forage sweetpotato varietal and location trials to identify the best forage varieties for each location and determine the annual vine yield
- Feeding trials to determine the percentage of Napier grass that can be replaced by sweetpotato vines without adverse effects on milk production, milk quality, and calving quality

Turning to production systems, there are two types of production system in which forage sweetpotato can be produced. Both should be tested. The first is monocropping of forage sweetpotato and the second is the local system called *Tumbukiza*. Monocropping is the straight-forward planting of forage sweetpotato as the only crop on one piece of land, without mounding, specifically for vine production. *Tumbukiza* is a system in which two crops, Napier and sweetpotato, are planted on the same piece of land. It differs from regular inter-cropping in that Napier would be planted in between rows, in very deep trenches in order to avoid competing for the same moisture and nutrients needed for sweetpotato vines. Since weeding is generally a highly labor-intensive activity for Napier grass production, growing sweetpotato in between rows of Napier would greatly reduce the labor requirement for weeding as sweetpotato, soon after planting, will keep the ground covered until the final harvest.

The vine cutting intervals and length of cuts of the forage sweetpotato need to be tested to determine the interval and length in order to achieve the highest vine production. Unlike the dual-purpose sweetpotato, forage sweetpotato can be and should be cut far more frequently. In Asia, the best results are achieved by cutting the same vines every 10-15 days, during the rainy season. The practices in eastern and central Africa seem to have farmers harvesting only two or three times during the cropping season of four to six months. This can be increased to advantage.

2.2.2 Selection of dual purpose sweetpotato varieties

Selecting dual-purpose sweetpotato for feed purposes could have a significant impact on feed for smallholder pig production, as pigs feed on both the roots and vines. Currently, the pigs are fed the same varieties that humans consume; these are not necessarily the highest biomass yielding varieties because taste and high Vitamin-A content are important to human consumption. This is not to suggest that farmers should replace all sweetpotato production with feed varieties since human consumption cannot be ignored (particularly in Rwanda). However, we should offer farmers a choice of two options:

- Cultivating one type of sweetpotato mainly for human consumption and another type for feed purpose. The feed varieties are selected for the highest amount of biomass from roots and vines, without any regard to taste.
- Cultivating only one type for both humans and pigs, as they have always done. In this case, selection can be based on mixed criteria of high biomass production, taste, and Vitamin-A content.

The reasons for the choices by farmers are researchable issues.

2.2.3 Sweetpotato processing

2.2.3.1 Cutting

Sweetpotato vines and Napier grass are often fed separately. If the cows are fed vines in the morning, they are then fed Napier grass in the afternoon, or vice versa. The reason for this is the lack of a cutting machine to cut the vines and Napier grass so that they can be mixed together. When not cut-and-mixed, the cows prefer sweetpotato vines and will pick out only the vines; thus farmers prefer to feed them separately. But in reality, the mixture of Napier and sweetpotato vines provides more balanced feed and is superior to either of them as individual feeds. But only farmers who can offer to purchase a large cutter, which seems to be the standard-size in East Africa, can benefit from this balanced feeding.

Sweetpotato vines are also traditionally cut for pig consumption; otherwise, as observed in Soroti, pigs pick out the leaves and leave all the stems behind. Those stems may be less nutritious than the leaves, but are not without any nutritional value. Vines cut in small pieces make more efficient feed than the whole vines.

Along with the introduction of forage sweetpotato for dairy cow or goat production, and increased vine production of the dual-purpose sweetpotato, more sweetpotato vines will be available to feed to either pigs or dairy animals. Smaller and less costly cutters that are available in China and Vietnam may be used a prototype to be adapted to East Africa so that such cutters can be available and affordable to the general livestock raisers.

2.2.3.2 Silage

During the dry seasons, such as July, and December-January in the Kisii area, feed is less available and milk production is greatly reduced (Table 15) and sweetpotato vines are scarce and more costly (see Table 2). Silage that is processed during the wet season when vines are abundant would provide nutritious feed during the dry season. Kept in anaerobic condition, silage can be stored up to six months without spoilage.

Table 15. Feed availability in various seasons and corresponding milk production

	Feb - June	July	Aug - Nov	Dec – Jan
Local cow				
Feed	Grazing 10 kg Napier 20 kg SP vine 1 kg	Grazing 5 kg Caliandra/SP vine/maize stalk, 20 kg	Grazing 10 kg Napier 20 kg SP vine 1 kg	Caliandra/SP vine 5 kg Banana leaves
Milk (L/day)	3	1-2	3	0 – 0.5
Cross-breed dairy cow, management not as intensive				
Feed	Napier, 40 kg Molasses, 0.2 liter SP vine, 2-3 kg	Hay 12.5 kg Napier 20 kg Molasses 0.2 L Vine 2-3 kg	Napier, 40 kg Molasses, 0.2 liter SP vine, 2-3 kg	Napier 10 kg SP vine < 2 kg Hay 17 kg Molasses 0.2 L
Milk (L/day)	13	13	13	7 – 8
Pure breed dairy cow, intensive management				
Feed	Napier, 60-70 kg Desmodium, 10 Maize stems 10-20 A total of 90 kg	Napier, 60-70 kg Desmodium, 10 Maize stems 10-20	Napier, 60-70 kg Desmodium, 10 Maize stems 10-20 A total of 90 kg	Napier 10 kg SP vine < 2 kg Hay 17 kg Molasses 0.2 L
Milk (L/day)	14	14	14	7 – 8

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There are several advantages of ensiling the roots and/or the vines:

- Farmers will have the option of harvesting all-at-once, instead of the traditional piecemeal harvesting. This would allow the land to be cultivated three crops instead of two crops a year
- Vines would not have to be discarded but could be processed for later use. Currently, much of the vines are discarded at harvest time, as farmers do not have any way of storing and conserving the vines, and they are saved for only the following purposes:
    - Give some to neighbors as planting material
    - Save some for themselves as planting material
    - Feed to pigs for three days
    - Discard the rest in the field
- The nutritional value of sweetpotato roots and vines are improved through the silage process
- The long storage life allows farmers to feed the livestock a regular diet, instead of a large volume at harvest time, soon to run out of feed until the next harvest season

A great deal of research has been conduct on-farm on developing sweetpotato vine and root silage in Southeast Asia, by adding different quantities of different additives. For more details on various ways of making root silage or vine silage, their nutritional values, and effects on pig growth, please refer to Annexes 1 to 3.

2.2.3.3 Feeding

Balanced feed. Smallholder pig farmers feed large quantities of both sweetpotato roots (up to 10 kg/day/pig) and vines (up to 20 kg/day/pig), particularly during the harvest season, but much of the nutrition is being wasted due to excess feeding of this one particular item of feed. Balancing the sweetpotato-based feed composition in order to decrease the unnecessarily large amount of sweetpotato consumed by pigs is an important aspect of improving the sweetpotato-feed system. Adding small amounts of protein to the diet, such as soy meal, fish meal, concentrated feed, rice bran/wheat bran/maize bran can reduce the quantity of sweetpotato roots and vines considerably (1-3 kg of each, depending on the size of the pig).

Seasonality of feed. Another aspect of balancing the feed composition is to take into consideration the seasonality of the farm feedstuff, as different feedstuff is available in different seasons. For example, when sweetpotato vines are in short supply during the dry season in Rwanda, cassava leaves are widely available as the dry season is also the largest cassava harvest season so that farmers can easily dry the roots. This is good time to consider ensiling sweetpotato roots with cassava leaves as feed.

Feeding trials. The following table lists suggestions of some feeding trials related to feeding sweetpotato roots and vines for pig production and vines for dairy goats and cow production.

Table 16. Some suggested feeding trials

Feeding trial	Animal	Test variables
Sweetpotato-based feed composition balanced with locally available protein sources	Smallholder pigs	• Growth rate • Cost of weight gain
Feed composition of combining different seasonally-available feedstuff	Smallholder pigs	• Growth rate • Cost of weight gain
Sweetpotato vine silage, with various additives, such as chicken manure, bran (rice, wheat, or maize)	Smallholder and contract farming pigs	• Growth rate • Cost of weight gain • Fat content
Sweetpotato vine silage, with various additives, such as chicken manure, bran (rice, wheat, or maize)	Dairy cow and dairy goats	• Milk production • Milk marketability • Return on land
Sweetpotato root silage with various additives such as chicken manure, bran, cassava leaf meal, sweetpotato vines,	Smallholder pigs	• Growth rate • Cost of weight gain • Fat content
Replacing Napier grass with different percentages of vines--10%, 20%, 30%, 40%, and up to 50%	Dairy goats and cows	• Milk production • Return on land • Milk marketability

3. Potential of sweetpotato for commercial feed production

3.1 SOPAB (*Société pour la Production d'Aliments pour Bétail*), Rwanda's largest Livestock feed factory

The zero-grazing policy has not helped increase demand for their feed because too many small factories manufacturing livestock feed are not subject to quality control by the Rwanda Bureau of Standards (RBS), as the large factory is. In this case, the feed produced by these small and unlicensed small manufacturers is generally inferior with low quality and low price, but farmers, not understanding the difference, normally go for the cheaper products.

In order to understand the cost of maize as feed, one must understand the peculiar way maize is used in Rwanda as food and feed. Most Rwandans like white maize flour that is milled after the nutritious maize bran, which accounts for 35% of the maize weight, has been extracted. The remaining 65% maize, with little nutritional value, is used for human consumption while the 35% of bran, which contains the essential maize nutrients, only costs 20 RWF/kg normally, though lately it has shot up to 80 RWF/kg. The most peculiar aspect of this division of maize is that the 65% white maize, devoid of nutrients, normally costs 200 RWF/kg, or twice as much as the whole maize and 10 times as much as the nutritious maize bran (Table 17).

Table 17. The prices of whole maize, white maize, and maize bran in Rwanda

	Price (RWF/kg)	
Maize product	**Usually**	**Currently**
100% maize	100	200
65% white maize	200	400
35% maize bran	20	80

This maze bran, of extreme low price and high nutrient value, is the main ingredient of all the commercial livestock feed (Table 18).

Table 18. The main feed ingredients of various types of livestock feed

(% of feed composition)	Chicks	Dairy cows	Sows	Meat pigs	Calves
Maize	30	10	10	12	26
Maize bran		50	75	50	20
Total from maize	30	60	85	62	46

In fact, SOPAB does not use any maize at all when they use the maize bran that is extracted at their own factory (i.e., they have the confidence that this is indeed 35% of the maize bran). Given this low price of maize bran, it is almost impossible for sweetpotato roots or vines to compete with maize, which has been promoted by the government in recent years and has replaced a lot of sweetpotato cultivation land, particularly in the valleys where water is available and hybrid maize thrives. Lately, a factory made a contract with farmers to provide 10,000 MT/yr of maize for human consumption, though the capacity of this factory is 44,000 MT/yr. In other words, maize supply is still below the demand volume.

Whether sweetpotato roots and/or vines can compete with maize in commercial feed production depends on the comparative economics of the two crops, both for farmers and for the factory. The economics of maize differs greatly between the hybrid and the local variety. The former requires productive valley bottoms with sufficient moisture and provides high return on the land; the latter can survive on the droughty uplands but in turn only produces1-2 ton/ha, thus yielding low return on the land (Table 19).

Table 19. Cost, yield, gross income, and return on land of three varieties of maize in Rwanda

Various maize varieties	Seed price* (RWF/kg)	Seed cost (RWF/ha)	Yield (Ton/ha)	Gross income (RWF/ha)	Return on land* (RWF/ha)
Hybrid	1,200	30,000	5-7	600,000	570,000
Katumani	75	1,875	1-2	150,000	148,125
Long 1	350	8.750	3-4	350,000	341,250

*Counting only seed cost, all other input costs are the same, including fertilizer level

The prices of sweetpotato vary with season and size of the tuber: higher in the dry season when roots are scarce while lower in the wet season when roots are abundant, and higher for large roots and lower for small roots (Table 20).

Table 20. Sweetpotato prices for farmers at the farm-gate and for traders when sold to customers

	Farm-gate (Sell by basket)		Traders (Sell by sack)	
	Large roots	Small roots	Large roots	Small roots
Dry season (RWF/basket or sack)	500	400	9,000	5,000
Wet season (RWF/basket or sack)	400	300	8,000	3,500
# kg	12	10	140	65
# basket/sack			12	6.5
Dry season price (RWF/kg)	42	40	64	77
Wet season (RWF/kg)	33	30	57	54

With the prices of small sweetpotato roots (30 RWF/kg at farm gate, 54 RWF/kg for traders), the economic return on land during the wet season is 372, 000 RWF/ha, which is lower than that of the hybrid maize, but higher than that of the local maize, Katumani (Table 21). What this means is that farmers, particularly those who do not have valley land, but only uplands where they have to plant Katumani, might have incentive to change over to produce sweetpotato as feed in order to generate more income. But sweetpotato, with the current human-consumption variety, cannot compete with hybrid maize. That is to say that sweetpotato varieties that are specifically bred for dual-purpose root and vine production could potentially produce more value per hectare.

At these prices, feed factories should be looking at sweetpotato roots as an alternative source for animal feed. Given that maize contains 8% protein while sweetpotato roots contain only 3-4%, the price of maize for feed is usually double that of sweetpotato or cassava roots. During the “usual” price of 100 RWF/kg, dry sweetpotato at 160 RWF/kg certainly cannot compete (as price of sweetpotato needs to be half of that of maize to be competitive). However, as prices of maize increased globally, the price in Rwanda has doubled, to 200 RWF/kg. At this point, 120 RWF/kg of dry sweetpotato should begin to look attractive. Dual-purpose varieties selected for feed purposes should increase the yield considerably. Thus even at 100 RWF/kg (dried), or below, the total income would be higher than with current low yield and current price of 120 RWF/kg (dried).

