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A critical review of sweetpotato processing research conducted by CIP and partners in Sub-Saharan Africa

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[1] C. Loechl updated Section 2.6: Use of orange-fleshed sweetpotato.

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Comments are invited.

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Executive summary

This review summarizes research undertaken on sweetpotato post-harvest utilization and processing in East Africa, with the objective of making recommendations on future research and development (R&D) priorities for CIP and its partners. It is based on literature available in mid-2006, with the exception of section 2.6.

Sweetpotato (SP) in East Africa is still predominantly a supplementary food crop, for on-farm or local consumption of fresh roots. Urban marketing has developed since about 1990, and is growing from a low base. While some research has focused on fresh root quality and post-harvest storage, most attention has been placed on processing fresh roots to more stable intermediate products (dried chips, flour) and their use in a range of locally important snack foods such as mandazi and chapatti. The technical and economic feasibility of small rural or urban enterprises based on these products has generally been assessed as positive, but only very limited commercial development of these technologies has occurred to date, usually within the supportive environment of development projects.

Sweetpotato R&D in East Africa is now very focused on the evaluation and promotion of orange-fleshed sweetpotato (OFSP) varieties, based on the nutritional benefits of consumption of a food rich in vitamin A and its precursors. OFSP varieties have been demonstrated to be capable of providing sufficient vitamin A to counteract nutritional deficiencies found in rural populations. Fresh roots and processed products made from them - which retain significant levels of vitamin A if cooked and/or processed correctly - have proven acceptable to consumers when accompanied with a nutritional promotion campaign. There are indications that without such an associated effort, uptake of OFSP varieties in non-intervention areas is more limited.

Sweetpotatoes are widely used in Asia for starch extraction and animal feed. The potential for starch in East Africa is not high, based on the absence of any compelling functional advantages of sweetpotato starch and a high raw material cost. Animal feed uses have more potential, especially for intensive cattle production (fodder including SP vines), pigs and small ruminants, although there is a lack of basic information on the two latter options.

Recent projects have emphasized development of market chains linking sweetpotato producers to urban fresh markets (via wholesalers and supermarkets) and to the developing food industry, including the potential for flour and chip intermediate products. It is too early to evaluate these continuing efforts but it appears that they have potential to improve existing chains as well as to initiate novel chains (e.g. with food firms in the private sector).

Studies undertaken in the 1990s identified a strong demand constraint for sweetpotato roots in East Africa - only a small percentage of production is traded (5%), and urban markets did not appear to be growing. More recent evidence points to growth in urban markets for sweetpotatoes in line with rapid urbanization, with 'supermarketization' of agricultural production, and with the advent of OFSP varieties (and the promotional campaigns associated with them) that provide an added reason to consume this crop. However, improving cost-competitiveness of non-OFSP as a food industry raw material (flour, chips, starch) requires significant investment to improve productivity and root dry matter content in farmers' fields. Given that other crops are also receiving R&D investment in these areas, it may not be a good use of limited research funds for sweetpotatoes.

Future research priorities identified from this review include:

- Studies on more efficient use of sweetpotatoes in animal feed, especially pigs and small ruminants.
- OFSP - evaluation of food preparation and processing technologies that maintain vitamin A content.

- Determining whether the nutritional advantages of OFSP are sufficient to overcome its cost disadvantages versus other starchy substitutes (e.g. maize, and cassava) for both fresh consumption and food industry uses as raw material.
- Careful evaluation of case studies now in progress for market chain development with OFSP and non-OFSP, to identify options for future prioritization. This is especially relevant for chains involving the food industry (processing, supermarkets) in growth market segments.

A critical review of sweetpotato processing research conducted by CIP and partners in Sub-Saharan Africa

INTRODUCTION

Across Sub-Saharan Africa, sweetpotato roots are mainly and traditionally eaten as a supplementary staple food or secondary food crop, consumed directly on the farm in a subsistence economy. The fresh roots are commonly consumed directly - usually boiled or steamed and occasionally mashed or roasted. The young vines are also eaten as a vegetable in many places. Sweetpotato is an important food security crop when maize is in short supply or in years of drought. It can adapt to a wide range of climatic conditions, including marginal areas. In addition, the ability of sweetpotato to establish ground cover very fast, enables suppression of weeds, control of soil erosion and maintenance of soil fertility. Therefore, it is an attractive crop for many farming systems (GTZ, 1998).

As agriculture becomes more market-oriented, sweetpotato is one of several crops that farmers can produce to obtain cash income in addition to subsistence food security. Supply and demand factors are therefore increasingly important in determining the role that sweetpotatoes will play in a more market-oriented smallholder farm sector. Markets for fresh roots and vines do exist, but are not large and, like cassava, consumption of fresh sweetpotato roots tends to decrease with urbanization, due to shifts in diets related to factors such as price, convenience and status.

Sweetpotato does have some "points of difference" with other root crops that justify efforts to maximize the role that the crop can play in urban diets as well as in rural incomes and nutrition:

- Some orange-fleshed varieties (OFSP) have high levels of beta-carotene (pro-Vitamin A) in the roots, sufficient to play a key public health role in interventions aiming to reduce the prevalence of the Vitamin A deficiencies that occur across much of Sub-Saharan Africa.
- A short growth period, with the potential to produce relatively high fresh and dry matter yields (of roots and vines) in less fertile, lowland tropical conditions, as a component of sustainable multiple cropping systems.
- A wide range of varieties/cultivars offering potential for many different types of utilization, including:
  - Colors from white, cream, yellow, orange and purple.
  - High and low dry matter and starch contents.
  - High and low sugar contents (sweet and non-sweet varieties).

- Unique starch properties of interest to the food industry (especially in Asia).

On the other hand, some less positive characteristics of the crop exist, but are susceptible to either genetic improvement and/or post-harvest management, including:

- A lower dry matter and starch content than cassava (in general), reducing competitiveness for uses dependent on dried root chips/flour.
- Relatively indigestible roots (due to the presence of trypsin inhibitors), complicating use of fresh roots for animal feed.

Since the early 1990's, CIP and partner institutions have undertaken a range of research projects in Sub-Saharan Africa on sweetpotato utilization and processing, with the overall aim of increasing the role of sweetpotatoes in urban and rural diets, maximizing nutritional benefits, as well as enhancing incomes of rural producers. This involves research in the following areas:

- Varietal selection for different end uses
- Inclusion of sweetpotato roots, and derived intermediate products, in a range of commonly consumed foods
    - Technical aspects of processing and product quality.
    - Economics of production and processing.
    - Consumer and market acceptability studies.
- OFSP
    - Varietal variation and selection.
    - Levels of beta-carotene/Vitamin A in fresh roots and processed products.
    - Evaluation of public health/nutritional benefits of OFSP promotion at community level.
- Market chain and enterprise development action-research based on sweetpotato processing ventures.

This review will assess the current state of knowledge of the research to date, and its application in the field. Gaps in knowledge will be identified, and some recommendations made to orient future research and development efforts.

Much of CIP's research in Sub-Saharan Africa has been carried out in East Africa, especially Kenya and Uganda, where sweetpotato plays a more important role than in many other countries of the region. This review will therefore focus mostly on these countries.

CRITICAL EVALUATION OF ECONOMIC VIABILITY OF SWEETPOTATO PRODUCTS AND NEW USES

Overview of product types

Fresh roots for own consumption are the principal traditional sweetpotato product. In addition to on-farm consumption of sweetpotato roots, markets for the fresh roots are developing, with sweetpotato roots found from rural to major urban wet markets, in the rapidly expanding supermarket sector of Kenya, and even for export to Europe. Some marketing of fresh vines also occurs. Fresh roots can also be grated and used directly as an ingredient in some bakery goods.

Fresh roots and vines are used for animal feed, although this is usually directly on the farm, with limited marketing for this purpose.

Like other starchy staples, sweetpotato can be used to make two stable intermediate products that each have a wide range of potential end uses in the food industry:

- Dried chips or flour produced from milled chips.
- Extracted starch.

To date, research has focused on chips and/or flour in Africa—CIP was only involved in starch research in Asia in the 1990s.

Sweetpotato also has another, less stable intermediate product, namely boiled and mashed sweetpotato. This can be used as an ingredient in a range of food (bakery) products commonly eaten in East Africa.

Much CIP research has focused on the use of sweetpotatoes in some traditional bakery goods commonly found as staples or snack foods in East Africa, such as chapatti, mandazi and bread/buns. These are common food items across the region, and are usually made from wheat flour as the sole source of starch. Trials have been conducted using sweetpotatoes to substitute (in varying percentages) some of the wheat flour. The sweetpotato was used in either of three forms:

- Fresh, grated roots.
- Boiled and mashed roots.
- Flour produced by milling dried root chips.

This research therefore assesses the relative merits of these three sweetpotato presentations, as well as their performance compared to that of wheat flour.

Post-harvest research on OFSP has included:

- Assessments of the retention/loss of beta-carotene during fresh root storage and product processing.
- Trials of the above bakery goods including OFSP flour or mash as an ingredient.
- Human health benefits of consuming fresh roots, vines and bakery products containing OFSP.

Methodology of socio-economic assessments and their assumptions

The assessments carried out by CIP and partners to date have comprised:

- Cost-benefit analysis of specific processing technologies, and of the inclusion of sweetpotato in food products as a substitute for other ingredients (e.g. wheat flour). These have often been based on trials carried out in a small-scale commercial setting (i.e. where conditions and costs will be closer to a real life situation than in a research or pilot facility). This also has the advantage that feedback from potential processors can be obtained first hand.
- Enterprise feasibility studies, based on the use of technologies and production of the products outlined above. These may include some financial analysis (discounted cash flows, rates of return etc), but are usually based on long-run extrapolations from short trial processing periods.
- Consumer acceptability studies (including taste panels in some cases) for the food products containing sweetpotatoes. One major consumer study (Omosa 1997) looked in detail at sweetpotato acceptability in a range of products, in two urban areas of Kenya:—Nairobi and Kisumu.

Assumptions that these analyses use are:

- That sweetpotato roots or intermediate products (flour, boiled/mashed roots) are continuously available, often at a constant price.
- That competing raw materials—wheat flour and cassava flour—are similarly available and relatively price-stable.
- That no technical barriers to the use of sweetpotato remain.
- That no anti-competitive practices will be employed by other—competing—economic agents.
- That no changes in government policy will adversely affect sweetpotato, or provide an advantage to competing raw materials.
- That no pests/diseases or climatic factors will adversely affect supply of sweetpotato.

Scale

These studies have been conducted almost entirely at a micro-enterprise or small-scale business level, suited to application by individual households or small farmer/women's groups. In addition, some studies have been conducted from the perspective of small urban businesses such as bakeries. A few studies have involved collaboration with larger scale firms, including bakeries, and with fresh root exporters, although these efforts have mainly been concerned with market chain development, not economic analyses.

Omosa's 1997 study did survey some industrial enterprises in Nairobi and Kisumu, but none were using sweetpotato as a raw material at the time.

The Family Concern project currently in progress (Anon, 2005 and 2006) is working with some major industries on the use of OFSP flour in a range of food products. However, results from this pilot effort are currently being evaluated (Potts, personal communication). Several studies on sweetpotato use in snack food products were carried out in Lira, Uganda in the late 1990s. In Lira (population about 100,000) one hundred people gain a living by trading in bakery products, mainly bread and mandazis. Forty people gain a living making and selling chapattis (Hagenimana and Owori 1997a and b). These are exclusively micro- and small-scale enterprises, often street sellers, although some more formal businesses also exist.

Fresh market for sweetpotato roots (including export market)

Sweetpotato fresh root storage

Fresh sweetpotato roots are not as perishable as cassava, which can undergo physiological deterioration as soon as 24-28 hours after harvest. Omosa (1997) reports that 72% of sellers of fresh sweetpotato in Nairobi sell all roots from any consignment by the third day. Allowing for the time taken to reach the market, this implies a normal storage time of a week or less during the marketing process. However, Feruzi et al. (2001) report that the best varieties for fresh consumption are those that deteriorate fastest.

As for other root crops, various storage techniques that take advantage of root "curing" at high temperature and humidity have been developed (and are also used traditionally). For example, fresh roots have been stored for up to 5 weeks at ambient temperatures in Kenya, and for 14 weeks when packed in sawdust (to allow curing), but some sprouting occurs, which is likely to affect eating quality (Karuri and Hagenimana, 1995). Fresh roots respire during storage—but at a lower rate if cured—and this produces incremental changes in eating quality. Sweetness may also change, as starch is converted to sugars during the respiration process.

Rees et al. (1998) suggest that breeding sweetpotatoes for enhanced fresh root shelf life is possible, based on an evaluation of variation in storage characteristics of existing varieties in East Africa.

In Uganda, the Sweetpotato Coalition Project (PRAPACE, undated) carried out a cost-benefit analysis of on-farm investment in storage structures for sweetpotatoes in three districts, and found that for every Uganda Shilling invested in the construction and management of storage structures for sweetpotatoes, farmers can obtain 12.7, 15.9, and 12.7 Uganda Shillings in the Mukono, Luweero and Mpigi districts, respectively. These benefits largely accrue from savings on food purchase, and easing of food security constraints at the farmers' level due to the greater availability of sweetpotato on farm, outside the harvest period.

Sweetpotato fresh root market

Several studies have looked at existing fresh local and domestic market chains, especially in East Africa. Omosa (1997) studied the fresh market in Nairobi and Kisumu, Kenya, and found that:

- Sweetpotato roots were relatively recent entrants to the market in both places (since 1989).
- Supply was highly seasonal.
- The market is poorly developed due to bulkiness and perishability.
- Sweetpotato was more available in Kisumu, close to the production region, than in Nairobi.

The Family Concern project (Anon, 2006) estimates that the main Nairobi wholesale fresh market receives almost 20,000kg SP/day.

The GTZ study (1998) in Kenya (Kisii) found that fresh sweetpotato is considered an inferior food, used more as a snack than as a staple. An improvement in marketing conditions for sweetpotato was found in one of the study sites, but it was not possible to determine whether this was due to an increase in overall demand fostered by the increasing price of maize and bread, or due to the development of a more efficient marketing system. In general, marketing margins were high, especially at the retail level (Table 1).

Table 1. Sale prices at different stages in the marketing chain for fresh sweetpotato from Kisii, March 1997 (GTZ 1998).

Level	Price per bag Sweetpotato	Price per kg
	KSh per bag	***KSh per kg***
Farm gate	600 to 650	
Roadside assembly for Mombasa Mkt	800	
Kisii wholesale	800-900	
Nairobi wholesale	1,200	9-10
Nairobi 2nd wholesale		15-20
Nairobi retail		30-40

Average exchange rate in 1997 was 58.7 Ksh/$1 USD.

The study recommended a number of interventions to improve sweetpotato post-harvest systems in Kenya, including:

- Investment in roads, wholesale markets, and other rural infrastructure.
- Standardizing weights and measures.
- For the research-extension system to pay more attention to opportunities for rural and urban processing of sweetpotatoes.

This last recommendation implies that the future of sweetpotato as a cash crop is linked to the development of new uses than through expansion of demand for fresh roots.

Lastly, in Uganda the Sweetpotato Coalition Project evaluated the production and marketing of both roots and vines from a business perspective using cost-benefit analysis (PRAPACE, undated). They found that for every Uganda Shilling invested in the production of tubers, farmers can obtain Shs. 2.1, 2.1, and 1.5 in the Mukono, Luweero and Mpigi districts, respectively, from the sale of fresh roots in local markets. Commercial vine production is also viable, resulting in 2.4, 2.3 and 1.6 Uganda Shillings for every Shilling invested in production in the same Mukono, Luweero and Mpigi districts, respectively. These results imply that commercial production of sweetpotato tubers and vines for local markets are viable, and so are worthwhile projects for the farmers to invest in.

Export market for fresh sweetpotato

Only one reference mentions consideration of the export market for fresh sweetpotato roots (Lemaga, 2005). In this project from Uganda, a database of 300 potential European importers of fresh sweetpotatoes was established. One importer, Jimmy Pan Impex Ltd of London expressed an intention to import about 80 tones of sweetpotato per month by sea freight. In order to evaluate the suitability of local sweetpotatoes to supply this market, a sea freight simulation study was carried out, in which improved sweetpotato varieties were kept at 14°C and 90% relative humidity for 50 days. This showed that if properly handled and cured, these sweetpotatoes retained market quality during the expected freight period. The roots appeared visually fresh and showed no significant weight loss, rotting or sprouting. African and European panelists said that the sweetpotatoes had acceptable flavor and texture. Sea freighting was estimated to fetch a high profit margin of US$489-2500/ha compared to a profit margin of US$54-1194/ha obtainable from local markets.

No commercial shipments resulted from this trial because of funding constraints to gather the necessary quantity of roots for the consignment (Lemaga, personal communication). Despite the positive outcome (by the end of the project period) there is still significant work to be done to ensure that production and harvesting procedures result in a harvested crop that meets the standards expected for export markets, including minimal mechanical damage to minimize post-harvest losses during transport—especially if produced by smallholder farmers. Careful sorting/grading and sale of reject roots to the local market will probably be necessary, and thus high export prices will not be obtainable for the entire crop.

Snack foods

These snack foods are usually based on wheat or other flours, not sweetpotato. The inclusion of sweetpotato thus represents a departure from normal practice in most cases. Studies have looked at (a) the demand for these existing products (i.e. no sweetpotato included) and (b) acceptability—and potential demand—for similar products formulated to include sweetpotato in some degree. Sweetpotato may take the form of:

- Fresh, grated roots.
- Boiled, mashed roots.
- Sweetpotato flour.

This section will describe, for each snack food product, the existing consumption characteristics and the potential for including sweetpotato based—usually—on trials carried out with existing processors, bakers, sellers and consumers of these products. All these studies were carried out with non-OFSP varieties. Results of similar trials with OFSP are reported in a later section.

Kabalagala

Kabalagala is a Ugandan pancake-like breakfast snack food usually made from cassava flour (65-70%) and banana pulp (30-35%), and is normally purchased, not made at home. Owori et al. (2003) studied the use of SP flour instead of cassava flour in this product. Ninety-five percent of the small scale processors (mostly female) who make *kabalagala* were willing to try the SP flour substitute. Ninety percent of retailers thought SP flour in *kabalagala* was acceptable/marketable if the flour quality was good and the price competitive, but relative costs and prices were not considered in this study. SP flour would have to be price-competitive with cassava flour (then priced at 625 Uganda Shillings per kg).

Chapatti and mandazi

Two papers by Hagenimana and Owori (1997a and b) report on trials carried out with the inclusion of sweetpotato in the traditional food products chapatti and *mandazi* in Lira, Uganda, using the methodology of Wheatley et al. (1995). In this town, bread is an expensive treat, while chapatti is a staple, ranking as one of the eight main foods. A survey of local markets found over 4,800 pieces of *mandazi* on sale by 36 sellers, 710 pieces of chapatti by six sellers and 2,600 pieces of *kabalagala* by 16 sellers. Bread was only being sold in one place, about 100 loaves and 450 packets of buns daily. This gives a rough indication of the relative demand for each product. The production scale varied from 50-4,000 units/week, i.e. these were micro- to small-scale enterprises.

According to the Sweetpotato Coalition Project (PRAPACE, undated) chapatti is usually served as a snack with tea. Chapattis can also be served with a thick sauce for lunch or dinner. The major customers in the study area included school children, individual households and institutions that buy chapatti during tea break and lunch/dinner time. The current technology does not allow commercial large scale production and currently only small-scale production is practiced.