Table 21. Comparison of the economic return on land of various types of maize with sweetpotato of various seasons in Rwanda

	Price (RWF/kg)		Total income (RWF/ha)		
	Usually	**Currently**	**Hybrid**	***Katumani***	**Long 1**
100% maize	100	200			
65% maize	200	400	780,000	195,000	455,000
35% bran	20	80	42,000	10,500	24,500
Total income (RWF/ha)*			600,000	150,000	350,000
Total (RWF/ha)**			822,000	205,500	479,500
	Wet season	Dry season	Wet season	Dry season	
Fresh SP root (RWF/kg)	30	40	150,000	160,000	
SP DM (RWF/kg)	120	160			
Fresh SP vine (RWF/kg)	15	15	222,973	225,000	
SP vine DM (RWF/kg)	68	68			
Total (RWF/ha)			372,973	385,000	

*This is the farmers' income from selling one hectare of whole maize
**This is the factory's total worth from one hectare of maize, by separating maize bran from white maize flour

In other words, the feasibility of sweetpotato in commercial feed production in Rwanda depends on the following factors:

- The maize price remains at the current level or even continues to increase. This assumption is subject to different views. The managers at the SOPAB factory believe this price increase is only a blip and they are optimistic that it will soon return to normal. However, the owner of Ugachick (see section below) was not nearly as optimistic
- Sweetpotato root and vine yields can increase significantly with the selection of the dual-purpose varieties
- There is no more fertile bottomland on which hybrid maize can continue to expand production

SOPAB has a capacity of 4 ton/hour, but it is not operating anywhere near its capacity as the small feed manufacturers take a large market share. SOPAB management believes that the feed produced by the small manufacturers does not contain nearly the nutritional value it claims to have, thus can sell for lower prices. SOPAB perceives this as unfair competition and believes that smaller factories should be subject to the same vigorous regulation that applies to them. Competition aside, such control may indeed provide consumer protection for livestock growers, if the feed indeed contains significantly less nutritional value than it claims.

3.2 Ugachick, Uganda's largest feed factory

As with most of the commercial feed in the world, the major ingredient of the feed manufactured at Ugachick, the largest feed factory in Uganda, is maize (Table 22). It is supplemented by cassava and fish meal as protein sources. The owner of the factory is far less optimistic than the managers at the feed factory in Rwanda about the future prospects of maize as animal feed because of the global increase in maize price.

As the price of maize keeps going up, Ugachick is actively seeking alternative feed sources. Since maize consists of 8% protein it is a preferred feed to sweetpotato or cassava roots because it does not need nearly as much costly protein supplement. Thus, the price of sweetpotato roots has to be comparable to cassava, which currently is 300 Ush/kg.

Table 22. The percentage of each major feed ingredient and its purchase prices

Feed ingredient	%	Purchase price (UGX/kg)
Maize	60	600
Cassava	10-15	300
Broken maize	10	
Fish	15	

Ugachick has already been doing contracting farming with farmer groups and is interested in collaborating with CIP in conducting some on-farm trials, with their farmers, to test various sweetpotato varieties as potential feed sources. The feasibility of replacing part of the maize with sweetpotato roots (and perhaps vines as well) depends on the same analysis as above. Thus, the first step is to identify the high yielding dual-purpose varieties and test them in various locations. Based on the results of the trials, the price analysis can be performed to determine the feasibility of sweetpotato in commercial feed production at Ugachick.

3.3 Farmer's Choice, Kenya's largest piggery and feed factory

Unlike the factories in Rwanda and Uganda, Farmer's Choice (FC) is both a piggery and a feed factory. The feed produced here is of high international standards, made with imported soy bean meal, maize, maize bran, and barley brewery residue. FC has tried to substitute some cassava in its feed composition but found the protein level too low compared to maize, and thus has since discontinued this practice. According to the piggery manager, the daily weight gain of FC's pigs reaches 1 kg/day, which is extremely high, indicating that the feed is of very high protein content. In this context, there is little scope for sweetpotato to be incorporated into this commercial feed. Sweetpotato roots and vines have more potential to contribute to the 40% of pigs that are raised by the contract farmers whose pigs' daily weight gain is only 330-350 grams with mainly commercial feed and some sweetpotato vines.

4. Summary/conclusions

The objective of the study was to examine whether sweetpotato can play a more significant role in livestock production in East Africa, under what conditions it can play such a role, where it could make the most noteworthy contribution, and what research and development activities need to be carried out to realize this potential.

The study found:

- Sweetpotato can play the most significant role in livestock feed in East Africa in the partial replacement of Napier grass used as feed mainly for dairy cow and goats, and even for pigs.

- CIP-SSA sweetpotato breeders estimate that in East Africa the advanced forage varieties should easily yield 35 ton/ha of vines per season (i.e., 70 ton/ha/year), and up to 60 ton/ha per season (120 ton/ha/yr) under more favorable agro-ecological conditions and farmer management.

- At this level of productivity, forage sweetpotato reduces the cost of production by reducing the amount of land required to feed one animal (for dairy cows and goats) by for the larger contracting pig farms which feed purebred pigs on a combination diet of commercial feed and sweetpotato vines.

- .Advanced dual-purpose varieties selected specifically for feed production (with high biomass yield from both roots and vines) have the potential to contribute to the growth and economic efficiency of smallholder pig production. This production relies on sweetpotato roots and vines as the main bulk of pig feed and the extent of advanced varieties will depend on the increase in total biomass of the improved varieties relative to current varieties.

The demand for feed is a derived demand from the particular animals that are raised. Comparing the relative merits of dairy cow, dairy goat, and pig production, we see the following advantages and disadvantages:

- Pure breed cows provide the most steady daily income because they are milked 9 – 12 months, but it requires a massive amount of feed and a great deal of skilled care.
- Pure breed goats, due to the high prices of goat milk, yield very high income for the small amount of feed needed daily. However, as is with most pure exotic breeds, pure breed goats also require care, investment, and skills to keep them alive and productive.
- Smallholder local pig production, fed on sweetpotato roots and vines based diet, have comparable profitability to the pure breed dairy cow and goat.

Working within the perimeters of the pros and cons of each livestock, we conclude two things:

- Sweetpotato could make a noteworthy contribution in any of these production systems. Forage sweetpotato could be adopted by dairy cow, dairy goat, and larger contracting pig farmers; while the dual-purpose varieties would contribute to the smallholder pig production.
- Geographically, the contribution would be greatest in areas where sweetpotato grows well and where there is a large concentration of cows, goats, and pigs. These areas are likely to be closer to urban markets where land scarcity is apparent and sweetpotato offers an efficient return to land relative to Napier grass.

Research and development activities are needed in several different domains:

- To test the forage and dual-purpose varieties in regions where they are most needed. Potential yields in each location must be determined before varieties can be widely disseminated to interested farmers.
- Post harvest activities--cutting, silage, and feeding techniques are important to fully realize the potential of sweetpotato in various type of livestock feeding systems. Cutting is needed for three reasons a) to allow vines to be mixed with other feeds in order to balance the feed, b) to reduce feed waste, and c) as a pre-requisite for silage. Silage can be made with various additives, and the appropriate additive depends on the local availability and affordability.
- Feeding trials are needed to determine the replacement rate of sweetpotato vines for Napier grass for dairy production and also to examine the effects of sweetpotato silage on economic and growth efficiency.

The use of sweetpotato in commercial feed rations is a longer-term undertaking because its feasibility depends on the trend of global maize prices. The potential of substituting maize with sweetpotato in commercial production will be determined only when the trend becomes a known reality. Until then factories will not change its feed production system. However, prospective research by CIP should look at the following conditioning factors:

- Feed companies may be on the lookout for, and anxious to experiment with, alternatives to maize.
- Cassava and sweetpotato are two such alternative sources. Cassava is often cheaper because it is better adapted to higher altitude and more drought-tolerant, and can grow on marginal land. However, in agro-ecological zones suitable for sweetpotato, sweetpotato is more competitive than cassava because of the multiple harvests per year and abundance of vines in addition to roots. The choice depends on the agro-ecological zone. CIP is able to identify the appropriate zones.

The strategy for CIP is to collaborate with these factories to test the advanced feed varieties either on their station or with their contracting farmers in the expectation that it can be proven to be a feasible alternative to maize or maintained as a standby alternative. Sweetpotato will make the most significant contribution when it is adopted in commercial feed rations to improve the smallholder dairy cow, dairy goats, and pig production.

References

Lykuyu, M., Romney, D., Ouma, R., and K. Sones. 2007. Feeding Dairy Cattle: A manual for smallholder dairy farmers and extension workers in East Africa. ILRI. Nairobi, Kenya.

Goodman, D. E. *Raising Healthy Pigs under Primitive Conditions*. Third edition revised. Christian Veterinary Mission, Seattle, WA. (1994).

Holland, D. E., M. D. Solomon, J. K. Flanagan, J. B. Pilcher, and V. C. W. Tsang. “Cysticercosis in Haiti in 1995: Seroprevalence and epidemiological characteristics.” Center of Veterinary Epidemiology and Animal Disease Surveillance systems, Collage of Veterinary Medicine and Biomedical Sciences, Colorado State University, Ft. Collins, CO. (1995).

Annex 1

Sweetpotato root silage for efficient and labor-saving pig raising in Vietnam

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Abstract

Three sequential on-farm trials were conducted in the Red River Delta area near Hanoi, Vietnam, to test the potential of ensiling sweetpotato roots to increase storability and nutritional value, reduce trypsin inhibitor, improve feeding efficiency while decreasing labor demand of raising pigs. The first trial tested twelve different ways of ensiling sweetpotato roots. Six treatments with sliced sweetpotato roots and six with grated roots were ensiled with cassava leaf meal, rice bran, sun-dried chicken manure and salt, and the nutritional values were analyzed 14, 30, 60, and 90 days after ensiling. The lab results showed no significant different nutritional value across time. Silage with chicken manure and cassava leaf meal had significantly higher crude protein content then rice bran silage ($p< 0.001$). However, only treatments with chicken manure had higher dry matter and ash contents than the other silage products. No difference found between chopped or grated roots. None of the preparations with chicken manure were found to contain aflatoxin or Salmonella. *E. coli*, although present in the original samples, disappeared after 14–21 days of silage.

The subsequent three-month on-farm feeding trial compared pig growth and economic efficiency of three treatments--cooked fresh sweetpotato roots (T1), uncooked roots silage with rice bran (T2), and uncooked roots silage with sun-dried chicken manure (T3). The results showed the daily weight gain of T3 pigs to be 640g, 605 g of T2 pigs, while only 552 g of the control pigs of T1. These differences are not statistically significant because of the combination of small pig samples (42) and large standard deviation, resulting from high variation of the seven households, the types of pigs, and pigs' variable taste for silage feed. The most important result was that the modest increase of growth was achieved without cooking which are labor intensive and fuel demanding because cooking pig feed on rice husks normally take 2-3 hours a day. Such constraints lifted, farmers subsequently tripled their pig production.

The second on-farm feeding trial examined the proportion of root silage--10, 20, and 30% of total dry matter of diet--best suited for pig growth and economic efficiency. The trial results suggested that feeding 30% during the first month, 20% second month, and 10% of the last month may lead to the greatest efficiency.

Introduction

About 43% of the world's annual sweetpotato production is used as animal feed each year (International Potato Center, 1998). Feeding sweetpotato roots as feed to pigs, and other livestock, is commonly practiced in many countries, including China, Vietnam, a few eastern islands of Indonesia (Bali and Irian Jaya), Philippines, Papua New Guinea, Cuba, and Uganda. In China, which produces 85% of the world production of sweetpotato, for example, a large part of the crop goes to feed animals, mainly pigs (Scott, 1991). In Vietnam, feeding sweetpotatoes to pigs is common in the north and central parts of the country. In Irian Jaya, the western part of the New Guinea island, sweetpotato roots and vines are the only feed source besides rooting. Uganda, the largest sweetpotato producing country in Africa, sweetpotato roots provide the major energy source for pigs. In general, sweetpotato roots are used fresh, sun-dried, or as silage to feed livestock under subsistence farming systems, often to supplement other cereal feed ingredients, particularly corn (Yeh and Bouwkamp, 1985).

Starch in sweetpotato roots provides energy source for livestock, while they contain insignificant levels of protein. The crude protein content of sweetpotato ranges from 1.3 to 10% on dry weight basis (Li, 1974; Purcell et al., 1976; Walter et al., 1984). In general it is about one-third the crude protein content of corn meal. Not only the crude protein content is low in sweetpotato, up to 40% of the total nitrogen has been found to be non-protein nitrogen (NPN) (Purcell at al., 1976). Consequently, low level of available protein poses a major constraint to growth in sweetpotato-based diet. When available and affordable, farmers overcome this constraint by supplementing this diet with rice bran, fish meal, soy beans or residue, sweetpotato and cassava leaves, and, to a lesser extent, commercial supplement.

In addition to low protein content, trypsin inhibitor and low starch digestibility are additional constraints to sweetpotato-based diet. Unsatisfactory feeding efficiency have been observed when uncooked roots are used as pig feed because trypsin inhibitors cause poor protein digestibility (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). Bradbury et al. (1984) estimated about 0.03-2% of trypsin inhibitors present in the total protein of sweetpotato. Zhang et al. (1998) estimated sweetpotato roots to be about 28% of the TIA level in the soybean seeds and found a positive correlation between TIA and protein content in roots. Therefore, the sweetpotato-based diet, if not processed or cooked, may be partially responsible for poor feeding efficiency (Lee and Lee, 1979; Yeh and Bouwkamp, 1985).

Poor starch digestibility is another major factor that has been suggested to be responsible for low feed efficiency (Yeh and Bouwkamp, 1985; Tsou and Hong, 1989). Sweetpotato starch needs to broken down by some form of processing for complete uptake. To overcome these constraints, farmers in China and Vietnam have diligently cooked sweetpotato-based feed daily to eliminate trypsin inhibitor and increase starch digestibility. In turn, the farmers pay the price of high labor and fuel inputs. Where labor or fuel is in short supply (which limits the cooking options, such as in Uganda and Irian Jaya), farmers suffer the consequences of low growth rate and minimum economic return on the investment. The need to cook in order to fully utilize the nutrients in sweetpotato-based feed becomes a socio-cultural limitation to pig growth in sweetpotato-based diet.

Storage is another constraint facing sweetpotato farmers in the sub-tropical and tropical zones. While Chinese farmers can store roots up to six months because sweetpotato in China are grown in temperate climate and harvested at the beginning of the winter; tropical farmers cannot store the roots without some major loss to weevils, rats, and rotting. To minimize loss, farmers often feed large quantities of roots to pigs during the two months after harvest, which leads to waste since excessive quantity of starch does not lead to proportional growth. On the other hand, soon after that farmers may no longer have any starch sources until the next harvest. Low storability of the roots in the tropic and sub-tropics leads to unbalanced feeding and waste of nutrients.

In an attempt to overcome these constraints without requiring extra inputs which are in short supply among farmers, sweetpotato root silage was tested for its feasibility as a processing method which would address the constraints of storability, protein, starch digestibility, and trypsin inhibitor. Three logically sequenced trials were conducted and reported in this paper to test this feasibility:

1. Root silage trial. Twelve treatments of ensiling sweetpotato roots--six with sliced roots and six with grated roots--were tested to determine the method that would yield the highest protein and lowest cost.
2. Silage combination feeding trial. Pig feeding trial with three treatments, fresh roots and two combinations of root silage, to test which feeding method would yield the best pig growth with the lowest cost.
3. Silage proportion feeding trial. Pig feeding trial with three levels of silage in the diet to test the proportion that would yield the best growth with the lowest cost.