In this seasonally dry region of Uganda, there is a tradition of chipping and drying sweetpotatoes. In this study, the foods were made by substituting 30 or 50% of the wheat flour usually employed, with sweetpotato, either as flour or boiled and mashed fresh roots. The trials were carried out with three groups of women, three individual processors and one bakery in Lira.

The results were encouraging. While all products were acceptable using SP flour or grated/mashed SP, higher levels of wheat flour substitution were possible for grated and mashed SP (40-60%) than for SP flour (30%). Mashed SP gave the highest consumer acceptability. The sellers could sell the snacks for the same price as normal chapatti and mandazi in local markets. In detail, the results by product (Hagenimana and Owori, 1997b) are:

- *Bread* made with fresh mashed SP was the most liked by consumers, but bread made with SP flour was more filling. Normal bread was ranked third, except for colour. Seventy-five percent of consumers would pay the same price for SP bread from mashed cooked roots as for normal wheat flour bread; 20% would pay more and 5% would pay less. For bread from SP flour, only 66% would pay the same price, no one would pay more. Costs were calculated with help from a bakery in Lira, where the trials were carried out. Using then current market prices for SP, mashed cooked SP increased net revenue per loaf by 12%, and by 19% if SP flour was used. Net revenue cost ratio increased by 21% for cooked mashed SP and by 26% using SP flour. Even greater advantages were found for buns than for loaves. Savings were due to use of less wheat flour and sugar.
- *Chapattis* made with boiled, mashed SP were also well accepted—80% of consumers would pay same price as for 100% wheat flour chapattis, 15% would pay more, and 5% pay less. For chapattis made with SP flour, 60% would pay the same price as for wheat flour products, while 27% would not buy it. Mashed SP is clearly preferred over SP flour here. Using cooked mashed SP for chapattis increased net revenue per piece of chapatti by 42%, or by 49% if SP flour was used.
- *Mandazis* – again, using mashed SP, 80% of consumers would pay same price, 10% would pay more, and 10% pay less for an SP-based product than for a 100% wheat flour one. Using SP flour, 65% would pay the same, and 30% would not buy it at all. Again, mashed SP is preferred over SP flour. Production costs decreased using SP –

net revenue per piece of mandazi increased by 56% for mashed SP and by 68% for SP flour compared to wheat flour-based products, due to use of less flour and added sugar. One advantage of using sweetpotato for mandazis is that costs were reduced, since less additional sugar was needed.

However, Owori and Hagenimana (2001) also identified the following practical issues that may limit adoption of the SP raw material:

- Although extra labor costs for washing, peeling and boiling SP were said to be minor, bakers complained that using boiled, mashed SP required too much labour and preparation time.
- SP flour did not produce such a good quality product, giving a brownish discoloration.
- Initial consumer reaction was negative, due to different size, shape and colour. With experience, products improved in quality and taste testing showed that acceptance was better than for the traditional products.

An earlier study (Hagenimana, 1995) looking at the technical aspects of SP inclusion in these products, carried out with a bakery in Kampala, found that areas for improvement with SP-based bakery products were:

- Bread—lack of sweetness (consumers in Kampala like very sweet bread!).
- Chapatti—texture too oily and brittle.
- Mandazi—needs to be larger and less sweet.
- In general, products made from fresh grated SP were too oily.

In summary, from an economic perspective, use of SP instead of a percentage of wheat flour reduced costs by 20-64%, depending on the product, substitution percentage and type of SP ingredient used.

SP flour is easier for bakers and others to use, but produces a lower quality product (or can only be used at a lower level of substitution). The boiled, mashed sweetpotato produces the best result, but implies extra effort on the part of the processor/baker to use it. At a micro-scale this may not be a big problem, but for a bakery it could reduce their interest in using SP. The seasonality of supply of fresh roots may also be a problem, although it is not mentioned in these reports. Fresh roots may not be available all year, implying reliance on SP flour (and a lower quality product) or reversion to 100% wheat flour. Such variation in product quality may not be acceptable to bakers/processors, especially for larger scale businesses.

More recently, a cost-benefit analysis of sweetpotato-based on-farm enterprises in central Uganda was completed as part of the Sweetpotato Coalition Project (PRAPACE, undated).

This analysis was intended to determine the viability of the sweetpotato post-harvest technologies introduced by the project. These comprised[2]:

- Juice production
- Chips
- Flour

The data included costs and benefits (direct and indirect) incurred/obtained by farmers in employing the various technologies, their input requirements, the prices of inputs and outputs, the availability of inputs, as well as qualitative information regarding the acceptability of the technologies by the farmers.

The Uganda study gave the following results:

- *Chapattis:* the production process involves mixing sweetpotato flour with wheat at a ratio of 1:1, then adding water to make a fine thick paste. The paste is moulded into balls, and flattened to make them thin. This is fried in a thin layer of hot cooking oil to form a local snack called chapatti. From 1 kg of sweetpotato flour and 1 kg of wheat flour, one can obtain 25 chapattis. The technology requires little start-up capital, though with relatively high working capital requirements, yet the price of chapatti is stable at 100 Uganda Shillings (approximately US$0.058). The enterprise is viable, but performance would be better if combined with other on-farm technologies like sale of fresh roots and vines. Except for the Luweero district, the investment in snack production out of sweetpotatoes was viable, with a cost-benefit ratio of 1.1 for the Mukono and Mpigi districts.
- *Chips:* The profitability of sweetpotato chips was generally low for the farmers surveyed. At the effective interest rate of 13%, the cost-benefit ratio was less than one for commercial chip production in all the districts surveyed. The Mukono district had a cost-benefit ratio of 0.9, the Luweero district had 0.66, and the Mpigi district had 0.89. These results show that the enterprise is currently not worthwhile in the study districts. The low viability of chips is largely due to the combination of low market price and the high costs associated with production and marketing. For instance, farmers are paid 500 Uganda Shillings per kilogram, yet they are required to transport the chips to the miller's factory, among other costs. The production of chips requires heavy start-up capital in the form of chippers and construction of drying racks. The required start-up capital is over US$1000. Such investment may be worthwhile over a longer period of project life with a lower discount rate, however.
- *Flour:* One kilogram of dry chips yields about 950 g of flour. Flour is sold to millers, who mix it with other products to make porridge and snacks. A kilogram of flour

[2] Storage structures and fresh roots and vine production/marketing were also considered - see other sections of this report for details

costs 1000 Uganda Shillings on average, which is almost twice as much as the income earned from the sale of chips alone. The biggest marketing challenge that farmers face is quality assurance of the flour. This is mainly due to two factors: a) Farmers cannot determine the required moisture content of the chips and often mill chips that are not properly dried and b) Since farmers use public mills, the sweetpotato flour is often mixed with impurities from other products such as maize, sorghum, and millet. The other important challenge is that sweetpotato products like flour, cakes, porridge, and others are new to the local market and their demand is currently low due to limited awareness. The economic analysis found that flour processing was viable among the surveyed respondents. The cost-benefit ratio was highest in Mukono with 3.7, followed by Luweero with 2.0 and then by Mpigi with 1.7 (Tables 2).

- *Conclusions:* As expected, the most viable technologies generally required the lowest start-up capital, and produced products that are in high demand in most of the intervention districts (Table 2).

Table 2. Summary of sweetpotato enterprise cost-benefit analysis for three districts in Uganda.

Enterprise	Mukono	Luweero	Mpigi
Sweetpotato fresh roots	2.10	2.10	1.50
Improved vine production	2.40	2.30	1.60
Juice production	0.98	0.90	0.99
Storage structures	12.70	15.90	12.70
Sweetpotato chips	0.90	0.66	0.89
Sweetpotato flour	3.70	2.00	1.70
Sweetpotato snacks	1.10	0.90	1.10

Based on the findings, the following conclusions were obtained (PRAPACE, undated):

- Sweetpotato has the potential to improve rural household incomes and to be instrumental in fighting rural poverty.
- Commercial production of fresh roots both for the local and export market is viable and the financial indicators can improve when sale of fresh roots for either market is combined with sale of vines.
- Production of chips is not viable in the short term; but may be viable in the long term and if a lower discount rate prevails.
- Processing of flour is viable whether home-grown or purchased roots are used.

This report is useful because it provides a recent economic comparison of a range of technologies. Perhaps the most interesting finding is that while SP chip production is not a viable stand-alone economic activity, production of flour potentially can be, if demand for the flour can be developed. The report does not state how the price of 100 Uganda Shillings per kilogram of flour was obtained nor how it compares with wheat flour or cassava flour prices.

However, if these prices, and those used for the different snack foods are correct, then there does appear to be potential for SP inclusion in these specific districts of Uganda. Of course, there prices may vary elsewhere in the country, so the danger is that positive economic factors will only be present in a minority of production areas.

From an enterprise perspective, the study indicates that a stand-alone SP chip production business is not viable, but one that produces flour (with chips as an intermediate product) may be. One additional potential enterprise was not considered: the production of boiled, mashed SP for sale to bakers. With a better product quality than SP flour, the use of boiled mashed SP could have more potential than the flour, apart from the disincentives faced by bakers due to the extra cost and labor required.

SP crisps

A study was made of SP fried crisp production by a women's group enterprise in Nairobi (Gatumbi and Hagenimana, 1998). The Ni Witu women's group had 15 members. The process involves root washing, peeling, slicing and frying in oil (Elianto) for 5 minutes, and subsequent packaging. An artesanal SP slicer was an important item of locally made equipment, producing 2mm-thick slices. The product was sold to schools and kiosks. Yellow- and white-fleshed varieties were both used and accepted. The yield of SP crisps was 45-50%. Fat content was only 21%—less than for potato crisps, but moisture content was higher at 8% (potato moisture content was only 1-2%). Profit was 17% per packet sold. They produced 40kg/week in 1995. Sales fall off in school holidays. A 100g bag sells for 20ksh (potato crisps are 40ksh/bag).

A linear relationship between high dry matter (DM) content of roots and low oil uptake during frying of SP crisps was found. Using SP roots with the same DM content as potato results in crisps with a much lower oil content. Use of boiled, mashed SP (50% wheat flour substitution) reduces oil uptake in mandazis and other products as well (but 30% substitution does not) (Hagenimana and Oyunga, 1998).

In another study (Hagenimana et al., 1998), a correlation between high root DM content and low oil uptake during frying was found. Use of high DM roots was recommended for processed products as this lowers cost through less use of expensive oil. However, wheat flour substitution rates of 50% were needed if the oil content of end products was to be significantly lower than in products made using 100% wheat flour.

Thus, while the SP crisp product offers an interesting technical advantage over potato crisps in terms of lower oil content and has been successfully marketed on a small scale, the profitability of an enterprise based on this product has not yet been assessed.

Use of orange-fleshed sweetpotato and the role of beta-carotene

The previous sections have dealt with the predominant sweetpotato varieties in East Africa, i.e. white-or cream-fleshed varieties. Their utilization is based on either traditional consumption patterns, or on their potential use in a range of value-added foods, where they could contribute to profitability by lowering costs. The last decade has also seen the development of significant interest in orange-fleshed sweetpotato roots (OFSP) with an additional, nutritional advantage—a high content of beta-carotene (Vitamin A). OFSP offers potential for inclusion in nutritional programmes to reduce or eliminate Vitamin A deficiency in many areas of Africa, and this could be a way for the crop to escape from the need to compete with other sources of starch or flour (wheat, cassava, maize) on a purely cost basis.

The information for this section comes from two main community-based projects, the VITAA project in East Africa and the Towards Sustainable Nutrition Improvement (TSNI) project in Mozambique, supplemented by other references, especially as regards technical data.

Production

The VITAA project has promoted 15 new OFSP varieties across the East African region, with estimated adoption ranging from 1-2% of the planted area in Tanzania, to 10-15% in Kenya. Markets for the planting material of these varieties exist, and this can be an income generating opportunity for farmers, particularly when non-governmental organizations need vines for distribution to their clients (Kapinga et al., 2005). A range of OFSP varieties that are adapted to local growing conditions and are accepted by consumers exist (Carey et al., 1999) and breeding work is on-going to improve drought resistance, virus resistance, and increase dry matter content, offering scope to expand production across the region in the short and medium-term (Low, personal communication).

Carotene/Vitamin A contents

The beta-carotene content of SP roots varies greatly, from a trace to >90μg/g fresh root weight. The orange root flesh color correlates with beta-carotene content (Hagenimana et al., 1999a). The highest level is found in deep orange-fleshed cultivars.

Hagenimana et al. (1999b) reported that in Western Kenya, beta-carotene content of some SP cultivars was found to be over 40μg/g fresh root weight, considered to be a moderate content of pro-vitamin A. For these varieties, root dry matter content exceeded 25%. One variety, Pumpkin, was lower in beta-carotene (13μg/g fresh root weight) and dry matter content, but was liked by infants due to its soft texture. It was also quick to cook, using less fuel.

A first grouping of sweetpotato varieties based on beta-carotene content was done by Simonne et al. (1993):

- *non-detectable*: <1 µg/g dry weight basis (dwb) (0.26 µg/g fresh weight basis (fwb) for dry matter content (DM) of 25-28%).
- *low* beta-carotene: 1-39µg/g dwb (0.26-10.4 µg/g fwb for DM of 25-28%).
- *moderate* beta-carotene: 40-129 µg/g dwb (10.5-34.0 µg/g fwb for DM of 25-28%).
- *high* beta-carotene: >130 µg/g dwb (>34.0 µg/g fwb for DM of 25-28%).

More recently, as knowledge on bioavailability and losses due to processing has improved, CIP breeders defined different cut-off points for classifying sweetpotatoes based on their beta-carotene content (Gruneberg, personal communication, based on evaluation of 1,300 germplasm clones across two locations):

- *non-detectable*: <0.26 µg/g fwb for dry matter (DM) of 25-28%.
- *low* beta-carotene: 0.26-24.9 µg/g fwb for DM of 25-28%.
- *moderate* beta-carotene: 25-50 µg/g fwb for DM of 25-28%.
- *high* beta-carotene: >50 µg/g fwb for DM of 25-28%.

Storage and processing effects

Several references report how fresh root storage and a number of different post-harvest processes affect the carotenoid or beta-carotene content.

Fresh root storage

Fresh roots of six varieties were stored for 60 days in three different rustic storage conditions (jute sacks, in ground trench and basket). The fresh roots had a mean beta-carotene content of 11µg/g fresh root weight (retinol content of 0.93µg/g fresh root weight), ranging from 8-18µg/g fresh root weight, while the three storage treatments produced a mean beta-carotene content of 5µg/g fresh root weight (ranging from 4µg/g in baskets to 5µg/g in jute sacks) (Feruzi et al., 2001). Thus, while over 50% of the provitamin was lost, this did constitute an unusually prolonged storage period for fresh roots. It is likely that losses for shorter periods likely to facilitate fresh root marketing or processing operations, for example 1-2 weeks, would be more acceptable.

Boiling of fresh root pieces

Boiling, the usual cooking method in East Africa, reduced carotenoid content (and beta-carotene content) by between 14 and 59% after 30 mins in four different cultivars from Kenya, and by 29 to 57% after 1 hour according to Hagenimana et al. (1999b). According to Van Jaarsveld et al. (2006), boiling of a dark orange variety (Resisto) reduces beta-carotene content by between 12 (open pot) and 24% (closed pot) after 30 mins, depending on whether same sized pieces or different sized pieces were used. Similar levels of losses were found by Bengtsson et al. (2008) in seven different improved OFSP cultivars from Uganda: boiling in water for 20 mins (open pot) reduces the all-*trans*-beta-carotene content (which compromises the major provitamin A carotenoid found in OFSP roots and have highest provitamin A activity) by between 19 and 30%, depending on the variety.

The effect of home preparation practices on the beta-carotene content in six orange- and yellow-fleshed sweet potato varieties from Kenya was demonstrated by Kidmose et al. (2007). Boiling in water (covered pot) of the two high beta-carotene content varieties (Tainung and SPK 004; >50 µg/g fresh root weight) for 39 and 22 mins respectively reduces all-*trans*-beta-carotene content of Tainung by about 15%, whereas it increases all-*trans*-beta-carotene content of SPK 004. The latter might be related to a higher chemical extractability of beta-carotene due to changes in the cell wall structure during a mild heat treatment. Stollman (2005) also observed that beta-carotene content is slightly higher in boiled samples of the OFSP variety Ejumula compared to fresh roots.

Drying and storage of dried slices/chips

Drying of white and yellow-fleshed SP roots at 65ºC for 12 h reduced carotenoid content by 30% (Hagenimana et al., 1999a). Dried chips stored at ambient temperature then lost a further 11% of carotenoid content after 11 months storage, showing a relative stability of carotenoids once tissue moisture content had been reduced below the critical level of normal metabolic processes. Kosambo (2004) reports that the beta-carotene content of cabinet-dried chips of Kakamega and Jonathan stored for 3 months at room temperature was reduced by about 50%.

According to Bengtsson et al. (2008), oven-drying slices of Ejumula at 57ºC for 10 h reduced the all-*trans*-beta-carotene concentration by 12%, whereas solar-drying (at temperatures between 45 and 63ºC for 6 to 10 h) resulted in 9% reduction. Highest losses were observed for open-air sun dried slices (16% for drying temperatures between 30 and 52ºC for 6 to 10 h). Differences in losses between the different drying methods were not significant (Bengtsson et al., 2008). A thesis study of the effect of processing on pro-vitamin A in sweetpotato (Stollman, 2005) also confirmed that solar-drying of Ejumula chips produced higher residual beta-carotene content than did open-air drying of root slices in direct sunlight. This was due to shorter drying times and reduced exposure to sunlight. Solar drying takes place at a higher temperature (45°C) compared to 25°C for air-drying, but this does not seem to matter.

Similarly, Kosambo (2004) found that cabinet drying (oven-drying at a temperature of 58ºC for 4 hours) is less destructive on beta-carotene than sun-drying on Kakamega (28% versus 83%) and Jonathan (47% versus 72%). The average loss of all-*trans*-beta-carotene content observed in 13 OFSP varieties from Kenya was 35%. Higher beta-carotene content varieties seem to loose more carotenoids during cabinet drying than varieties with lower beta-carotene contents (Kosambo 2004).

In the TSNI project (Low et al., 2005) during 2004, 39% of intervention households dried OFSP and 75% of those followed the recommended practice of shade drying. Samples of chips dried under local conditions showed good beta-carotene content for the darker orange-fleshed Resisto variety (ranging from 716-1,050µg RAE[3]/100g or 86-126µg beta-carotene/g product) and a much lower content from the light orange-fleshed CN-1448-49 (165-191µg RAE/100g or 20-23µg beta-carotene/g product). Therefore, use of darker orange-fleshed varieties such as Resisto for chipping and drying was recommended as superior to using light orange-fleshed varieties like CN-1448-49. However, contrary to expectations, the beta-carotene in the samples dried in direct sunlight was not completely destroyed. Average levels for Resisto were only 21% lower in direct sunlight than for non-direct sunlight treatments.

Recent studies reported by Bechoff et al. (2008a) aimed to clarify extent and nature of provitamin A losses during drying of chipped and sliced sweetpotatoes (high beta carotene variety from the US). Interestingly, losses in all-*trans*-beta-carotene for hot-drying (cross flow drying; chips at 42ºC for 2 hours; slices at 42ºC for 7.5 hours), solar drying (chips and slices at 38ºC for 8.5 hours) and sun-drying (chips and slices at about 29ºC for 8 hours) were low and ranged from 16 to 34%, which confirms the above findings reported by Bengtsson et al. (2008). Drying by hot air showed significantly lower losses than sun drying, but no significant difference was found between drying by hot air and solar drying. The high retention of beta-carotene in sun dried samples may be in part due to favorable weather conditions during drying (hot and dry, windy), which allowed quick drying. The effect of sun-drying on total carotenoid content reduction was significantly higher for chipped sweetpotatoes compared to slices.