Materials and methods

Sweetpotato Root Silage Trial

The silage trial, conducted between March 18 and June 18, 2000, consisted of 12 treatments (Table 1), six of which were sliced sweetpotato roots and the other six with grated roots. The sliced or grated sweetpotato roots were mixed with combinations, and various proportions, of rice bran, cassava leaf meal, and sun-dried chicken manure, all locally available and affordable material. The weight was calculated based on dried ingredients except sliced or grated sweetpotato roots. To facilitate farmers preparing these combinations, the weights were calculated from the ingredients as they were fed to pigs, not on a dry matter basis. All materials were prepared (weighed, sliced, or grated, mixed, and put into labeled double-aerobic plastic bags) on-farm in a village in Thai Nguyen Province in the Red River Delta, by the farmers. Each treatment consisted of three replications for each scheduled analysis—at14, 30, 60 and 90 days after ensiling process started; hence a total of 12 samples for each treatment, 144 samples in total. The samples remained on farm until the scheduled date for analysis when they were transported to the laboratory of National Institute of Animal Veterinarian or National Institute of Animal Husbandry in Hanoi to be analyzed. Chemical analyses included pH and dry matter, crude protein, ether extract, crude fiber and ash contents. These analyses were derived from Vietnamese standards (TCVN), with dry matter content based on 4326-86 and from IS0-standard 6496, total ash based on TCVN-4327-86 and ISO-standard 5984, crude fiber based on TCVN-4329-86 and ISO-standard 5498, crude protein based on TCVN-4328-86 and ISO-standard 5983 (Kjeldahl method), ether extract based on TCVN-4327-86 and ISO-standard 5986, and pH determined by electrode method. Costs of the nutrients were calculated to determine the economic efficiency.

Microbiological tests for aflatoxin, *Salmonella* and *E.coli* were performed on root silage with various types of chicken manure, to ensure feed safety. When silage uses any type of chicken manure, it is essential to check feed safety. Aflatoxin analysis utilized thin layer chromatography while *E. coli* and *Salmonella* were determined from enterobacteria diagnosis. Costs of the nutrients were calculated to determine the economic efficiency.

Silage Combination Feeding Trial

The subsequent on-farm feeding trial was conducted in the same village from 20 August to 18 November, 2000. Seven households participated, each with six pigs (a total of 42 pigs). All trial pigs were F1 pigs, a cross breed between the local *Mong Cai* sow and introduced Largewhite boar. Efforts were made to ensure there was no significant difference in the weight of the piglets in each treatment of the feeding trial in order not to bias the results (P = 0.628) (Table 7). The sex ratio was also evenly distributed, with 7 female and 7 male pigs in each treatment. The piglets went through 10 days of adjustment period before the trial, during which the piglets were fed increasing amount of silage feed each day to acclimate them to the new diet.

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

- Treatment 1: fresh sweetpotato roots, cooked
- Treatment 2: grated roots ensiled with 20 % of rice bran and 0.5 % of salt, uncooked
- Treatment 3: grated roots ensiled with 20 % of chicken manure and 0. 5 % of salt, uncooked

The basal feed was common to all three treatments and it consisted of rice bran, corn meal, cassava meal, cassava leaf meal, fish meal, and soy bean. The first three ingredients are commonly used for all farmers as pig feed. Cassava leaf meal, though high in protein, was not usually used as pig feed. It was often discarded in the field because the local farmers failed to recognize its nutritional value. Fish meal and soy bean are less common in the rural area, but more commonly used by peri-urban farmers who raise pigs for the urban centers. The percentage of each ingredient was formulated based on the basis of pig weight category: the bigger the pig, the lower percentage of protein and higher percentage of starch (Table 2). The recommended daily ration of this basal feed also varied according to pig weight category: the bigger the pigs, the more feed ration per day (Table 3). Water was added to the mixed feed before feeding to pigs.

During three months of the trial, the pigs were weighed four times: on the first day, after one month, after two months, and on the last day. 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 while Tukey was used to test the mean differences among categories.

Silage Proportion Feeding Trial

The follow-up feeding trial was conducted in the same village from 2 February to 5 May, 2001, after an adjustment period from 25 January to 2 February, in which the piglets were fed increasing amount of silage feed each day to help them adjust to the new diet. Only six households participated, each with six pigs (a total of 36 pigs). All trial pigs were also F1 pigs. Average weight of piglets were 16-17 kg, with no significant difference among the piglets in each treatment (P = 0.678) (Table 8). The sex ratio was also evenly distributed, with 6 female and 6 male pigs in each treatment.

The silage comprises the following ingredients: 79.5% grated sweetpotato roots, 20% rice bran, and 0.5% salt. The three treatments were--10, 20, 30% of DM, or 26, 44, 57% of fresh, of the total feed. The basal feed, consisting of 90, 80, and 70% of the DM, included rice bran, corn meal, cassava meal, fish meal, and soy bean (Table 4). The recommended daily ration of basal feed and silage feed per day is shown in Table 5.

The weighing schedule, calculation of cost and benefits, and statistics procedure are identical to those of the previous root silage feeding trial.

Results and discussion

Sweetpotato Root Silage Trial

Dry matter (DM), crude protein (CP), ether extracts (EE), crude fiber (CF), and ash showed no significant difference over time (at 14, 30, 60, and 90 days of silage). However, these parameters did differ significantly across treatments, and the differences can be summarized below (Table 6).

- No significant difference between sliced and grated roots.
- Treatments with 20% of chicken manure or 20% of cassava leaf meal, or the combination of the two (10% each), all have the highest crude protein content statistically (16.59%, 16.62%, and 17.10% respectively).
- Treatments with 20% of cassava leaf meal do not have the same level of pH, DM, or ash content as the one with 20% of chicken manure.

In addition to containing the highest protein and pH level, chicken manure also has the lowest cost per kilo. Therefore, treatments with chicken manure showed the greatest potential as feed. In practice, farmers may also collect and use manure from their own chickens.

Microbiological tests on vines ensiled with various types chicken manure showed no aflatoxin or *Salmonella* in freshly dried chicken manure**.** *E. coli* was found when freshly dried, but was no longer detectable after 21 days of ensiling. In a previous trial with vine silage, other types of chicken manure had been subjected to microbiological tests. The results showed that sun dried manure from Kabir dual-purpose broilers and Tam Hoang layers, which are commonly raised by farmers, showed no aflatoxin or *Salmonella*. *E.coli* might present when first ensiled, but was no longer detectable after 21 days of silage.

Silage Combination Feeding Trial

The daily weight gain of the pigs over 89-day trial period showed no significant difference between the three treatments (Table 7). Even though the daily weight gain of the three treatments were not statistically significant due to the large SD that resulted from the highly variable households, varied pig potential, and varied palatability for silage feed, the differences (640, 605, and 552 g) are quite substantial (Table 7). The costs of per kilo of weight gain of Treatments 1 and 3, silage with chicken manure, were very comparable (6,724 and 6,767 respectively) while the rate of growth T 3 was 16% higher. The cost of Treatment 2 was considerably higher, at 7,354 VND per kilo of growth (Table 7).

The most important aspect of the result was that root silage could achieve comparable or improved growth with comparable cost without cooking. The saving in labor time and fuel was considerable. In addition, silage resolved the problem with storage as it could store at least 5 months, if processed and stored properly.

Having done away with the limitation of cooking, the participating farmers tripled their pig production with sweetpotato root silage, as well as cassava root silage which was an innovation of the farmers. Many non-participating farmers also adopted this technology from their neighbors. Even commune leaders from the neighboring province came to inquire about the technology and would even like to extend the technology to potato silage for feed.

Silage Proportion Feeding Trial

The total weight gain and three-month average daily weight gain (539 g) of Treatment 1 was significantly higher than those of Treatment 3 (454 g), while the daily weight gain of Treatment 2 (500 g) showed no significant difference from the other two treatments (Table 8). The cost of per kilo weight gain, on the other hand, was lowest for Treatment 1 (8,182 VND/kg) while highest for Treatment 3 (8,693 VND/kg), with Treatment 2, as in weight gain, in between (8,335 VND/kg). This would suggest that feeding only 10% of sweetpotato root silage as the total amount of dry matter of the feed was the best option.

The data of the monthly weight gain and feed cost, however, suggested that there might be a better alternative (Table 9). The data showed the following:

- The first month daily weight gains of the three treatments were not significantly different, but Treatment 3 required lowest feed cost (6,664 VND/kg).
- The second month daily weight gains of the three treatments were also not significantly different, but Treatment 2 required the lowest feed cost (7,897 VND/kg).
- The third month daily weight gains of the treatments were also not significantly different, but Treatment 1 required the lowest feed cost (8,852 VND/kg).

These data indicated that a feeding regimen of Treatment 3 (30%) during the first month, followed by one month of Treatment 2 (20%), and finish with one month of Treatment 1 (10%) may yield a better growth and economic efficiency than the regimen of feeding 10% root silage of total feed for the three-month period.

Conclusions

Feeding sweetpotato roots to pigs offers a good opportunity of converting an undesirable and often unmarketable crop into a high-value commodity—pork. The benefits of this opportunity, however, are diminished by the constraints of low storability, trypsin inhibitor, low starch digestibility, and low protein content. These physiological constraints lead to yet another greater social constraint—the need to cook the feed—which places high demands on both labor and fuel. Sweetpotato root silage, ensiled either with rice bran, cassava leaf meal, or chicken manure, offers a solution to overcoming some of these constraints. During the feeding trials, the silage was stored for five months without spoilage. As long as carefully stored in tightly packed plastic bags in an anaerobic condition, root silage can be stored for at least five months.

Ensiled with cassava leaf meal and chicken manure, the root silage contains the highest crude protein level. But the most important characteristics of root silage for farmers is the fact it requires no cooking to achieve the same growth rate, or higher, while the no increased cost is necessary. Once liberated from the constraint of daily cooking for pigs, the farmers who participated in the first feeding trial have since tripled their pig production. Farmers stated that heavy labor requirements for cooking have been one of the major obstacles to increasing production. On their own, the farmers have been using rice bran to ensile sweetpotato roots because they find it to be most convenient.

With increased pig production, finding the appropriate proportion of silage to be included in the pig diet that would lead to the highest growth and economic efficiency becomes a principal concern. The data of the silage proportion feeding trial suggested that feeding 30% silage of the total dry matter in the first month and reducing 10% for each of the following months might lead to the highest efficiency. The effects of this feeding regime, however, need to be verified by a trial specifically designed to test this hypothesis.

Table 1. Ingredients of sweetpotato root fermentation[1].

Chopped SP root				
Treat-ments	SP root (%)	Rice bran (%)	Cassava leaf meal (%)	Sun dried chicken manure (%)
1	79.5	20		
2	79.5		20	
3	79.5			20
4	79.5	10		10
5	79.5		10	10
6	79.5	10	10	
Grated SP root				
Treat-ments	SP root (%)	Rice bran (%)	Cassava leaf meal (%)	Sun dried chicken manure (%)
7	79.5	20		
8	79.5		20	
9	79.5			20
10	79.5	10		10
11	79.5		10	10
12	79.5	10	10	

[1] All treatments also contained 0.5% salt.

Table 2. Composition, nutritive value and price of the basal feed formulated for each pig weight category of the root silage feeding trial (%)

Feed ingredients	Composition of basal feed (%)		
	Month 1	Month 2	Month 3
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
Soybean	10	10	10
DM (%)	88.04	88	87.95
CP (%)	15.55	15.32	15.19
ME (kcal/kg)	2,916	2,927	2,948
Price (VND)	2,960	2,098	2,079

[1] Estimated based on National Institute of Animal Husbandry. 1995 (p. 108, 114, 120, 124, 128, 134).

[2] Exchange rate: US$1 = 14,000 VND. The exchange rate is fairly stable and remained approximately at 14,000 for 1-2 years.

Table 3. Daily feeding schedule in the performance trial for each treatment based on pig weight categories for root silage feeding trial.

Treatment	Feed	Pig Weight (kg)				
		20-30	31-40	41-50	51-60	>60
T1; T2; T3	Basal feed	1-1.5	1.5-1.8	1.8-2	2-2.3	2.3-3
	Fresh SP vine	0.5	0.5	0.5	0.5	0.5
T1	Cooked SP root	1.1	1.3	1.6	1.8	2.0
T2	SP root ensiled with rice bran	1.0	1.2	1.5	1.6	1.8
T3	SP root ensiled with chicken manure	1.0	1.2	1.5	1.6	1.8

Table 4. Composition, nutritive value and price of the basal feed formulated for each pig weight category of the silage proportion feeding trial (%).

Feed ingredients	Composition of basal feed (%)		
	Month 1	Month 2	Month 3
Corn meal	47	46	44
Cassava meal	13	18	23
Rice bran	15	14	13
Fish meal	10	10	10
Soybean	15	12	10
DM (%)	88.39	88.37	88.37
CP (%)	16.05	14.85	13.93
ME (kcal/kg)	2,916	2,927	2,948
Price (VNd/kg)	2,613	2,622	2,422

Table 5. Daily feeding schedule in the performance trial for each treatment based on pig weight categories for silage proportion feeding trial.

Treatment	Feed	Pig Weight (kg)				
		20-30	30-40	40-50	50-60	>60
1	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
2	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
3	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

Table 6. Nutrient composition of the 90-day silage (percent of dry basis).

Treatments[1]	pH	DM	CP	Ash
1 (20% rice bran)	a3.28	a27.63	a9.18	b9.13
2 (20% CLM*)	a3.31	ab28.85	c16.62	ab8.42
3 (20% CM**)	e4.09	c30.48	c16.59	d16.50
4 (10% RB, 10% CM)	c3.69	bc29.30	b13.35	c13.15
5 (10 CLM, 10 CM)	d3.81	c30.75	c17.10	c12.39
6 (10 RB, 10 CLM)	b3.48	ab28.51	b13.17	ab8.63
P	0.000	0.000	0.000	0.000
With CM	3.91	30.00	15.14	14.79
With CLM	3.38	29.09	14.93	8.47

[1] See text and table 1 for description.

[2] Letters to the left of the means are significantly different (P<0.05) across rows.

Table 7. Performance traits of pigs fed on fresh sweetpotato roots and two types of grated sweetpotato root silage under on-farm conditions.

Weight	100% fresh SP Roots cooked		79.5 SP roots, 20% rice bran, uncooked		79.5 SP roots, 20% manure, uncooked		P
	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		
Cost wt. gain (vnd/kg)	6,724		7,354		6,767		

*Not significantly different due to large SD. SD is large because: 1) high variable households, 2) variation in pigs, and 3) some pigs like silage feed, some don't.

Table 8. Performance traits of pigs fed on various proportions of sweetpotato root silage under on-farm conditions.

Weight	10%		20%		30%		P
	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[b]	8.18	63.46[ab]	8.55	58.75[a]	9.31	0.041
Total weight gain (kg)	49.64[b]	6.77	45.99[ab]	7.38	41.78[a]	8.94	0.049
Average DWG (g/d)	539[b]	73.6	500[ab]	80.3	454[a]	97.2	0.049
Rate of weight gain (%)	278		263		246		
Feed cost (VND/kg WG)	8,182		8,335		8,693		

Table 9. Breakdown of monthly performance traits of pigs fed on various proportions of sweetpotato root silage.

Weight	10%		20%		30%		P
	Mean	SD	Mean	SD	Mean	SD	
First month weight gain (kg/m)	15.53	4.37	13.50	2.33	12.85	3.75	0.178
First month DWG (g/d)	517.5	145.6	450.0	77.7	428.3	124.8	0.178
First month feed cost (VND/kg WG)	7,702		7,540		***6,664***		
Second month weight gain (kg/m)	17.12	3.97	17.45	3.57	14.89	3.94	0.221
Second month DWG (g/d)	552.2	128.0	562.9	115.3	480.4	127.0	0.221
Second month feed cost (VND/kg WG)	8,245		***7,897***		9,048		
Third month weight gain (kg/m)	17.00	3.79	15.04	4.64	14.04	4.78	0.264
Third month DWG (g/d)	548.4	122.3	485.2	149.6	453.0	154.3	0.264
Third month feed cost (VND/kg WG)	***8,852***		9,558		10,172		

References

Bradbury, J.H., J. Baines, B. Hammer, M. Anders and J.S. Miller. (1984) Analysis of sweetpotato (*Ipomoea batatas*) from the highlands of Papua New Guinea: relevance to the incidence of *Enteritis necroticans*. J. Agric. Food Chem. 32: 469-473.

Bradbury, J.H., B. Hammer, T. Nguyen, M. Anders, and J.S. Miller. (1985) Protein quantity and quality and trypsin inhibitor content of sweet potato cultivars from the highlands of Papua New Guinea. J. Agric. Food Chem. 33: 281-285.

Chien, S.L. and P.K. Lee. (1980) The effect of physical treatment on the available lysine and trypsin inhibitor of sweet potatoes. Taiwan Livestock Res. 13: 75-84.

Dickey, L.F., W.W. Collins, and C.T. Young (1984) Root protein quantity and quality in a seedling population of sweet potatoes. Hortscience 19: 689-692

International Potato Center. (1998) Sweetpotato Facts. A compendium of key figures and analysis for 33 important sweetpotato-producing countries. International Potato Center, Lima Peru

Lee, P.K. and M.S. Lee. (1979) Study on hog feed formula of using high protein sweet potato chips and dehydrated sweet potato vines as the main ingredient. J. Taiwan Livestock Res. 12: 49-55. [In Chinese].

Li, L. (1974) Variation in protein content and its relation to other characters in sweetpotatoes. J. Agric. Assoc. China. 88:17-22.

Lin, Y.H. and H.L. Chen. (1980) Level and heat stability of trypsin inhibitor activity among sweet potato (*Ipomoea batatas* L.) lines (Chinese & English summery). Bot. Bul. Acad. Sinica 21:1-13.

Purcell, A.E., W.M. Walter and F.G. Giesbrecht. (1976) Distribution of protein within sweet potato roots (Ipomoea batatas L.). J. Agric. Food Chem. 24:64-66.

Scott, G. J. (1991) Sweet potato as animal feed in developing countries: present patterns and future perspectives. Paper presented at the FAO Experts Consultation on “The Use of Roots, Tubers, Plantains and Bananas in Animal Feeding” held at the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 21–25 January 1991.

Tsou, S.C.S. and T.L. Hong. (1989) Digestibility of sweet potato starch, p. 127-136. In: Improvement of sweetpotato (*Ipomoea batatas*) in Asia. Rep. 'Workshop on sweetpotato improvement in Asia', ICAR, India, October 24-28, 1988. International Potato Center, Lima, Peru.

Walter, W.M., W.W. Collins and A.E. Purcell. (1984) Sweet potato protein: a review. J. Agric Food Chem. 32:695-697.

Yeh, T.P and J.C. Bouwkamp. (1985) Roots and vines as animal feed. In: Bouwkamp, J.C. (ed.), Sweet Potato Products: a natural resource for the tropics. CRC Press Inc., Boca Raton, FL, pp 235-253.

Zhang, D. P., W. W. Collins, and M. Andrade. 1998. Genotype and fertilization effects on trypsin inhibitor activity in sweetpotato. HortScience 33:225-228.

Annex 2

Fermented sweetpotato vines for more efficient pig raising in Vietnam

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Abstract

In the Red River Delta area near Hanoi, two on-farm trials were carried out to see if using fermented sweetpotato vines could reduce women's labor and feed processing costs, and improve pig growth efficiency. First, twelve different mixtures of sweetpotato vines, corn and cassava meals, rice bran, sun-dried chicken manure and salt were fermented, and the results were analyzed for nutritional value. Nutritional analyses conducted 14, 30, 60, and 90 days after fermentation showed no significant differences over time. However, vines fermented with chicken manure had significantly higher crude protein, dry matter and ash contents than the other fermentation treatments ($p<0.001$). None of the preparations were found to contain aflatoxin or *Salmonella*. *E. coli*, although present in the original samples, disappeared after 14–21 days of fermentation.

The subsequent three-month on-farm feeding trial compared fresh sweetpotato vines, vines fermented with cassava meal, and vines fermented with sun-dried chicken manure and cassava meal in terms of pig growth and economic efficiency. Pigs fed the preparation containing chicken manure achieved statistically higher growth rates than those fed fresh vines ($P< 0.05$); neither of these feeds was significantly different from the vines fermented with cassava meal in terms of feed efficiency ($P=0.013$). The chicken manure preparation was also considerably cheaper (cost per kg of weight gain) than the other two preparations.

While vine fermentation addresses storage problems and increases pig growth, some farmers were concerned with their ability to balance the feed as prescribed in the trial. During an extension meeting, it was communicated to farmers that replacing fresh vines with chicken manure-fermented vines will lead to improved growth, the extent of which depends on the base feed. The policy implications are that favorable conditions should be created for farmers to experiment with using locally available materials to increase the necessary protein for pig feed instead of encouraging the use of imported commercial protein supplement.

Short title: Fermented sweetpotato vines for pigs

Keywords: fermentation, sweetpotato vines, pigs, on-farm trials, storage, Vietnam

Introduction

In recent years, as incomes in Asia have risen, meat has become a much more important part of the diet, particularly in urban centers (Pezo et al, 2000). In Hanoi, Vietnam, meat production increased from 31,000 t in 1997 to 33,000 t in 1999**,** but this production meets only 50% of the total demand of the city: the rest must come from neighboring provinces and rural areas (Tinh, 2000). Meat demand is expected to increase to 87,000 t by 2005 and to 119,600 t by 2010, with

80% of the production coming from peri-urban farmers (Anh, 2000). Meat production in Vietnam is often constrained by shortages of feed. both local and imported. The profitability of current pig-raising practices is low, and better feed--hence enhanced growth efficiency--are necessary for pig farmers to increase profits. Low profitability presents a serious constraint to pig farmers because pigs often provide the only source of cash income.

Sweetpotato is a valuable pig feed: the roots provide energy and the leaves protein, and both can be used fresh, dried or fermented into silage (Woolfe, 1992). It is a common feed for pigs, and other livestock, in many countries in Asia, including China, India, a few eastern islands of Indonesia (Bali and Irian Jaya), Korea, Philippines, Papua New Guinea, Taiwan, Uganda and Vietnam. In China, for example, which produces 85% of the world production of sweetpotato, a large part of the crop goes to feed animals, mainly pigs (Scott, 1991; Yi Wang, CIP-Beijing, personal communication). In Vietnam, feeding sweetpotatoes to pigs is common in the north and central parts of the country.

The main constraints to using sweetpotato vines as pig feed are labor and storage. Regardless of how they are fed to the animals, the vines must first be chopped into small pieces, a daunting and time-consuming task mainly undertaken by women. If the vines are fed fresh, the women must allocate time each day for this task, even during the busy field season. Silage offers a potential alternative to overcome this constraint: sweetpotato vine silage has been a common livestock feed during winter (Sutoh et al, 1973) whenever seasonal lack of feed for livestock may limit productivity (Brown and Chavalimu, 1985). Use of vine silage overcomes both main constraints: the women are able to process the vines during the off-season when labor is more abundant, and store the silage for use when feed is limited. Moreover, there is also the economic advantage of ensiling/storing vines: to process and store the sweetpotato vines during the harvest season when vines are cheap and feed them to pigs during off-season when vines are expensive.

Ensiling may also increase nutritional value and feed efficiency if it involves a fermentation process which converts nitrogen into protein. This paper describes a fermentation trial to compare the nutritional value (particularly crude protein content) of 12 fermented mixtures of sweetpotato vines with various combinations of additives. Moreover, because high crude protein content does not necessarily guarantee better quality feed (Gerpacio et al, 1967), a subsequent on-farm pig-feeding trial was conducted to test the hypothesis that sweetpotato vines fermented with chicken manure gives better pig growth and economic efficiency.

Materials and methods

Sweetpotato Vine Fermentation Trial

The fermentation trial consisted of 12 treatments—(Table 1) sweetpotato vines with combinations of corn meal, cassava meal, rice bran, and sun-dried chicken manure, all locally available and affordable material. The weights were based on dried ingredients except for pre-wilted sweetpotato vines which still contained 60-70% moisture. To facilitate farmers preparing these combinations, the weights were calculated from the ingredients as they were fed to pigs, not on a dry matter basis. All materials were prepared (weighed, chopped, pre-wilted, mixed and put into labeled double-aerobic plastic bags) on-farm in a village in Ha Tay Province in the Red River Delta, by the farmers. Each treatment consisted of three replications for each scheduled analysis—at 14, 30, 60 and 90 days after fermentation started; hence a total of 12 samples for each treatment, or 144 samples in total. The samples remained on farm until the scheduled date for analysis when they were transported to the laboratory of the National

Institute of Animal Veterinarian or National Institute of Animal Husbandry in Hanoi to be analyzed. Chemical analyses included pH and dry matter, crude protein, ether extract, crude fiber and ash contents. These analyses were derived from Vietnamese standards (TCVN), with dry matter content based on 4326-86 and from IS0-standard 6496, total ash based on TCVN-4327-86 and ISO-standard 5984, crude fibre based on TCVN-4329-86 and ISO-standard 5498, crude protein based on TCVN-4328-86 and ISO-standard 5983 (Kjeldahl method), ether extract based on TCVN-4327-86 and ISO-standard 5986, and pH determined by electrode method.

Microbiological tests for aflatoxin, *Salmonella* and *E.coli* were performed on vines fermented with various types of chicken manure, to ensure feed safety. When fermentation uses any type of chicken manure, it is essential to check feed safety. Costs of the nutrients were calculated to determine the economic efficiency. Aflatoxin analysis utilized thin layer chromatography while *E. coli* and *Salmonella* were determined from enterobacteria diagnosis.

Pig-feeding Trial

The on-farm feeding trial was conducted in the same village. Five households were selected, each with six pigs (a total of 30 pigs). All trial pigs were F1 pigs, a crossbreed between the local *Mong Cai* sow and the introduced Largewhite boar. Efforts were made to ensure that there was no significant difference in the weight of the piglets in each treatment of the feeding trial in order not to bias the results (P = 0.657) (Table 2). The sex ratio was also evenly distributed, with five female and five male pigs in each treatment. The piglets went through an adjustment period of five days before the trial began. During this period, the piglets were fed increasing amounts of fermented feed each day to help them adjust to the new diet.

In each household, two pigs were assigned to each of three treatments (i.e., two replications per treatment per household):

- fresh or unfermented vines
- vines fermented with cassava meal (equivalent to Treatment 5 of the previous trial: 93.5 % SP vine + 6 % of cassava meal + 0.5 % of salt)
- vines fermented with chicken manure and cassava meal (equivalent to Treatment 6 of the previous trial: 83.5 % SP vine + 10 % chicken manure + 6 % cassava meal + 0.5 % of salt)

Treatment 5 and Treatment 6 of the previous trial were selected for the feed trial due to the abundance of cassava roots in this area.

The base feed was common to all three treatments and it consisted of rice bran, corn meal, cassava meal, fish meal and soy bean. The first three ingredients are commonly used by all farmers as pig feed. Fish meal and soy bean are less common in the rural area, but more commonly used by peri-urban farmers who raise pigs for the urban centers. The percentage of each ingredient was formulated based on the weight of the pigs: the bigger the pig, the lower percentage of protein and higher percentage of starch (Table 3). The recommended daily ration of this base feed also varied with pig weight: the bigger the pigs, the more ration (i.e., kg of feed) per day (Table 4).

The trial lasted three months between 29 January and 30 April 2000 (93 days). The pigs were weighed four times: on the first day, after one month, after two months, and on the last day. The amount and the price of feed were recorded to calculate the costs of total feed and per kg weight gain.

ANOVA one way classification by Minitab 12.21 was performed to analyze the variance and determine the P value while Tukey was used to test the mean differences among categories.

Results and discussion

Sweetpotato Vine Fermentation Trial

At 30 days after fermentation, the pH of all the treatments with chicken manure met the basic requirement of the acidity level (pH 3.7) for livestock (Ruiz et al. 1981) (Table 5). The pHs of the treatments with chicken manure were significantly higher than the ones without, and had already attained the required level after only 14 days of fermentation. In terms of pH, therefore, the treatments with chicken manure are better feed than fresh vines or fermented vines without chicken manure.

Dry matter (DM), crude protein (CP), ether extracts (EE), crude fiber (CF), and ash showed no significant difference over time (at 14, 30, 60, and 90 days of fermentation). However, these parameters did differ significantly across treatments, especially between treatments with and without chicken manure (Table 6): DM, CP and ash contents of the treatments with chicken manure were all significantly higher than those of the treatments without.

Microbiological tests on vines fermented with various types chicken manure showed no aflatoxin or *Salmonella* in freshly dried chicken manure**.** *E. coli* was found when freshly dried, but was no longer detectable after 21 days of fermentation. The chicken manure used in this trial was purchased from a chicken farm near the trial village and the low price of the manure resulted in the low cost of crude protein and ash content in the fermented mix. In practice, farmers may collect and use manure from their own chickens. Therefore other types of chicken manure were also subjected to microbiological tests in this study. Sun dried manure from Kabir dual-purpose broilers and Tam Hoang layers, which are commonly raised by farmers, showed no aflatoxin or *Salmonella*: *E.coli* was a little more persistent in the fermented mixture, but was no longer detectable after 21 days of fermentation.