Bechoff et al. (2008b) also evaluated Ugandan OFSP varieties for total carotenoid retention after drying in solar dryers of different types (tunnel and tent) and sun drying, and after subsequent storage of four months at room temperature. Drying of Ejumula and Kakamega was investigated under wet and dry weather conditions. Higher carotenoid losses were observed in wet weather (11%) compared to dry weather (7%), i.e. lower losses occur when drying time is reduced (3 days in wet weather versus 1.5 days in dry weather). No significant difference was observed between carotenoid retention in solar or sun dryer. Again, higher losses resulting of sun-drying compared to solar-drying were not found, which is in contrast to several authors (see above), but in line with the results of previous studies of Bechoff et al. (2008a). The lack of differences might be in part due to the fact that sun-drying in this study was faster than solar-drying and was controlled (samples were covered at night or in case of rain; end of drying was carefully monitored). Other findings are that varieties with high moisture content lose more carotenoids and that the initial total carotenoid content is positively correlated with losses during drying.

Dried Kakamega and Ejumula chips showed high losses of carotenoids after four months of storage at ambient temperatures in polythene bags with an average of 68.2%, ranging from 63.7 to 76.6 % (Bechoff et al., 2008b). If losses from drying and storage are combined, the range is from 75.8 to 85.4% (overall loss). The packaging material did not influence the levels of loss. Bechoff et al. (2008b) also studied the effect of sweetpotato variety on provitamin A retention. The losses in total carotenoids after storage of four months in local black polythene bags at room temperature were high in all six Ugandan OFSP varieties and reached 70.4% (overall losses: 74.7%).

SP flour

According to Stollman (2005), SP flour had higher beta-carotene content than the dried slices (from which they were derived). This unexpected result may be due to the relative ease of extraction from ground tissues, and also to inherent variability between root samples. However, it is in contrast to more recent findings of Kidmose et al. (2007) that demonstrated a further reduction in all-*trans*-beta-carotene content by 17% if Zapallo chips were processed into flour.

Deep-frying

Interestingly, according to Bengtsson et al. (2008), deep-frying of OFSP roots for 10 mins (at 160-170ºC) reduces all-*trans*-beta-carotene content by about the same percentage as boiling or steaming – between 20 and 24%, depending on the variety. Bengtsson et al. (2008) explain that the similar retention values obtained for the three preparation methods could be due to the fact that the OFSP roots were prepared as ready-to-eat products with different preparation times. Using the same preparation time might lead to higher retention for the steamed samples compared to boiled and deep-fried samples. However, Stollman (2005) reports that frying at 150°C of Ejumula chips (no indication of frying time) greatly reduces beta-carotene content (by 72%).

Baking

Levels of beta-carotene in baked products made of Ejumula flour, such as cakes, chapattis and mandazis are very low according to Stollman (2005), both because of additional ingredients added and high temperatures the products are exposed to (mandazis were deep-fried in 180°C and chapattis were shallow fried at 150°C). An exception is bread made from fresh boiled and mashed OFSP roots; despite losses during processing, the beta-carotene

[3] Retinol Activity Equivalent (RAE)=12µg beta-carotene in mixed foods.

content of bread rolls is still important if dark orange-fleshed varieties are used (about 15µg/g product; see below) (Low et al., 2005).

The conclusion from these studies is that normal cooking procedures—especially steaming or boiling for reasonable preparation times—and solar-, shade- or sun-drying (if carefully controlled) of fresh roots to produce chips will allow significant and useful amounts of beta-carotene to remain if a variety with high beta-carotene content is used. Storage has a far more damaging effect on beta-carotene content than drying and further losses are likely to occur during re-hydration of dried chips/slices into porridge or other dishes.

Varieties differ significantly in beta-carotene content, and medium-to-dark orange fleshed varieties should be preferred for processing over lighter orange-fleshed materials (those with beta-carotene contents in fresh roots less than 50µg/g fresh root weight). The findings reported above suggest that storage of dried roots should be for less than 4 months, when dramatic carotenoid losses were shown, and that losses may be lower with fresh roots when stored for short periods. However, further work is needed to understand losses after different time periods of storage (1 month, 2 months etc.) and how to reduce degradation during storage of fresh and dried roots.

Contribution to vitamin A intakes

As shown in an efficacy study in South Africa with primary school children, OFSP with high beta-carotene content (approximately 830µg Retinol Activity Equivalent (RAE)/100g or 100µg beta-carotene/g cooked root) can improve vitamin A status and has the potential to control vitamin A deficiency in developing countries (van Jaarsveld et al., 2006). An estimated fifty million children stand to benefit from improved vitamin A intake if widespread adoption of OFSP can be achieved (Low et al., 2001). Carey et al. (1999) also report that small amounts of OFSP can supply the recommended daily allowance (RDA) of Vitamin A.

Despite the loss of beta-carotene during processing, substituting OFSP (Zapallo variety with moderate beta-carotene content) flour for some of the flour in buns (for example: 120g OFSP flour mixed with 400g wheat flour), chapattis and mandazis increased the vitamin A value calculated in RAE of these products from 8 to 152-167µg RAE[4]/100g product[5]. Hence, 100g of a bun could cover about 50% of the daily recommended vitamin A intake of 300µg RAE for young children (1-3 years old) (Hagenimana et al., 1999b; IOM, 2004). Hagenimana et al. (1999b) reported that these processed products were well accepted locally and sold well in Western Kenya.

[4] Assuming 87% of total carotenoids in the OFSP variety Zapallo is in form of beta-carotene and RAE is based on a 12:1 conversion rate of beta-carotene to retinol.
[5] This corresponds to 18-20µg beta-carotene/g of product.

In the TSNI project in Mozambique, Low et al. (2005) found that OFSP was a relatively inexpensive source of calories and a very cheap source of vitamin A in the Zambezian food system. On average, OFSP was the second cheapest source of vitamin A in local markets in 2003 (60 MT (0.25 cents) per 100 RAE units), and the cheapest in 2004 (34 MT (0.14 cents) per 100 RAE units). In 2004, meeting the RDA for a child less than 6 years old with OFSP cost less than 1 cent per day.

Four recipes for OFSP-based processed products developed by TSNI partner SARRNET/INIA were adapted for the Zambezian market. The most popular and profitable product proved to be golden bread, in which 38% of wheat flour is substituted with boiled and mashed OFSP. Bread is one of the first processed products produced in rural markets when wheat flour is available and is widely consumed by the rural poor in small amounts when available for purchase. Golden bread increased profit margins of bakers in the three pilot test sites from 50% to 92%. Profits rose by 92% for one baker primarily due to the lower cost of OFSP in relation to imported wheat flour and extending by one day the baker's use of a bag of purchased wheat flour.

The majority of consumers preferred golden bread to white bread because of its heavier texture and golden color. Golden bread made from fresh boiled and mashed roots was preferred in terms of taste and appearance to golden bread made from re-hydrated dried OFSP chips. However, the use of dried OFSP chips may extend the period over which golden bread can be baked if the chips could be economically ground into flour prior to use, as bakers disliked the laborious process required to mash the re-hydrated chips.

Laboratory analysis conducted by Paul Jaarsveld of the Medical Research Council in South Africa (reported in Low et al., 2005) on bread samples from five OFSP varieties showed that dark orange-flesh varieties like Resisto produced buns with sufficient all-*trans*-beta-carotene content to be considered excellent sources of vitamin A for young children and good sources for adults. For a child 1-3 years old, a small bun of 60 gm made with Resisto would contribute 25% of the daily recommended vitamin A intake level, whereas a medium-sized bun of 110 gm provides 45%. Results indicate that three-quarters of the beta-carotene found in the bread samples is in the bio-available all-*trans*-beta-carotene form. ***As a rule of thumb, processed products with at least 15 µg/g product of all-trans-beta-carotene can be considered good sources of vitamin A.*** Bread made from the fresh, boiled and mashed dark orange-fleshed sweetpotato varieties MGCL01 (Persistente), 440215 (Gabagaba) and Resisto meet these criteria as does bread made from dried chips of Resisto.

Bechoff et al. (2008a) found that the flours studied (hot air dried, solar dried and sun dried) had estimated vitamin A activities between 1,596 and 2,012µg RAE/100g flour and therefore provide substantial amounts of vitamin. For 1-3 year old children, these vitamin A activities represent 532-671% of their daily vitamin A requirements and for 4-8 year old children, about 400-500% of their daily vitamin A requirements (IOM 2004). These estimations do not consider losses, which can be significant, during further processing (Bechoff et al., 2008a). Looking at dried chips of six Ugandan OFSP varieties shows that most varieties have high vitamin A activity after drying (>400µg RAE/100g product with an average of about 843µg RAE/100g) (Bechoff et al., 2008b). But after four months of storage at ambient temperature the average vitamin A activity drops to 228µg RAE/100g. If further processing losses, estimated at about 50% during preparation of dried OFSP into the finished product (*mandazi*, bread etc.), are also considered then only chips used for processing immediately after drying could provide a major part of the daily recommended intake of vitamin A for young children provided 100g of the finished product are consumed (Bechoff et al., 2008b).

Based on the presented results, it can be concluded that processed products such as bread, buns and mandazis can contribute significantly to meeting daily vitamin A requirements in young children if high beta-carotene content OFSP varieties are used. But, beta-carotene losses during the storage period for the chips seem critical and have not been considered in most of the above cited studies and calculations. As Bechoff et al. (2008) point out, the contribution to the daily vitamin A requirements reduces greatly if dried chips are stored for 4 months before further processing.

OFSP pilot projects at community level

OFSPs need to be accompanied by nutrition education and utilization information in order to obtain nutritional benefits (Carey et al., 1999). An intervention group exposed to such information in Western Kenya (Hagenimana et al., 1999b) increased consumption of Vitamin A foods, while the control group actually decreased consumption. Promotional and educational activities were critical to this result.

Low et al. (2005) report combined results of pilot activities and research from Central Mozambique that indicate that OFSP can significantly improve intake of vitamin A among rural populations, and represents an attractive and sustainable complement to vitamin A capsule distribution. Results indicate that the intervention succeeded in improving diet diversity, energy and vitamin A intake at the household level and among reference children during the main sweetpotato harvest period (August-October). Median intake of vitamin A was 8.3 times higher among intervention than among control children. 100 grams of medium or darker intensity OFSP could easily provide the RDA (300 µg RAEs for children 1-3 years old and 400 µg RAEs for children 4-8 years old) (IOM, 2004). Three-quarters of the consumers said they preferred OFSP to white-fleshed sweetpotato after a promotional campaign.

Kapinga and Ndunguru (2006) report that in the VITAA project in Eastern Uganda, CIP-VITAA in liaison with the National Agricultural Organization (NARO) and district farmer-oriented organizations (NAADS and SOCADIDO) have facilitated the availability of OFSP planting material and two chipper machines for pilot processing by the farmer groups (FFS). Out of 87 acres of sweetpotato planted in 2003 in the Soroti district alone, 57 belong to graduated and on-going FFS groups, 20 acres to individuals and 20 acres to SOCADIDO groups. An estimated 15 tones of roots were harvested and delivered for chipping. The acreage has grown to be about nine times that planted during the initial promotional season of the previous year. To date, more than ten tones of OFSP chips have been processed. The challenge is still the limited market for chips and the intending processors are cautiously adjusting to use of sweetpotato chips in their mixtures. Meanwhile more food processors are being sensitized on the viability of incorporating sweetpotato chips into their products.

A focus on the enterprise aspects of SP product would appear to be needed to provide the demand-pull that can complement the production-push the project has already achieved. Limited work has been done in this area, especially in analysis of the financial viability of the processing enterprise. A pilot study was initiated in 2003 in Eastern Uganda, conducted by NARO scientists in collaboration with CIP-VITAA. The major objective was to assess the efficiency of new processing technology and the profitability of processing and marketing dried OFSP. Two FFS groups were identified for processing in the villages of Gweri and Kyere in the Soroti district. These were provided with the motorized chippers. The groups were trained in improved processing and drying techniques. Fresh roots were bought from farmers who committed themselves to feed the processing units with fresh roots. Varieties processed include SPK 004 and Ejumula. Results showed that it is more efficient to process dried sweetpotato chips using a motorized chipper.

However, the VITAA report states that "*based on the current data, it is not profitable to process and market the dried sweetpotato chips with the current production trends*" implying that even with the nutritional advantages offered by OFSP, the high cost of the SP flour is a major drawback for commercial and consumer acceptance, at least in this region of Uganda. It is unfortunate that more economic data were not collected to guide future actions in this area.

The overall conclusions from the OFSP projects to date are that:

- OFSP varieties have beta-carotene contents high enough to contribute significantly (after cooking/processing) to daily recommended vitamin A intake of young children in Africa.
- Some food products containing OFSP such as golden bread are of good quality and acceptable to consumers, including children.
- Nutritional education and OFSP promotional campaigns form an integral part of the strategy for the adoption of these varieties.
- Bakers/processors can reap some advantages from the use of OFSP raw materials, but cost disadvantages—in some regions at least—may hinder their commercial uptake as a raw material for food product manufacture, despite successful promotion of the varieties at farm level.
- Collection of relevant data on profitability and beta-carotene content of products varies among products and needs to be standardized.

Sweetpotato starch and derived products

There has been no reported research on sweetpotato starch by CIP in SSA. This is understandable, since the:

- Starch content of sweetpotato roots is lower than that of cassava, giving a poor, uncompetitive conversion rate from fresh roots to starch for general food industry uses.
- Sweetpotato starch extraction process, especially at small-medium scale, is complicated by the binding of colored pigments to the starch, resulting in an off-colored product unless additional purification steps are added to the extraction process.
- The starch industry in East Africa is relatively undeveloped (low cost cassava starch imported from Thailand constrains development even of a cassava-based starch industry).
- Sweetpotato starch is produced in Asia—essentially China—for use in a specific type of noodle (glass noodle). The properties of sweetpotato starch are especially suited to this product. Substitution with cheaper cassava or maize starch is not an option, since product quality would suffer—thus sweetpotato starch is produced despite having a higher price than cassava and maize starch in China. This would not the case in SSA, where these noodles are not produced or consumed.

It would only be justified to give attention to sweetpotato starch in East Africa if:

- The local starch producing industry becomes more dynamic.
- High yielding, high dry matter sweetpotato varieties allow the crop to compete with cassava and maize on a production cost basis (per kilogram of dry starch).

While there are some high dry matter content/low sugar content varieties of sweetpotatoes that could conceivably be evaluated for starch processing (were domestic demand for starch to expand in East Africa), there are also a number of very high yielding cassava varieties that could also be tested, and would provide difficult competition. This must remain a long shot for sweetpotatoes, and research funds would be best invested elsewhere.

Sweetpotato for animal feed (roots and vines)

Sweetpotato vines are used as one component of cattle feed in intensive dairy production systems in East Africa (Kenya) and there may be potential to expand this, on a limited scale, within these specific production areas. Other fodder crops provide stiff competition, however.

As far as roots for animal feed are concerned, Tewe (1994) reports some very high dry matter varieties from an IITA field trial that produced up to a very high 220t/ha DM yield, but under field station conditions in small experimental plots. Although these figures are unrealistically high for commercial or on-farm conditions, they do indicate the potential of the crop to be a high yielding option for dry matter production, and also to fit into short-cropping systems unlike some other feed alternatives (e.g. cassava).

While pigs are common livestock in many African villages, they are not usually raised for the market. Unusually, Low (1995) reports that SP roots and vines are fed to pigs in Ndhiwa district (Southwest Kenya) and that a market for SP roots developed in the locality for this purpose. In this area, the production of pigs appears to be intensifying as it takes on a more commercial aspect.

Peters (1998) reports a short field survey in Soroti District, Uganda, where 39 out of the 57 homesteads interviewed raised pigs. The head of the Farmers' Association of each village estimated that 40% of homesteads in Dokolo, 70% in Aukot, and 80% in Awoja raise pigs. Pigs and sweetpotato were perceived as ways to gain quick turnaround of cash while cattle and cassava were for the long haul. The average number of pigs per homestead in the three villages was 1.69, 2.13, and 1.67. 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.

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. Pig growth was poor, with an average monthly growth rate of 3.45 kg in Dokolo, 2.11 kg in Aukot, and 2.7 kg in Awoja In general, after seven to eight months of rearing, the pigs reach only 20-30kg, a weight range commonly associated with piglets elsewhere in the world. The pigs were mainly fed on sweetpotato roots and vines, along with other locally available feeds—brew residues, fish bones, grass, mango, and papaya—which had little cash value. At this rate of growth, the average value of sweetpotato was as low as 24.4 ush/kg^{-} in Aukot, up to 32.7 in Dokolo (due to the low prices of the piglets), and as high as 38.7 in Awoja. These values were lower than the fresh market prices, which made pig rearing not particularly profitable at these growth rates.

The slow growth rate is surprising, indicating considerable potential for improvement. The following factors contributed to slow growth rate:

- Pigs rooted around the trees on which they were tethered and often were infested with worms. Most homesteads in Awoja treated their pigs for worms while few did so in Aukot; consequently, despite feeding the lowest amount of sweetpotato, Awoja achieved the highest growth rate.
- Pigs were often tethered next to open latrines and exposure to human faeces put pigs at risk for infection.
- The local breed may not be a fast growing race of pigs.
- 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.
- The pigs lacked any protein supplement, especially in light of the fact that sweetpotato vines, the main source of protein, were fed only during the harvest season. The vines were not chopped or cooked and whole vines were given to pigs, which ate only the leaves and left the vines untouched.

The fact that SP roots are fed raw or briefly cooked indicates that the anti-nutritional factor (trypsin inhibitor) has not been deactivated, and that the starch remains relatively indigestible, contributing to the slow growth rate.

None of the respondents cited “lack of market” as a constraint to pig rearing. Pigs in this area were marketed in three ways.

- Farmer slaughtered the pig himself and took the meat to the village market to sell it by weight. Pork sold by the kilogram earned a higher unit price than a live pig, but there was more work involved.
- Farmer sold the live pig to a butcher who would offer a set price for the pig. The value was lower, but it relieved the farmer from the butchering and selling task.

- Livestock was sold in a district market which rotates around various districts in this area each day, and one such market is available daily.

In addition to the local and district markets, Soroti used to have access to the Kampala market. Before the 1995 insurgency, Kampala trucks used to come to the Otuboi market each Saturday to collect pigs. The local middlemen would collect the pigs prior to the arrival of the city collectors with the trucks. Live pigs collected for the Kampala market commanded twice the price of the local market. The pig production in this area was much higher in the past when the Kampala market was available. The local district office in 1997 was encouraging farmers to raise the pig stock again so that they could regain a share of the Kampala market. The problem in the pig industry is not demand but rather supply. Until the Kampala market revives, pigs are sold in these district markets in relatively small quantities. For example, the Otuboi marketers slaughtered 15 pigs and sold 10 pigs and 15 piglets each Saturday, a total quantity of 450 kg per week. Assuming similar quantities were sold in other markets each day of the week, there is a local demand of 225 pigs a week in the Soroti district.

SWEETPOTATO MARKET CHAIN DEVELOPMENT

Proposed models

The bulk of the literature on sweetpotato post-harvest deals with technical aspects of processing, or with the economics of processing from the perspective of individual enterprises. There has been very little consideration of the whole supply chain from farmer through trader, processors (if any), wholesaler, retailer to consumer, apart from studies of existing fresh root supply chains mentioned earlier (e.g. GTZ, 1998). These mainly focus on identifying technical constraints in the chains.