Pig-feeding Trial

In the feeding trial, the daily weight gain of the pigs over 93 days showed no significant difference between the fresh vine and non-chicken-manure fermentation (Table 2). Growth of pigs on the chicken manure treatment, however, was significantly greater than that of pigs fed fresh vines. Even though the daily weight gain of pigs on the two fermented treatments was not significant, because of the large SD that resulted from the highly uneven weight of the pigs, the difference (554 versus 488 g) is quite substantial.

The chicken manure treatment achieved the highest feed and dry matter conversion rates (i.e., lowest feed or DM input per kg of weight gain), and consequently the lowest feed cost per unit of weight gain (Table 2). No statistics were performed for feed costs because the two pigs in each treatment in each household were fed together and the feed costs for each individual pig could not be determined. The farm gate prices of live pigs in the Red River Delta area have been fluctuating between 9000 and 10,000 VND/kg, so farmers would suffer a loss by feeding fresh vine and would make only a small profit by feeding the non-chicken-manure treatment. The chicken manure treatment, however, would provide farmers with a substantial profit, as well as the highest weight gain.

Conclusions

Fermentation is a simple process that requires little investment or equipment. Chicken manure is readily available and cheap because only small quantities are required. The only equipment needed is a set of scales for weighing the ingredients, and bags for storing the ferment. Thus, this fermentation method can easily be adopted, or even adapted, by farmers to improve pig growth and increase profit. During the extension meeting held soon after the trial, 40 women showed great interest and enthusiastically copied the fermentation formula and the daily feeding formulation without any prompting from the extension staff.

During the extension meeting, the women voiced their concern about the formulation of the daily diet for pigs: not all crops included in the formulation are available year round, even though all are used as pig feed at different times of the year; and farmers cannot afford to buy fish meal or soy beans every day, however small the amount required. So farmers may not be able to follow the complete feed formulation. But the trial shows that, holding the base feed stable, vines fermented with chicken manure should yield higher daily weight gain with lower cost per unit of weight gain than feeding fresh vines or vines fermented with cassava meal. In other words, replacing fresh vines with chicken manure-fermented vines will lead to improved growth, the extent of which depends on the base feed.

These results may be disseminated widely to pig farmers in north and central Vietnam where sweetpotato vines are an important component of pig feed. Policy should be made to encourage the Departments of Agricultural and Rural Development at the district and commune levels to disseminate the information and demonstrate the processing and feeding method to farmers. Instead of encouraging the use of commercial protein supplement which is mainly imported, the policy should create favorable conditions for farmers to experiment with using locally available materials to increase the necessary protein for pig feed.

Table 1. Ingredients of sweetpotato vine fermentation.

Treat-ments	Proportion (Percent by weight)[1]				
	Sweetpotato vine	Corn meal	Cassava meal	Rice bran	Sun-dried chicken manure
1	93.5	6			
2	83.5	6			10
3	87.5	6		6	
4	83.5	3		3	10
5	93.5		6		
6	83.5		6		10
7	87.5	6	6		
8	83.5	3	3		10
9	93.5			6	
10	83.5			6	10
11	87.5		6	6	
12	83.5		3	3	10

[1] All treatments also contained 0.5% salt

Table 2. Performance traits of pigs fed on fermented sweetpotato vines under on-farm conditions.

Weight	100% fresh sweetpotato vine		93.5% sweetpotato vine, 6% cassava meal, 0.5% salt		83.5% sweetpotato vine, 6% cassava meal, 10% chicken manure, 0.5% salt		P
	Mean	SD	Mean	SD	Mean	SD	
Initial weight (kg)	20.35	3.24	20.75	4.06	21.85	3.92	0.657
Final weight (kg)	60.40a	7.79	66.10ab	10	73.40b	10.47	0.018
Total weight gain (kg)	40.05a	7.86	45.35ab	8.18	51.55b	7.99	0.013
Daily weight gain (g)	431a		488ab		554b		
Rate of weight gain (%)	100.00		113.20		128.70		
Feed cost (VND/kg weight gain)	10,784		8,875		7,383		

* Letters to the right of the means are significantly different (P<0.05) across columns (Tukey test by Minitab 12.21).

Table 3: Composition, nutritive value and price of the base feed formulated for each pig weight category (%).

Feed composition	Feed composition		
	15–30 kg pig	30–60 kg pig	>60 kg pig
Rice bran (%)	30	28	25
Corn meal (%)	40	39	36
Cassava meal (%)	13	28	25
Fish meal (%)	9	8	7
Soya bean (%)	8	7	7
Dry matter (%)	88.76	88.76	88.79
Crude protein (%)	14.45	13.48	12.64
ME (Kcal/kg)[1]	3,040	3,046	3,065
Price (VND/kg)[2]	2,428	2,318	2,211

[1] Estimate based on National Institute of Animal Husbandry (1995, pp. 108, 114, 120, 124, 128, 134).
[2] Exchange rate: US$1 = 14,000 VND. The exchange rate is fairly stable and has remained approximately 14,000 for the two-year period, 1999-2000.

Table 4. Daily feeding schedule in the performance trial for each treatment based on pig weight categories.

Treat-ments[1]	Feed	Daily feed quantity (kg/head)				
		20–30 kg pig	30–40 kg pig	40–50 kg pig	50–60 kg pig	>60 kg pig
T1	Base feed	1-1.5	1.5-1.8	1.8-2	2-2.3	2.3-3
	Fresh sweetpotato vines	1.6	2.0	2.3	2.5	2.9
T2	Base feed	1-1.5	1.5-1.8	1.8-2	2-2.3	2.3-3
	Fermented sweetpotato vines	1.0	1.2	1.5	1.6	1.8
T3	Base feed	1-1.5	1.5-1.8	1.8-2	2-2.3	2.3-3
	Fermented sweetpotato vines	0.8	1.0	1.2	1.3	1.5

[1] See text and table 1 for description.

Table 5. pH profile in sweetpotato fermentation.

Treat-ments [1]	Number of days after the fermentation started								
	14		30		60		90		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P
1	a3.53a	0.04	ab3.73b	0.09	a3.72b	0.05	a3.65b	0.09	0.000
2	c3.92	0.03	c4.03	0.13	b3.89	0.12	b3.98	0.04	0.068
3	a3.55a	0.02	a3.70b	0.08	a3.65b	0.02	a3.71b	0.05	0.000
4	c3.97ab	0.01	cd4.08c	0.04	b3.90a	0.02	b3.99b	0.08	0.000
5	a3.52a	0.01	ab3.81bc	0.03	b3.88c	0.08	a3.73b	0.07	0.000
6	c3.95a	0.03	de4.14b	0.01	bc3.94a	0.14	bc4.05ab	0.04	0.000
7	a3.51a	0.04	ab3.76b	0.04	a3.67b	0.11	a3.75b	0.04	0.000
8	c3.91a	0.03	de4.10d	0.02	cd4.06c	0.02	Bc4.03b	0.01	0.000
9	b3.61a	0.02	b3.82d	0.04	a3.75c	0.01	a3.66b	0.03	0.000
10	d4.05a	0.03	e4.20c	0.06	d4.19c	0.02	c4.12b	0.02	0.000
11	a3.51a	0.03	ab3.76b	0.05	b3.83c	0.04	a3.74b	0.06	0.000
12	c3.93a	0.04	de4.17c	0.01	bc4.00b	0.04	b4.03b	0.03	0.000
P	0.000		0.000		0.000		0.000		

[1] See text and table 1 for description.
[2] Letters to the left of and to the right of the means are significantly different (P<0.05) across rows or columns respectively.

Table 6. Nutrient composition of the 90-day fermentation (percent of dry basis).

Treatments[1]	Dry matter (DM)	Crude protein	Ash	Ether extract	Crude fiber
1	a25.04	bc14.86	b11.85	b3.43	bc17.04
2	c31.31	e18.59	d16.46	bc3.53	abc15.66
3	b28.57	b14.32	a10.7	de5.01	bc16.69
4	c31.85	e18.62	de17.35	c4.14	abc15.19
5	a25.72	a13.19	bc12.25	a2.44	bc16.64
6	c30.09	d17.63	de17.1	ab2.99	ab14.47
7	b28.47	a12.76	a10.16	ab2.96	a13.97
8	c31.92	d17.53	de17.33	b3.23	a13.98
9	a25.85	c15.45	c13.54	e5.62	c17.32
10	c31.63	e19.11	e18.34	de5.41	abc16.06
11	b29.26	a12.60	ab11.45	de5.21	abc15.95
12	c31.45	d17.78	de17.16	d4.91	abc15.11
P	0.000	0.000	0.000	0.000	0.000
with chicken manure	31.38	18.21	17.29	4.04	15.08
without chicken manure	27.15	13.86	11.66	4.11	16.27

[1] See text and table 1 for description.
[2] Letters to the left of and to the right of the means are significantly different (P<0.05) across rows or columns respectively.

References

Anh, M. T. P. (2000) Current status and prospective planning upon agricultural development in Hanoi. Paper presented at the "CGIAR Strategic Initiative on Urban and Peri-urban Action Plan" development workshop for South East Asia pilot site, Hanoi, Vietnam. 6–9 June 2000. Hanoi, Vietnam. CIP-Lima, Peru.

Brown, D. L. and. Chavalimu E. (1985) Effects of ensiling or drying on five forage species in western Kenya: *Zea mays* (maize stover), *Pennisetum purpureum* (Pakistan Napier grass), *Pennisetum sp*. (bana grass), *Impomea batata* (sweetpotato vines) and *Cajanus cajan* (pigeon pea leaves*). Animal Feed Science and Technology*, **13**:1–6.

Gerpacio, A. L., Aglibut, F. B., Javier, T. R., Gloria, L. A. and Castillo L. S. (1967) Digestibility and nitrogen balance studies on rice straw and camote vine leaf silage of sheep. *Philippine Agriculturist*, Vol. 51 (3): 185–195.

National Institute of Animal Husbandry. (1995) *Composition and nutritive value of animal feeds in Vietnam*. Hanoi, Vietnam, Agricultural Publishing House.

Pezo, D., Li-Pun, H. H. and Devendra C. (2000) Crop-animal system in Southeast Asia: ILRI research agenda. Paper presented at the "CGIAR Strategic Initiative on Urban and Peri-urban Action Plan" development workshop for South East Asia pilot site, Hanoi, Vietnam. 6–9 June 2000. Hanoi, Vietnam. CIP-Lima, Peru.

Ruiz, M. E., Lozano, E. and Ruiz A. (1981) Utilization of sweet potatoes (*Ipomoea batata* (L.) Lam) in animal feeding. *Tropical Animal Production*, **6**: 234–244.

Scott, G. J. (1991) Sweet potato as animal feed in developing countries: present patterns and future perspectives. Paper presented at the FAO Experts Consultation on “The Use of Roots, Tubers, Plantains and Bananas in Animal Feeding” held at the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 21–25 January 1991.

Sutoh, H., Uchida S. and Kaneda K. (1973). Studies on silage-making: the nutrient content of sweet potato (*Ipomoea batatas L. var. edulis*) at the different stages and the quality of sweet potato vine silage. *Japanese Scientific Report*, **41**: 61–68.

Tinh, N. T. (2000) Pig-raising in peri-urban Hanoi. Paper presented at the "CGIAR Strategic Initiative on Urban and Peri-urban Action Plan" development workshop for South East Asia pilot site, Hanoi, Vietnam. 6–9 June 2000. Hanoi, Vietnam. CIP-Lima, Peru.

Woolfe, J. A. (1992) *Sweet Potato: An Untapped Food Resource*. New York, USA, Cambridge University Press. 643pp.

Annex 3

Title

Rural Income Generation through Improving Local Crop-based Pig Production Systems in Vietnam: Diagnostics, Interventions and Dissemination

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Abstract

Sweetpotato-pig production is an important system that generates income, utilizes unmarketable crops, and provides manure for soil fertility maintenance. This system is widely practiced from Asia to Africa, with many local variations. Within this system, pigs are generally fed a low nutrient-dense diet, yielding low growth rates and low economic efficiency. This project in Vietnam went through a process of situation analysis, participatory technology development (PTD), and scaling up over a seven-year period to improve this system and to disseminate developed technologies. The situation analysis included a series of pig production assessments in several provinces in northern and southern Vietnam, and pig supply-market chain identification was conducted in 13 provinces. The analysis of these studies informed the project of appropriate locations for our activities, seasonal available feedstuff and farmers' feeding practices, market fluctuation and requirements, and the feeding and management improvement needs, based on which the following phase of PTD was designed. The PTD involved a limited number of farmers participating in sweetpotato varietal selection, sweetpotato root and vine silage processing, seasonal feeding combination, and pig feeding with balanced crop-feed diet and silage. Six years of multi-location and multi-season sweetpotato selection resulted in a couple of promising varieties that yielded up to 75% more dry matter and have since been formally released. The most significant results of silage processing and feeding trials were improved growth, higher feeding efficiency, increased year-round local feedstuff, and considerable labor reduction from eliminated cooking and vine cutting. Once these technologies were developed, a farmer-to-farmer training model was designed for scaling up the adoption and impact. Farmer trainers from seven communes in seven provinces received training in these technologies; in turn, they undertook the responsibility of training other farmers on sweetpotato selection, processing, and feeding. An impact study was also administered to monitor and evaluate (M&E) the dissemination process and to document the impact. The results showed that both participating and non-participating farmers have taken up the technologies, but the former more than latter. The participants also generated more income and saved more labor from the adoption of the technologies. While the scaling up and M&E activities are on-going, the project has since broadened from a sweetpotato-pig system perspective to a pig-crop feed system perspective based on farmers' needs, and included other crop feeds such as cassava and peanut stems in the research portfolio. New technologies based on on-going PTD will continuously be incorporated into the future training curriculum.

Abbreviations

DWG	daily weight gain
M&E	monitoring and evaluation
PTD	participatory technology development
VND	Vietnamese dong (approximate 2003 exchange rate 15,000 VND = $1.00 USD)

Introduction

Human consumption of fresh sweetpotato roots as a staple declines as income increases. This trend is reflected in the differences in per capita consumption of sweetpotato among developed and developing countries (Woolfe, 1992). As human consumption declines, sweetpotato's role as animal feed becomes increasingly important (Scott, 1991). China accounts for eighty-five percent of global sweetpotato production, with a high percentage of that production going to animal feed. Huang et al. (2003) estimates that forty percent of total sweetpotato output in China went to animal feed in the mid 1990s, regional utilization varying from 60% in Sichuan Province to 30% in Shandong Province. The principal author's study of Yilong County in Sichuan Province indicates that eighty percent of all harvested sweetpotatoes goes to animal feed, principally to pigs.