Commercial development of food products such as breads, chapatti and mandazi containing sweetpotatoes entails a novel linkage between existing sweetpotato producers and existing bakers, processors, and other players. This linkage may require new economic entities (e.g. enterprises to produce SP flour) that can link producers to bakers (for example) or it could simply require new links between existing entities (e.g. a SP fresh root trader selling roots to a small enterprise making mandazis, or to a larger food industry business using SP as a raw material).

Perhaps the most advanced project in this area for which reports are available is the Project on 'Commercialization and Marketing of OFSP in Kenya" implemented by Family Concern (Anon, 2006). This project is being implemented with 3,435 smallholder farmers in three provinces and with over 15 public and private sector partners. The report states that the programme has successfully established partnerships between smallholder farmers and private sector players in commercialization, product development and market linkages for OFSP. Achievements to date are:

- Partnership with market intermediaries established and sales of fresh roots commenced.
- Sales to two major supermarket chains in Nairobi (Uchumi and Nakumatt) commenced.
- Flour launched, 2 tones in the process of sale worth Kshs.80,7225.
- Two groups in the Central Province made sales of Kshs. 120,000 in one season
- Annual sales for fresh roots in Western Kenya estimated at Kshs. 200,000.
- Sales of vines (planting material) provided good income for farmers, and demonstrate popularity of the OFSP varieties with farmers.

At the time of writing, sales to Uchumi and Nakumatt supermarkets in Nairobi were continuing (Mumbi, personal communication). Achieving a sustainable market chain based on repeat sales implies successful management of quality criteria important to supermarket chains, and the ability to organise a continuous supply of sweetpotatoes, overcoming seasonal limitations of individual production areas. The project has been improving the organization skills of wholesale traders to improve the delivery of fresh roots to the Nairobi market with the aim of ensuring that traders will continue to deliver to existing markets and be capable of developing new urban buyers by the time the project is completed.

Another report from the same project (Anon, 2005) mentions a number of problems including a lack of reliable, ready and sustainable markets coupled with poor or weak marketing structures for OFSP and a lack of awareness of traders and consumers of OFSP.

The project countered these problems by building partnerships with those farmers who already market (non-OFSP) sweetpotatoes to Nairobi. They were trained and supplied with OFSP vines for planting, in close collaboration with traders. However, the implications of this shift in strategy are not clear—did this mean abandoning the farmers who were initially targeted with OFSP? Were the new, more market-oriented farmers less poor than those originally targeted?

The OFSP flour supply chain is also developing—Family Concern is collaborating with four private sector companies marketing various flours targeting different market segments (Table 3).

Table 3. Details of companies collaborating with Family Concern.

Company	Details
Proctor and Allan	A leading Eastern and Central Africa manufacturer in cornflakes and baby porridge from different flour mixtures
Touchstone	Distributes and sells nutritious porridge flour packaged by women group in Muranga
Healthy Living	Manufactures and sells nutritious flour
Joy Foods	Deals with nutritious flours and sells in Nairobi and Naivasha

In addition, another firm (in Busia) is targeted to be linked to a flour processor who will involve the producer groups in value-adding activities through the provision of marketing services like branding, packing, transportation and sales. Family Concern aims to work closely with the processor to offer promotional support and community mobilization services as well as marketing support services.

This report generates further questions—exactly who will be producing the OFSP flour—a farmer group enterprise perhaps. What are the costs and expected benefits of this enterprise? Will the sales price negotiated with the four industrial clients provide sufficient return on investment?

It would also be useful to have an indication of the food industry perspective on the nutritional and economic value of OFSP. Does the nutritional advantage represent a meaningful selling point that can be marketed to consumers? and, if so, does this give the flour a price premium over non-OFSP flour, or other competing flours (e.g. wheat)?

The Family Concern project thus represents a valid attempt to overcome the market limitations of a new raw material/product like OFSP. A more developed strategy would imply presenting a model of the supply chain from farm to consumer, with indications of the different actors present at each stage and the relationships between them.

In Mozambique, the TSNI project (Low et al., 2005) used a pro-active market creation model to introduce OFSP products to the market: A key challenge was to devise a system that encouraged households to produce surplus OFSP production for the market, but at the same time assured that home consumption remained adequate to obtain the nutritional benefits for the farming household as well. This was a particular challenge in those localities where men, rather than women, had more decision-making power concerning sales of OFSP.

The pilot concept consisted of enhancing the trading skills of a local small-scale trader. A market booth decorated with promotional messages in a highly accessible location for both producers and purchasers of OFSP was used, and the trader agreed to follow purchasing rules established by the project, in exchange for exclusive use of the decorated booth and assistance by extension staff in establishing links with farmer groups producing OFSP.

The guiding principle underlying the strategy was to introduce the concept of quality grades, whereby first quality OFSP is purchased for a higher unit price than second quality OFSP, and OFSP not achieving second quality status is never purchased, nor is white -fleshed local sweetpotato. At his stall, the trader purchased first quality roots at 1500 meticais (MT)/kg, and resold them at 3000 MT/kg. He purchased second quality roots at 1000 MT/kg and re-sold them for 1500 MT/kg[6]. This strategy sought to create a new and exclusive market for OFSP based on its visible trait, while at the same time guaranteeing that a significant quantity of OFSP remained for home consumption.

The trained trader successfully implemented the grading scheme to financially reward farmers for higher quality OFSP. Farmers responded to the presence of a buyer and other project promotional activities by significantly expanding area under production. Whereas no intervention households had OFSP plots over 500 square meters in size in 2003, 35% did in 2004. The trader purchased over 3.3 tones of OFSP and had a gross margin of US$188 for the 6-month season.

[6] In 2004, there were approximately 24,000 meticais (MT) to $1 USD.

In this way, the project actively stimulated a trader to start marketing OFSP, and a supply chain was established as a result. It would be useful to know whether the supply chain has continued to be operational after the end of the TSNI project—i.e. was it sustainable, or were the services of extension staff in making the links with farmers essential for its continuation. Presumably, if the market were attractive enough, the trader would invest in this himself in due course.

A third example of supply chain development is reported by Lemaga (2005) in the Sweetpotato Coalition project "Improving the livelihoods of small-scale sweetpotato farmers in Central Uganda through a crop post-harvest-based innovation system".

A multidisciplinary team of 12 partners from different organizations implemented the project with 37 farmer groups and 17 schools. Over 20 local market outlets including schools, tertiary institutions, hospitals and NGOs were identified and linked to farmer groups. Farmers responded positively and sold sweetpotatoes, but some were disappointed by the lack of timely payments.

Five rural-based pilot processing centers were established and used as focal points for assessing and demonstrating technologies for processing sweetpotato value–added products. Farmer groups used the pilot centers to produce and market sweetpotato dried chips to urban millers, who utilized it to process sweetpotato composite flour. Sweetpotato snack products and juices were also processed and sold to local markets in the rural communities. Cost-benefit analyses of processing technologies and other sweetpotato enterprises generally indicated that they were economically viable (see details in section 2.5). Although many of these processing activities had positive cost-benefit evaluations, it is not clear how many of them went on to become sustainable business activities, with lasting supply chain linkages with the producer groups involved in the project. Did the pilot activities on which the cost benefit analyses were based take off? Did the market for SP flour and products based on this ingredient materialize as expected? The report states that the Sweetpotato Coalition is being transformed into an Association to ensure sustainability after the project termination, so hopefully these issues are being addressed.

Possible models for organizing sweetpotato market chains

The models considered above are basically the following:

- TSNI project - OFSP farmers sell to a local trader, who sells to other rural consumers or local small businesses using OFSP as a raw material (bakers, etc.).
- Family Concern – organized OFSP producer groups sell to wholesale traders with truckers who in turn carry the raw material for sale at wholesale markets in Nairobi (main fresh produce market).

- Family Concern - OFSP farmers sell to small enterprise making SP dried chips, the miller produces flour as a service provider the enterprise (fee per kilogram), the enterprise packages the flour, and then they sell to a registered market development firm that identifies outlets (Touchstone), who sub-contracts a distributor to deliver the product to large-scale supermarkets and other outlets.
- SP Coalition project - SP farmers sell to SP chip/flour processors (also farm level enterprises) who sell to local food processors/bakers, etc.

The key stage in the value-adding process is the production of the intermediate raw material that food processors, bakers, small food sellers, and other players will use. They are unlikely to want to purchase and process SP roots themselves (except for some micro-scale rural sellers), so there is scope for a distinct business entity that can manufacture SP chips, flour and/or boiled/mashed SP roots.

This latter option is interesting, since:

- Technical reports suggest that it produces the best quality products (mandazi, bread etc.).
- Laboratory studies suggest that boiling—and especially steaming—results in less loss of beta-carotene than drying to produce flour.
- Bakers and others are reluctant to boil and mash SP roots themselves, seeing it as an additional labor-intensive step outside the core business.

Cost-benefit analyses have determined that, in some situations, production of flour (but not chips) is a viable business activity. No one has looked at production of boiled, mashed SP as a stand-alone business enterprise option. If viable, this could be a useful link in the supply chain from farm to consumer.

More attention to the business aspects of flour production could also be worthwhile. Presumably, flour production close to the SP production region is indicated, to minimise the cost of transporting SP roots that are mostly unwanted water. Does this imply farmer operated processing units at small-medium scale? What drying technology is indicated to provide the best combination of quality (microbial load, beta-carotene content, color, etc.) and cost? What scale of operation? When these are clear, the valued added SP supply chain from farm to consumer will be clearer. This will be taken up again in the conclusions section.