In addition to China, sweetpotato-pig systems play an important role in the rural economies of many parts of Asia, including Vietnam, the Philippines, a few of the eastern islands of Indonesia (e.g., Bali and Papua), Papua New Guinea, and previously Korea and Taiwan. This system is also practiced, to a lesser extent, in Latin America and some countries in Africa, like Uganda (Scott, 1991).

Although sweetpotato-pig farmers complain about the low profitability of raising pigs, the practice serves three important functions: 1) it generates one of the few sources of cash income for many rural households, 2) it provides manure for maintaining and improving soil fertility, and 3) it allows pigs to convert low-value sweetpotato into highly desired meat and/or highly marketable commodities. Therefore, this system is practiced by nearly every household in many sweetpotato-producing regions for these very reasons.

Considering the importance of this system to the rural household economy in many parts of the world, improvements in this system may have widespread positive impacts. This paper reviews the specific case of a project in Vietnam extended from 1997 to 2003, covering situation analysis to participatory technology development and scaling up to improve this system. The objective of the project was to enhance income generation through improved sweetpotato-pig feed systems by selecting advanced sweetpotato varieties and developing proper feeding management techniques with the local crop feedstuff. As it evolved, other supplemental crop feed such as cassava and peanut stems were also included in the research agenda in order to enhance the system more comprehensively. The project is currently in the phase of scaling up through farmer-to-farmer training model, while continuing on additional technology development.. A series of farm surveys to evaluate impact are scheduled and the first survey round has been completed and analyzed.

General characteristics of the sweetpotato-pig feed systems

The principal author's diagnostic studies of the systems from Asia to Africa reveal the following general characteristics as a basis for technology development to improve the system.

Sweetpotato roots, vines, or both, as a main component of feed

Generally roots are fed as an energy source and vines as a protein source. The quantities fed, though, vary greatly depending on:

1) farmers' preferences—Papuan/Indonesia farmers tend to feed large quantities of roots throughout a pig's lifespan while Chinese farmers prefer to feed large quantities only to fattening pigs,
2) sweetpotato availability—Chinese farmers have more sweetpotato available for pig feed than those in Vietnam or Uganda where sweetpotato production is lower than in China,
3) alternative feeds—in mountainous zones of Vietnam it is not necessary to feed sweetpotato roots since cassava roots are available to feed to pigs; thus, in areas like this sweetpotato vines are fed to complement cassava roots,
4) post-harvest processing opportunities—Ugandan and Papuan/Indonesian farmers do not dry and store the vines like the Chinese and Vietnamese farmers, so vines are fed to pigs only during the harvest season, regardless of the size of the pigs.

Sweetpotato supplemented by other farm crops or foraging

Under some systems, the sweetpotato-based diet is supplemented by other available farm crops, such as cassava in Vietnam. Maize is an important supplement in China since production is relatively high and price is relatively low; whereas in Vietnam where maize production is low, a combination of rice, cassava, and maize supplements sweetpotato. In Uganda, pigs are tethered to a tree in the field while they forage around the trees for supplemental feed; while in Papua/Indonesia pigs root for worms and forage grasses while roaming free or in confined fields.

Absence of protein supplements

Protein supplements are rarely observed. In China, commercial protein supplements have become widespread, but the farmers in remote counties of Sichuan were generally uncertain of their utility or usage, or cannot afford to invest in these commercial products. On the coast of Vietnam, it is not uncommon for farmers to add some unmarketable small fish or shrimp to the basic farm-crop diet, but this is done sporadically and seasonally. In Papua/Indonesia, the pigs supplement their sweetpotato-centered diet with the worms that they root while roaming around the forest. Otherwise, protein supplements are generally absent from these systems. One good source of protein is the sweetpotato leaves which contain 18-22% of protein.

Unbalanced nutrition

In addition to the absence of protein supplements, unbalanced nutrition is further aggravated by the following additional factors:

sporadic daily feeding schedules—many farmers, especially in Uganda and Papua/Indonesia do not follow a daily feeding schedule and feed sporadically.

1) nutritionally-unbalanced feeding practices—balanced daily feed formulation is absent and farmers generally feed whatever is available, and commonly feed excessive amounts of sweetpotato roots or vines at the time of harvest due to lack of means or technology for storage or processing.

Poor management of the environment

Whether the pigs are confined in pens as in China and Vietnam, tethered as in Uganda, or confined only at night as in Papua/Indonesia, pig health and growth is often adversely affected by conditions of poor sanitation and hygiene.

Lack of disease control
There are varying degrees of disease control in these traditional systems, but in general illness poses a serious threat to investments in pig husbandry. The fear of pig mortality often results in farmers who are unwilling to invest in pig-raising. The farmers feel more exposed to risk if the pigs require cash investment when they suspect that pigs may die from diseases such as pig cholera in Vietnam, excessive parasite burden in Papua/Indonesia, and allegedly African swine fever in Uganda.

Improving the systems: the case of Vietnam from situation analysis through participatory technology development to scaling up

The project in Vietnam went through the process of situation analysis, participatory technology development (PTD), scaling up and monitoring and evaluation (M&E) between 1997 and 2003. The situation analysis began with a series of production surveys conducted between 1997 and 1999 and a large-scale pig supply-market chain identification survey. Participatory technology development involved on-farm technical interventions such as sweetpotato varietal selection specifically targeted for pig feed, sweetpotato processing to increase the efficiency of using sweetpotato as pig feed, and pig-feeding trials to examine methods to increase pig growth efficiency with the processed feed and other available farm crop feeds (Table 1). As the project evolved along with the unfolding realities and the systemic needs of small-scale pig producers in rural Vietnam, other important or potential feed sources such as cassava and peanut stems were incorporated into the mix of intervention activities in order to address feed improvements in a holistic manner. After five years of PTD with a limited number of farmers on their own lands and facilities, a preliminary survey confirmed farmers' general interest in the selected sweetpotato varieties, the methods for processing sweetpotato roots, and the balanced feeding regime with crop feeds to improve their pig production. This convinced the project team that it had the appropriate products and approach to disseminate the technologies more widely to crop-feed based pig producers. A scaling-up curriculum development for farmer-to-farmer training was launched in May 2000, along with a process of monitoring and evaluation, culminating with a formal impact survey conducted in December 2002. The M& E results should inform us about future PTD activities needed to further improve the crop-based pig production system. As we continue with PTD in a wide range of subjects, the farmer-to-farmer training curriculum will continue to be updated to incorporate the new technologies that are tested and developed.

Situation Analysis

Pig Production Assessment

A pig production assessment was carried out in a series of studies: 1) a first set of exploratory studies with observations in a few locations in Thanh Hoa and Quang Nam provinces, and 2) a formal study in seven provinces in northern, central, and southern Vietnam, with a survey instrument based on the results from the exploratory studies, and 3) continuous reconfirmation and verification of the survey results in the field through informal discussions with farmers.

The pig production assessment showed that, with the exception of Vinh Long Province in the Mekong Delta, pig husbandry constituted an important household economic activity all over Vietnam, but the scale of the production was larger in the south than in the north (Table 2). The surveyed pig growth efficiency—the daily weight gain (DWG) in the north averaged only 288 g while the south had an average DWG of 448 g—also reflected the regional difference in the production scale and feeding methods. While in the north small farmers fed fresh sweetpotato roots and vines, dry cassava chips, rice, rice bran, maize, and various types of vegetables/grasses as the main feed sources, such crop feeds were not nearly as common in southern Vietnam, particularly in a province like Dong Nai where pigs were mainly produced on large-scale farms and fed commercial feeds (Table 3). In the southern province of Vinh Long, where there was substantial sweetpotato production, pigs were still fed very little sweetpotato because sweetpotatoes commanded such high prices in the fresh market that it was not economically feasible to feed them to pigs. These data indicated to us a focus for our efforts on sweetpotato-pig system improvements for the small pig producers of the northern and north-central provinces. Moreover, the realization that crop feeds were harvested in different seasons meant that the seasonal availability of crop feeds had to be taken into account to improve the systems (Table 4). This led to the later trials experimenting with cassava and peanut stems along with sweetpotato roots and vines. Experimenting with peanut stems was a response to farmers' requests for seeking alternative feed sources between August and November when little feed is otherwise available, and recognizing that the abundance of peanut stems served no other purpose than green fertilizer.

Supply-Market Chain Identification

In the pig production survey, the issues of marketing and price fluctuations emerged as major constraints to profitability; therefore, supply-market chain identification was undertaken in 1999 in an attempt to understand the forces which impacted the pig marketing chain in Vietnam. The marketing study included 1,140 samples in 13 provinces and 9 different survey instruments for 9 categories of respondents—pig raiser (n=637), pig collector (n=104), pig middlemen (n=52), pig wholesaler (n=26), slaughter house (n=13), pork middlemen (n=52), pork retailer (n=130), city household consumer (n=90), commercial consumer (foreign supermarkets (n=4), restaurant (n=8), Vietnamese hotels (n=16), and foreign hotels (n=8)). The study showed that Hanoi had the most complicated chain between producer and market, which was not observed in other municipalities or provinces. The supply-market chain most commonly shared by the provinces consisted of pig raisers, pig middlemen/collectors, pig wholesalers, slaughterhouses, pork middlemen, pork retailers, and consumers (Figure 1). Figure 1 also shows that the most expedient chain was from pig-raisers directly to the slaughterhouse which in turn sold directly to consumers, but this was unusual. Due to such complex supply-market chains, the profits were generally low for pig-raisers while pork prices for urban consumers were 37-57% above the farm-gate prices (Figure 2). Addressing such complexity, however, was beyond the scope of the project; the project's approach to increasing profitability was to enhance production efficiency. Since larger pigs commanded higher prices per unit of weight than smaller ones (Figure 3), this suggested that increased growth efficiency through improved feeding would generate higher income in a shorter time. Such increased efficiency would allow farmers to raise pigs to term because they often sold pigs of sub-optimal weight simply because cash was needed before the pigs reached full-term weight of 80-100 kg.

Participatory technology development

Sweetpotato varietal selection for pig feed

From 1997 to 2003, on-farm sweetpotato selection trials were conducted in multiple seasons because sweetpotato was planted two or more seasons a year, usually as a short stopgap in between rice crops, and in multiple locations because sweetpotato was grown in many different agro-ecological zones in Vietnam. As sweetpotato was replaced by peanuts and other high value crops in spring and summer seasons, the project correspondingly reduced the number of trial sites in these seasons. The selection trials aimed at selecting sweetpotato varieties that would provide more starch in the roots and protein in the vines per hectare than the local varieties. Unlike most other countries, it is common in Vietnam to grow sweetpotato specifically for vine production in order to complement the cassava root- or maize-based pig diet. Therefore, both dual-purpose varieties, which maximize the total dry matter from both roots and vines, and forage varieties, which maximize the total protein yield from the vines, were selected.

After the first 3 years of selection, two varieties, KB1 and K51, emerged as high-yielding clones with wide adaptability. After testing for two years in multiple locations (n=4-6, varying each year) both in winter, the major sweetpotato season, and spring, the secondary season (n=2-4, varying each year), variety KB1 consistently showed fifty-five to seventy-five percent improvement in dry matter yield and starch yield. K51 had high fresh yield and was well liked by farmers who are not yet “dry matter conscious” for pig feed, but it does not have a wide adaptability. Where it performs well, K51 has been widely adopted by farmers to replace the local varieties. KB1, along with K51, have since been released through the formal government channels as official sweetpotato varieties.

After KB1 and K51 were released, they were no longer included in the selection trials in subsequent years. Starting in winter 2001-2002, a new set of clones was tested during four subsequent seasons, with the last harvest in May 2003. Clone 98-8-24 emerged as a high-yielding clone across seasons and locations (Table 5). Other clones, 98-8-48 and KL5, yielded well in the winter and could be tested in farmers in larger scales for the winter season. In the mean time, many farmers have adopted, and are satisfied with, KB1 and K51.

Forage selections also showed potential to increasing the total protein yield in vines. However, despite the fact that many farmers grow sweetpotato for forage purposes only in the spring or summer, selection for such purpose did not seem to interest the farmers. Thus, this line of selection activities was suspended by 2001.

Sweetpotato root and vine silage

Sweetpotato root and vine processing trials experimented with a wide range of fermentation methods to increase the nutritional value, to extend the storage life, and to reduce the labor requirement for daily processing of pig feed. Twelve different ways of ensiling sweetpotato vines with various proportions of different additives were tested, which was later replicated for root silage. The results of the silage showed no significant difference in nutritional value from 14, 30, 60, and 90 days after silage. The root and vine ensiled with sun-dried chicken manure contained the highest crude protein, dry matter, ash, and pH, all of which indicate better feed potential (see also Peters et al., 2001, Peters et al., 2002).

Microbiological tests on vine silage with various types of chicken manure showed no aflatoxin or *Salmonella* in freshly dried chicken manure. *E. coli* was found when freshly dried, but was no longer detectable after 21 days of fermentation. The chicken manure used in this trial was purchased from a chicken farm near the trial village and the low price of the manure resulted in the relatively low cost of crude protein and ash content in the fermented mix. In practice, farmers may collect and use manure from their own chickens. Therefore other types of chicken manure were also subjected to microbiological tests in this study and yielded the same results.

Ensiling is a simple process that requires little investment or equipment and can easily be adopted, or even adapted, by farmers. Chicken manure is readily available and cheap because only small quantities are required, but most farmers have so far preferred to use rice bran as additive. Vine silage has an important implication for labor as well. Large quantities of vines can be processed during the harvest season and farmers, particularly women, old people, and children, no longer need to spend hours chopping vines each day for pig feed.

Sweetpotato roots typically have low starch digestibility and protein content, and contain trypsin inhibitors which reduce protein uptake. The traditional way to overcome these constraints is to cook the feed, which is expensive in terms of labor and fuel. Moreover, sweetpotato roots do not store well, so feed must be prepared fresh every day. Ensiling sweetpotato 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 conditions. Participating farmers stated that the heavy labor requirement for cooking was one of the major obstacles to increasing production; when freed from this chore, farmers were able to increase their production.

Feeding trials with silage

Feeding trials were conducted following the vine and root silage trials to examine the effects of feeding root or vine silage to pigs. All feeding trials were conducted on farm, and the results reported here were conducted in Pho Yen District of Thai Nguyen Province in northern Vietnam, with five to seven households participating in each trial, and 2-4 pigs per treatment. All trial pigs were F1 pigs, a crossbreed between the local *Mong Cai* sow and the introduced Largewhite boar. Efforts were always made to ensure that there was no significant difference in the beginning weight of the piglets in each treatment of the feeding trial in order not to bias the results. The piglets were always given an adjustment period of five days before the trial began. During this period, the piglets were fed increasing amounts of fermented feed each day to help them adjust to the new diet.

In the vine silage feeding trial, the daily weight gain (DWG) of the pigs over the course of 93 days showed no significant difference between those fed fresh vines and non-chicken-manure fermented feed (Table 6). Growth of pigs on the chicken manure treatment, however, was significantly greater than that of pigs fed fresh vines. Even though the difference in DWG of pigs on the two silage treatments was not significant at the 5% level, due to the large standard deviation (SD) that resulted from the highly uneven quality of the pigs and variations between participating farmers, the difference (554 g versus 488 g of DWG) is nonetheless quite substantial.

The average DWG of the pigs over the 89 days of the root silage feeding trial showed no significant difference at 5% level across the three treatments, due to the same variation mentioned above. Even so, the DWG were substantial different (640 vs 605 and 552). The most important result was that uncooked sweetpotato root silage could achieve pig growth comparable of that achieved with cooked sweetpotato roots, but at much lower cost in labor and fuel. Instead of being eliminated through cooking (i.e., high heat), more than thirty percent of the trypsin inhibitor was instead reduced through ensiling, which is enough to preclude the need for cooking. As with the vine silage, root silage can also be stored for at least five months, thus effectively resolves the storage problem.

A follow-up feeding trial was conducted in the same village to examine the growth efficiency of including ten (T_1), twenty (T_2) and thirty percent (T_3) (on dry matter basis) of sweetpotato root silage in the total diet. The results showed that total weight gain and daily weight gain for T_1 (539 g) were significantly higher than those for T_3; gains for T_2 were similar to those of the other two treatments (Table 7). Nevertheless, at the time of the trial, live weight pigs fetched 9,100 VND/kg; therefore, all three treatments showed 5% - 11% of return on the investment. This would suggest that adding as little as ten percent of sweetpotato root silage to the feed is an effective option since farmers' traditional practices often yield in loss, not profit. These results further suggest that a variable feeding regime would require the lowest input to achieve comparable growth as feeding the same amount of silage during the three-month period.

Trials with other crops as feed

As shown in Table 4, various crops are available in different months of the year as feed. Farmers expressed interest in learning how to combine these crops during each season, and to include as much and many of the root crops as possible to reduce feed cost. A trial was therefore conducted to examine the different ways of combining processed and unprocessed sweetpotato vines and cassava roots to satisfy the feeding needs at the end of the year. At this time of the year, the cold drizzle and cloudy weather may pose a constraint to sun-drying vines or roots; therefore, it was important to examine the effects of roots and vines processed in different ways on the growth of pigs. The trial results showed no significant difference between the different ways of combining ensiled and dried roots and vines (Table 8). This indicated that farmers had the option of drying or ensiling roots or vines depending on the weather and availability of labor without compromising growth.

In order to increase the proportion of on-farm feedstuff and decrease the proportion of purchased feed in the silage, a trial of replacing rice bran with sweetpotato vines to ensile the roots was tested (Table 9). Throughout the trial all the trial participating farmers were most adamant that Treatment 3 (ensiling with 15% of fresh sweetpotato vines) was the best because pigs appeared to like and finish the feed the quickest. The trial results coincided with the farmers' perception and showed no significant difference in weight gain at 5% level, but the feed cost of Treatment 3 is the lowest because of the highest feed conversion rate. These results showed that ensiling sweetpotato roots with vines not only use up the farm crop, it also yields better economic efficiency.

Feed is most limiting in the summer when sweetpotato roots and vines are the only available crops for pigs. At the same time, peanuts are harvested in June and July leaving an abundance of peanut leaves, which in their fresh form have little cash or feeding value. These peanut leaves, and stems, are normally mixed in with other green manures and used as fertilizer in the fields. Farmers expressed interest in turning these leaves into a viable pig feed. A trial was thus designed to investigate the nutrition value of peanut stem in silage form. The results showed that sweetpotato roots ensiled with fifteen, thirty or forty-five percent peanut leaves, had higher pH (i.e., not as acidic) and crude protein levels than roots ensiled with an equal amount of sweetpotato vines. Moreover, this generates additional income because peanut leaves have no cash value while sweetpotato vines are commonly sold as pig feed and the price can be quite high during the off season. As farmers in northern Vietnam increase peanut production to meet the demand for export peanut oil processing, the use of peanut stems as feed has the potential of contributing considerably to rural incomes. A pig-feeding trial is currently underway to examine the growth potential and economic efficiency of such silage as pig feed.

Scaling up and Monitoring & Evaluation

Farmer-to-farmer training

After six years of working closely with farmers to select advanced sweetpotato clones, to investigate ways to process roots and vines to increase nutritional value and extend storage life, and to experiment with balanced crop feeds to increase pig growth efficiency, farmers began to adopt some or all of the technologies to improve their pig production system. A Vietnamese-language manual "Pig feed improvement through enhanced use of sweetpotato roots and vines in Northern and Central Vietnam" was subsequently developed based on these results to provide guidance on sweetpotato selection and cultivation, pig-feeding and management technology, and veterinarian practices for Vietnamese farmers. The manual was later translated into English to target a broader audience who might have an interest in such a system (Peters et al. 2001).

Once we had advanced from the participatory technology development stage, in which a limited number of farmers were involved (approximately 100 farmers involved over a six-year period), to the dissemination stage when scaling up became necessary, a farmer-to-farmer training model was devised. In May 2002, three farmers (one from the local Women's Union, one from Veterans' Association, and one from the Farmers' Association) from seven communes in seven provinces were invited for four days of farmer-trainer training on the farm of our main farmer collaborator in PhoYen District of Thai Nguyen Province. Two sweetpotato breeders, one veterinarian, and one pig nutritionist from national research institutions and an agriculture university—the long-term collaborators on this project—provided the training. Using the manual as a resource book, the national collaborators developed training manuals for each topic to guide the training for the farmer-trainers and the subsequent training for the farmers. During these four days the farmer-trainers received training in both the training methods and the training contents.

These 21 farmer-trainers have since prepared their own teaching materials and conducted training on various subjects, depending on the relevant season (e.g., training on sweetpotato cultivation at the onset of the planting season and training on ensiling at the beginning of the harvest season), with the national collaborators serving as resource persons at all the training sessions. Responding to requests from other interested districts, a second farmer-trainer training session has been planned for other districts to train more trainers to disseminate these technologies to additional farmers. During this second session, new material, based on new PTD results since the last training session, will be included in the curriculum so that knowledge will be updated each year through these farmer-training sessions. For example, the research results from peanut stem silage will be included in the second session. This annual training event will also provide the trainers with the occasion to present the results of their training activities and share their experiences with the new trainers, as well as provide an opportunity for comments and feedback on the curriculum and training methods

Impact Study

The first season of impact study has been carried out to monitor the process of farmer-to-farmer training and to document the impact of these training activities. With the assistance of the farmer-trainers, the resource persons (i.e., the national collaborators who implemented the trials on this project) conducted survey interviews in the same seven communes where the training sessions were held. In each of the seven communes, 30 farmer households were interviewed, of whom 15 had participated in either the training or PTD and 15 had not. Thus, a total of 210 households were interviewed about past and current patterns of crop production and utilization in relation to pig production in order to analyze the adoption behavior of the farmers.

The data show wide-spread adoption of selected sweetpotato varieties since the winter season 2001-2002, and both participating and non-participating farmers exhibit an increasing trend in both total area and relative percentage of coverage with the selected varieties (Table 10). As mentioned earlier, spring sweetpotato planting has rapidly given way to peanut cultivation, thus only a small percentage of farmers plant sweetpotato during the spring season. However, the area planted in the spring with selected varieties is nearly equal to that planted with selected varieties in the winter season, indicating that those who do plant in the spring have increased area coverage with the selected varieties.

The silage technology, however, has been adopted at a slower rate than the varietal adoptions —only 11.2 – 13.5% of participating farmers have begun feeding pigs with sweetpotato root and vine silage (Table 11). Nevertheless, the fact that 6.1-7.4% of non-participating farmers have also processed silage feed indicates that this technology has potential for wider spontaneous adoption (Table 12). In terms of feeding practices, 75% of both categories of respondents said that they now feed balanced rations predominantly. Even though this could be attributed to the training since it is part of the curriculum and because, based on our previous assessment studies, farmers do not traditionally feed a balanced ration, this causal relationship cannot be firmly established since this was not addressed directly by the impact study. One marked difference in the feeding practice is that, among the training participants, commercial compound feeds, supplements, and concentrates consist of only 2.6% of the total pig feed while they consist of 3.5% of the total feed among the non-participants. Moreover, non-participants tend to feed a higher percentage of soy meal and fish meal. (Table 12). These high-cost inputs have resulted in lower economic returns to the non-participating farmers, as the non-participants finish a cycle in 136 days with a feed-to-meat ratio of 6.4, while the participants take only 122 days to finish a cycle with a feed-to-meat ratio of 5.6. This is likely attributed to the balanced ration used by training participants. Even though 75% of the non-participants also claim to prepare balanced rations, the accuracy of the ration may be questionable since they did not participate in the balanced feed training. The participants now raise an average of 12.9 finished pigs per year in 2.4 cycles while the non-participants raise 7.6 pigs in 2 cycles only (Table 12).

This increased production, at the same time, is achieved with reduced labor inputs as the participants invested 746 hours per cycle during the January-June 2002 production season while non-participants invested 757 hours per cycle. The difference in labor inputs is more evident in per pig production statistics—221 hours vs. 283 hours (Table 11). This still constitutes a substantial labor input (4 hours/day/per cycle, or 1.2 hours/day/pig) which could be further reduced if farmers would feed more ensiled root crops which do not require cooking. It is also worth pointing out that the ensiling technology has reduced women's share of the labor as participating women contribute 63.8% of the total labor while non-participating women account for 66% (Table 11).

The training participants are now less dependent on the veterinary services and only 76% of them consult veterinarians while 97% of non-participants continue to rely on veterinarian services.

Since the study was conducted adoption has further progressed. In Tinh Gia, the farmer trainer reports that 50% of sweetpotato area is now planted to KB1. The biggest advantage of KB1, in addition to high-yielding, is early maturity which is essential for Tinh Gia where sweetpotato is planted three short seasons a year. As planting material becomes more available next year he predicts the planting area will increase to 80%. The greatest advantages of root and vine processing technologies are: 1) it eliminates cooking, and 2) it saves roots and vines from rotting. With the adoption of these processing technologies those farmers who raised 5-10 pigs in the past now raise 15-25 each cycle. When he first organized the farmer-to-farmer training, he had to use commune funds to buy 20 simple root-processing machine introduced by the project as model. Now there are 50 such machines purchased by individual farmers and he predicts more will purchase these inexpensive machines.

Conclusions

Until a series of impact studies have been carried out and analyzed, the precise impact of these seven years of working to improve the local crop-based pig production systems in Vietnam cannot be definitively substantiated or quantified. Nevertheless, the process and methodology undertaken in this project and the approach to participatory technology development provide a useful framework for designers of livestock research and development projects for smallholders worldwide. If the process described in this paper is regarded as a case study of employing such a framework, one can learn how to apply the methodology step by step, from situation analysis and participatory technology development to scaling up and impact analysis, with continuous feedback to further inform and adjust each step in the process. Finally, this case study demonstrates the utility of an integrated approach for enhancing the entire pig production system through crop production for feed, crop processing to improve nutritional value and storage life, and balancing diets of crop feeds. The processing and feed-balancing technologies developed in this project and the integrated approach to pig production improvement may have wide applicability for small livestock holders who depend on a variety of root crops, vines, and vegetables for pig feed.

Table 1. Project activities conducted between 1997 and 2003.

Process	Activities	1997	1998	1999	2000	2001	2002	2003
Situation Analysis	Pig production assessment	■	■	■				
	Supply-market chain identification			■				
Participatory Technology Development	Sweetpotato (SP) varietal selection	■	■	■	■	■	■	■
	SP root and vine processing		■	■	■	■	■	■
	Pig feeding trials with silage		■	■	■	■	■	■
	SP & cassava combination feeding				■	■	■	■
	SP & peanuts silage							■
Scaling Up	Farmer-to-farmer training							■
M & E	Impact study							■

Table 2. The general characteristics of household pig production in seven provinces in north-central and southern Vietnam (n=160 per site).

Location	% households without pigs (%)	No of pig per cycle (no)	Begin Wt. (kg)	End Wt. (kg)	Months raised per cycle (mo)	DWG (g)
Southern VN						
Dong Nai	2.5	24.89	14.94	83.77	4.39	522
Vinh Long	72.5[a]	6.54	22	100	6.95	374
Average	**37.5**	**15.72**	**18.47**	**91.89**	**5.67**	**448**
North-Central VN						
Quang Nam	0	2.06	5.83	54.79	8	204
Thanh Hoa	0	1.99	12.78	69.86	5.95	319
Ha Bac	0	2.6	13.98	80.63	5.8	383
Hoa Binh	0	4.86	9.54	61.93	7.39	236
Vinh Phu	0	2.52	10.3	52.44	4.72	298
Average	**0**	**2.81**	**10.49**	**63.93**	**6.37**	**288**

[a]Vinh Long is a major sweetpotato (SP) producing province and 100% of SP is sold in the fresh market, hence no SP is available for pig feed and therefore there are few pigs.

Table 3. Daily feed composition (kilograms per pig per day, and the percentage of households (hh) using the feed) for finishing (large) pigs in seven provinces of Vietnam (n=160 per site).

Location	SP vine		SP fresh root		SP chips		Cassava chips		Rice	Bran	Maize	Vege-tables
	(kg/p/d)[a]	Hh feed (%)	(kg/p/d)	hh feed (%)	(kg/p/d)	hh feed (%)	(kg/p/d)	hh feed (%)				
Southern VN												
Dong Nai	0	0	0	0	0	0	0	0	0.03	0.25	0.29	0.13
Vinh Long	1.22	97.5	0.23	17.5	0	0	0.5	77.5	0.16	2.54	0	1.39
Average	**0.61**	**48.75**	**0.12**	**8.75**	**0**	**0**	**0.25**	**38.75**	**0.1**	**1.4**	**0.15**	**0.76**
North –Central & Northern VN												
Quang Nam	3	47.5	1.76	47.5	1.1	47.5	0.39	12.5	0.54	0.52	0	0.51
Thanh Hoa	5.9	80	1.28	75	0.77	42.5	0	0	0.56	1.37	0.67	1.3
Ha Bac	3.58	100	2.58	100	0.15	60	0.05	77.5	0.45	0.8	0.34	3.72
Hoa Binh	3.5	100	0	0	0	0	0.5	100	0.03	0.4	0.3	2.9
Vinh Phu	5.2	100	3.19	100	0	0	0.15	22.5	0	0.24	0.6	2.29
Average	**4.24**	**85.5**	**1.76**	**64.5**	**0.4**	**30**	**0.22**	**42.5**	**0.32**	**0.67**	**0.38**	**2.14**

[a] kg/p/d = Kilograms of feed per pig per day

Table 4. Seasonal availability of various crop feeds in northern Vietnam.

Season	Feed from farmers' fields	Purchased feed
Jun-Aug	SP root & vine, peanut stems	Rice bran
Aug-Oct/Nov	SP vine	Rice bran, maize (cheap at this time)
Oct/Nov-Feb	Cassava root, SP vine	Rice bran, maize (less available)
Feb-Apr	SP roots, cassava roots	Rice bran, maize (less available yet)
Apr-Jun	SP roots, SP vine, cassava (little)	Rice Bran, maize

Table 5. The total dry matter yield (DMY) of roots and vines and starch yield of roots of the various sweetpotato clones included in the varietal selection trials during three seasons from 2001 to 2003.

	Winter 2001		Spring 2002		Winter 2002		Spring 2003		Average	
Varieties	DMY	Starch yield	DMY	Starch yield	DMY	Starch yield	DMY	Starch yield	DMY	Starch yield
98-8-24	6.0	2.35	10.05	4.13	5.3	2.27	6.45	4.41	6.95 a	3.29 a
98-5-15	5.36	2.07	9.81	3.92	5.12	2.22	5.60	3.32	6.47 ab	2.88 ab
KL5	5.53	2.26	9.17	3.37	5.24	2.20	5.42	3.18	6.34 ab	2.75 abc
KL6	5.40	2.16	8.99	3.11	4.73	1.75	5.26	3.25	6.10 ab	2.57 bc
98-8-48	6.36	2.68	7.41	2.30	4.68	1.79	4.49	3.10	5.74 b	2.47 bc
98-8-118	5.83	2.05	7.94	2.52	4.6	1.55	3.58	2.46	5.49 b	2.15 c
Control	4.76	2.21	9.36	3.53	4.41	1.85	5.96	4.05	6.12 ab	2.91 ab
Cv(%)									10.6	14.5

[a] As peanut oil becomes increasingly in demand, spring fields are now increasingly allocated to peanut production in the spring, hence reducing sweetpotato production.

Table 6. Performance traits of pigs fed fresh and ensiled sweetpotato vines under on-farm conditions.

Weight	T_1 100% fresh sweetpotato vine		T_2 93.5% sweetpotato vine, 6% cassava meal, 0.5% salt		T_3 83.5% sweetpotato vine, 6% cassava meal, 10% chicken manure, 0.5% salt		P
	Mean	SD	Mean	SD	Mean	SD	
Initial weight (kg)	20.35	3.24	20.75	4.06	21.85	3.92	0.657
Final weight (kg)	60.40a	7.79	66.10ab	10	73.40b	10.47	0.018
Total weight gain (kg)	40.05a	7.86	45.35ab	8.18	51.55b	7.99	0.013
Daily weight gain (g)	431a		488ab		554b		
Rate of weight gain (%)	100.00		113.20		128.70		
Feed cost (VND/kg weight gain)	10,784		8,875		7,383		

* Letters to the right of the means indicate significant differences (P<0.05) across columns (Tukey test by Minitab 12.21).

Table 7. Performance traits of pigs fed various proportions of sweetpotato root silage under on-farm conditions.

Pig weight	% sweetpotato silage (DM basis) in total diet						P
	T1 10%		T2 20%		T3 30%		
	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, treatment means followed by the same letter do not differ significantly at P<0.05 by ANOVA and Tukey tests.

Table 8. Performance traits of pigs fed various combinations of dried or ensiled sweetpotato vines and cassava roots under on-farm conditions.

	SP vine silage[1] and dry cassava roots		Dry SP vine and cassava root silage[2]		Dry SP vine and dry cassava roots		P
	Mean	SD	Mean	SD	Mean	SD	
Initial weight (kg)	14.86	2.51	15.63	2.18	14.8	2.42	0.71
Final weight (kg)	60.06	6.1	61.39	8.19	60	8.38	0.958
Total weight gain (kg)	45.22	4.42	45.72	6.22	45.2	6.07	0.971
Cost wt. gain (VND/kg)	6,686		6,800		5,971		

[1]100kg vines + 10kg cassava root meal
[2]100kg roots + 10kg rice bran

Table 9. Performance traits of pigs fed sweetpotato root silage processed with various types and proportions of additives under on-farm conditions.

	T1 20% rice bran[a]		T2 9% rice bran[b]		T3 15% fresh SP vines[c]		T4 15% wilted SP vines[d]		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Initial weight (kg)	14.89	3.03	14.98	2.87	15.07	2.51	14.89	2.8	0.354
Final weight (kg)	62.63	11.12	60.40	11.66	61.48	9.42	60.71	13.88	0.927
Total weight gain (kg)	47.74		45.42		46.41		45.82		
Feed conversion	2.82		2.91		2.72		2.77		
Cost wt. gain (VND/kg)	8,922		9,769		8,699		8,815		

[a]80 kg of SP roots ensiled with 20 kg of rice bran
[b]100 kg of SP roots ensiled with 10 kg of rice bran
[c]85 kg of SP roots ensiled with 15 kg of fresh SP vines
[d]85 kg of SP roots ensiled with 15 kg of pre-wilted SP vines (55-60% weight of the fresh vines)

Table 10. Sweetpotato varieties

Area planted to sweetpotato (sao)	All	Training participants	Non participants
Share of area planted to selected varieties (%) *			
Winter 2001-02	53.4	55.8	49.5
Spring 2002	56.7	65.3	48.5
Winter 2002-03	67.9	67.3	69.1
Share of respondents planting selected varieties (%) *			
Winter 2001-02	63.3	67.8	57.3
Spring 2002	18.6	17.4	20.2
Winter 2002-03	73.8	78.5	67.4

* Varieties selected by the on-farm selection trials which consist of K51, K4, KL1, KL5, KB1.

Table 11. Sweetpotato preparation for animal feed

	Training participants			Non-participants		
	Fresh	Dried	Silage	Fresh	Dried	Silage
	(% used as)			(% used as)		
Roots	80.9	8.3	11.2	79.4	13.3	7.4
Vines	81.8	3.9	13.5	85.3	8.6	6.1

Table 12. Differences in pig-raising practices and the corresponding economic returns to the training participating farmers and non-participating farmers.

	Participants	Non-participants
Feeding practices (%)		
Prepare SP root silage for feed	11.2	6.1
Prepare SP vine silage for feed	13.5	7.4
Predominantly prepare balanced ration	75	75
Feedstuff (%)		
Compound feed, supplement, concentrates	2.6	3.5
Protein feeds—soy and fish meal	10.4	11.9
Root crops—SP and cassava roots and vine	29.5	29.6
Other	8.9	2.2
Feeding cycle		
Number of days per cycle	122	136
Number of cycles a year	2.4	2.0
Number of pigs per cycle	12.9	7.6
Feed-to-meat ratio	5.6	6.4
Labor inputs for pig-raising (Jan – Jun 2002)		
Per cycle of production (hours)	746	757
Per pig sold (hours)	221	283
Female share of the labor inputs (%)	63.8	66

Supply-market Chain

(Finished Pigs)

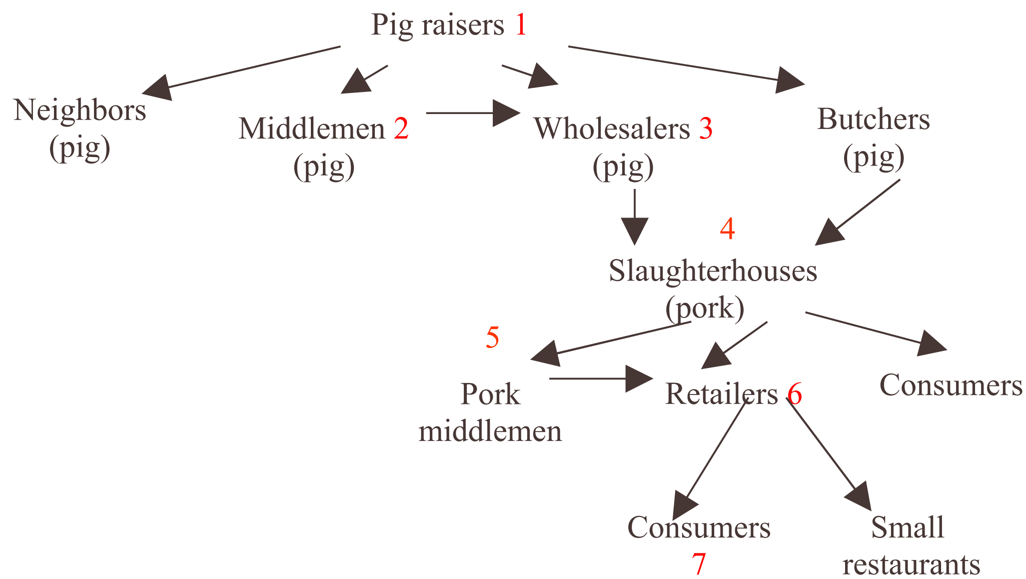

Figure 1. The most commonly observed pig supply-market chain in Vietnam.

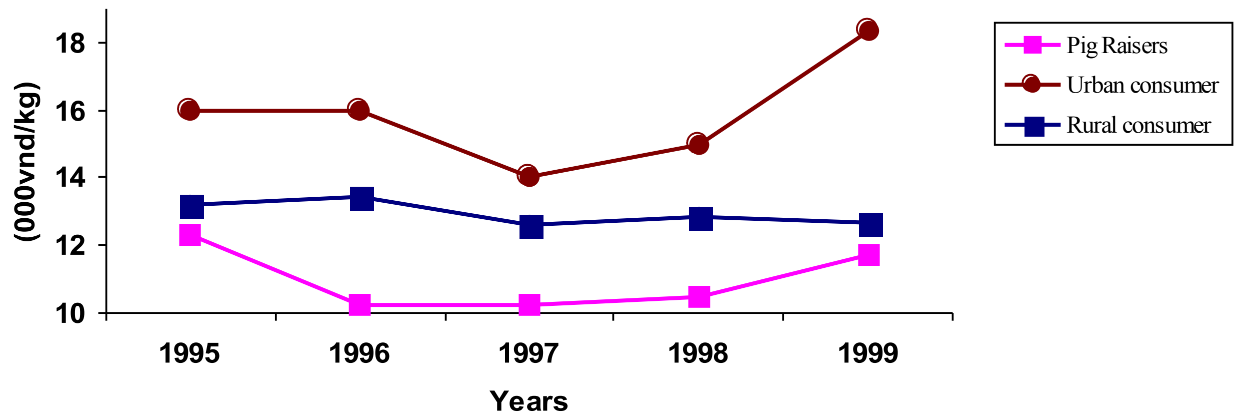

Figure 2. Annual fluctuations of finished pig and pork prices (Vietnamese dong (VND) per kilogram (kg)) for the pig raisers (suppliers), rural consumers, and urban consumers, based on survey data collected in 1998 in 13 provinces in northern, central, and southern Vietnam. ($1.00 USD = 15,000 VND, thus these prices range from the equivalent of $0.67 USD/kg – $1.20 USD/kg).

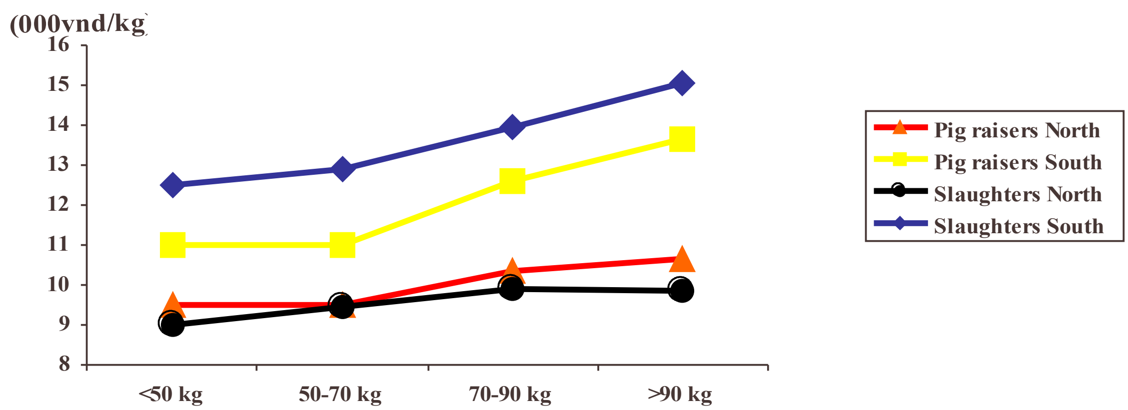

Figure 3. The live weight pig prices (Vietnamese dong (VND) per kilogram (kg)) that pig raisers receive and slaughterhouses pay in the north and south, according to the different weight categories of the pigs, based on survey data collected in 1998 in 13 provinces in northern, central, and southern Vietnam. ($1.00 USD = 15,000 VND, thus these prices range from the equivalent of $0.53 USD/kg – $1.10 USD/kg).

References

Huang, Jikun, Jun Song, Fanbin Qiao, and Keith O. Fuglie. Sweetpotato in China: Economic Aspects and Utilization in Pig Production. International Potato Center, Bogor, Indonesia, 2003.

Peters, D., N. T. Tinh, and P. N. Thach. 2002. Sweet potato Root Silage for Efficient and Labor-saving Pig Raising in Vietnam. *AGRIPPA*. Rome: Food and Agriculture Organization. www.fao.org/docrep/article/agrippa/554_en.htm

Peters, D., N. T. Tinh, and T. T. Thuy. 2001. Fermented Sweetpotato Vines for More Efficient Pig Raising in Vietnam. *AGRIPPA*. Rome: Food and Agriculture Organization. www.fao.org/docrep/article/agrippa/x9500e10.htm

Peters, D., N.T. Tinh, T. T. Minh, P. H. Ton, N. T. Yen, and M. T. Hoanh. 2001. Pig Feed Improvement through Enhanced Use of Sweet Potato Roots and Vines in Northern and Central Vietnam. International Potato Center (CIP), Lima, Peru.

Scott, G. J. 1991. Sweet Potato as Animal Feed in Developing Countries: Present Patterns and Future Perspectives. Paper presented at the FAO Experts Consultation on "The Use of Roots, Tubers, Plantains and Bananas in Animal Feeding" held at the Centro International de Agricultura Tropical (CIAT), Cali, Colombia, January 21-25, 1991.

Woolfe, J. A. 1992. *Sweet Potato: An Untapped Food Resource*. New York: Cambridge University Press.