DEMAND SIDE CONSTRAINTS TO SWEETPOTATO UTILIZATION

Current utilization patterns

As stated previously, current utilization patterns are essentially limited to fresh root consumption, both on farm and marketed to major urban centres. The relatively minor role of SP in the East African diet—except for some significant production regions—especially in urban populations, effectively limits the potential for expanding the role of fresh root of traditional SP varieties. This fits with the observation of Low (1995) that market constraints are the most limiting factor for SP development in Southwest Kenya (Low, 1995). Further more, the perception of the fresh root as an inferior good (GTZ, 1998) limits the potential to expand fresh root markets. In Nairobi, for example, SP roots have only been marketed commercially since 1989, and volumes are small (20t/day, Omosa 1997).

A consumer acceptance study was carried out in Nairobi and Kisumu, Kenya (Omosa, 1997). This survey of 60 households in Nairobi and 30 in Kisumu (both stratified by income) investigated existing sweetpotato consumption patterns. Omosa reports that in Kenya, fresh sweetpotato is virtually never a major food source, but has a supplementary role in the diet. The major staple in both Nairobi and Kisumu is *ugali* (stiff porridge made from maize and other meals) and—to a lesser extent in Nairobi only—rice. The study concluded:

- Fresh sweetpotato consumption in Nairobi and Kisumu is associated with the lower income groups, and with consumption of porridge, mandazi and rice (and not with consumption of bread, chapatti and other higher-income foods).
- Over 90% of households in Nairobi and Kisumu eat sweetpotatoes at least once a week, mainly at breakfast. Of these, 80-90% are purchased from the market (Nairobi) or roadside sellers (Kisumu). All ethnic groups except Luo and European see sweetpotatoes as an acceptable breakfast food in Nairobi, while in Kisumu the Luo have a more favourable opinion of sweetpotatoes.
- Sweetpotato consumption declines with education level, but higher education level correlates with more flexible food habits, open to change. Consumption also declines slightly by income level—sweetpotatoes are eaten by all lower income households, by 94% of middle-income households and by 84% of upper-income respondents.
- At both locations and all income levels and in all ethnic groups, fresh sweetpotato is usually prepared by washing or peeling and boiling/steaming. Occasionally it is fried.
- Fresh sweetpotato is viewed positively by surveyed households, and is associated with attributes such as satisfying, energy food, available, cheap and a substitute for bread.

Processed SP products do exist, and are consumed on-farm in some areas. There is some traditional small-scale marketing of these products, especially in the major production regions. But these are minor forms of utilization and do not account for significant volumes of production (GTZ, 1998). Section 2.4 provides additional information on fresh root marketing and storage.

Demand sensitivity to price and quality

No studies have been located that directly estimate price elasticies for fresh sweetpotato perhaps because currently it is less important as an urban foodstuff than maize, cassava and rice. Recent price rises for the latter crops may favor sweetpotatoes which because it is not traded internationally is not subject to these price changes in international markets.

Regarding the potential for sweetpotato to be used as an ingredient in value-added food products, through intermediate products such as flour, some studies have been carried out. Lemaga (2005), reports on the Uganda Sweetpotato Coalition project, where 20 urban flour millers were identified. Of these, nine were willing to discuss sweetpotato product development. Survey results showed that no respondents were aware of, or had knowledge about, the utilization of sweetpotato flour in food products. The main flour products processed by respondents were maize flour (88.9%), millet flour (55.6%) and cassava-millet composite flour (11%). The major end-use of the flours reported was for preparation of thick and thin porridge.

Respondents reported that the price millers paid for raw materials ranged between US$1.23–0.21 (Ug Shs 220-360)/kg for maize, US$ 0.07-0.26 (Ug Shs125-450)/kg for millet and US$ 0.07-0.2 (Ug Shs125-350) for cassava. End product prices ranged between US$0.23-0.34 (Ug Shs 400-600)/kg for maize flour US$0.24-0.35 (Ug Shs 420-620)/kg for millet flour and US$0.45 (Ug Shs 800)/kg for the composite flour.

Four out of the nine milling enterprises interviewed were willing to try incorporating sweetpotato flour into their flour products. Only one milling enterprise (Kasawo Grain Millers) promised to pay the suggested price of US$0.29 (Ug Shs 500)/kg for dried chips. This is understandable, since it is double the average price of cassava chips, for example. The poor image and low status of sweetpotato compounds this price problem.

Based on the results of the study, it was concluded that although these industrial markets are potential markets for sweetpotato dried chips, it is very difficult in the initial stages to penetrate these markets with new products.

Equally, it is not attractive for many farmers to produce sweetpotatoes for sale at prices that would make the flour competitive in price for the millers. Farmer groups in the Mpigi district and areas in Luweero located near the city were unwilling to engage in processing activities as they indicated that they had good local and export markets and got good prices of US$0.20-0.22 (Ug shs 350-400) per kilogram of fresh roots. Only the farmer groups in Kiboga and parts of the Luweero district located far from the city were interested in processing activities, because they did not have access to these markets for their fresh roots. Prices of fresh roots in these areas were 75%-88% lower than those obtained by farmers in the Mpigi district.

Experience with cassava flour production (see case study in Wheatley et al., 1995) suggests that there is a trade-off between price and quality. Faster, high-temperature artificial drying produces a more hygienic product that meets national flour standards for microbial load, but at a higher cost than sun/shade drying. For OFSP there is the added consideration of beta-carotene loss during processing. Finding the right technology and operating parameters to optimize product quality while minimizing cost can be a difficult task.

The Family Concern project in Kenya is currently involved in OFSP flour marketing with food industry clients in Kenya. Prices of OFSP flour (or processing technologies), compared to other flours, are required to evaluate whether OFSP flour can avoid a straight price-based competition with wheat, maize and/or cassava flours, based on its quality—i.e. nutritional value.

Consumer acceptance

The consumer acceptance study carried out in Nairobi and Kisumu, Kenya (Omosa, 1997) also investigated both existing sweetpotato consumption patterns and attitudes towards the potential incorporation of the crop in a range of processed food products such as chapatti, mandazi, bread, etc. In addition, market sellers of sweetpotatoes and potential industrial users of the crop were surveyed. The results of the SP consumption survey are reported in section 4.1.

For snack and other processed foods, the study looked at how these were currently used, and attempted to assess the prospects for consumer acceptance of the same products if sweetpotato was used to replace wheat or other flour ingredients.

Snack foods such as cakes and biscuits are seen by consumers in Nairobi and Kisumu as luxury items, eaten occasionally by higher income households, or only in celebrations by lower income groups. Porridge, mandazi, chapattis are consumed as breakfast foods on a small scale. Over 50% of households in both Nairobi and Kisumu consume bread for breakfast. Maize porridge is the most common baby food at breakfast time, with potatoes commonly given at lunch and supper.

The survey then assessed the potential of sweetpotatoes to be incorporated into these processed food products. These included *ugali*, porridge, biscuits, bread, cakes, mandazis, chapattis, crisps and chips. Consumers were presented with samples of these food products made with sweetpotato at some level of substitution[7]. Also, the author reports that it was not possible to obtain useful data on potential prices ("willingness to pay") for these products—rather; an assessment of "willingness to try" was obtained (Table 4).

Table 4. Consumer willingness to try a range of processed food products using sweetpotato as an ingredient (from Omosa 1997).

Product	Consumer willingness to try (%)	
	Nairobi	Kisumu
Biscuits	67	50
Chapatti	78	58
Chips	68	50
Crisps	74	68
Ugali	54	33
Bread	89	75
Cakes	84	75
Mandazi	83	69
Porridge	66	55

The main staple food *ugali* had the lowest level of acceptability once sweetpotato is incorporated into the ingredients, followed by porridge. Both of these are non-sweet foods, and the perception is apparently that use of sweetpotato would result in a marked change in taste. The sweet taste of the raw material is not an issue for some of the other products such as cakes and biscuits—and could even be an advantage to bakers as regards cost reduction—thus their higher "willingness to try" scores.

The implication is therefore that sweetpotato will be most easily accepted as an ingredient in those food products where consumption is fairly modest (i.e. snacks) and is higher among upper income consumers. The exception to this is perhaps bread, which features as a regular item for breakfast meals.

Consumers were in general very positive, however, about the concept of using sweetpotato in processed foods, with 95% of consumers in favor—as were 90% of traders. Consumers of snack foods are the most positive of all. Lower income groups have been most exposed to processed sweetpotato products to date, with women knowing most about preparation methods.

Section 2.5 contains further examples of consumer acceptability of sweetpotato use in a range of processed products/snack foods in both Uganda and Kenya. One potential issue

[7] The levels of inclusion of sweetpotato, and the form—flour, fresh mashed etc—are not stated in the study, however.

identified in these studies is that while flour is the easiest form of sweetpotato for bakers/processors to use, it may not be economic to produce at prices that compete with wheat or cassava flours, and tends to result in lower quality products—and consumer acceptability—than using fresh grated or mashed and boiled SP roots.

The OFSP project reports (section 2.6) demonstrate that golden bread containing OFSP has high consumer acceptability.

Market size and demand growth

Omosa (1997) states that the market for fresh sweetpotatoes in Nairobi is recent, small (20 ton/day) and very supply-dependent—i.e. when harvests are good and the availability of sweetpotatoes in urban centers is high, demand is also high. This could be a function of price, which would tend to fall at times of relative glut. Similarly, out of season, demand is lower (presumably other food stuffs fill the gap) and volumes traded are reduced accordingly. This implies that action to improve regularity and consistency of supply—i.e. make the crop more commercial, rather than relying on sales of eventual surpluses, could by itself increase demand. The actions of Family Concern in facilitating the development of supply chains with Uchumi supermarkets and other outlets in the capital city may well help in this respect.

The current market for processed SP products, or intermediates such as flour, is very small, and perhaps limited to a few local, traditional products in some areas plus recent market development efforts of specific projects (Family Concern, etc.). The potential for demand growth probably lies in this sector if economics are favorable and supply chains can be sustainably organized. Reliability of supply is a major issue for (potential) industrial consumers of sweetpotatoes—they are unlikely to invest in new capital equipment or reformulate products in include sweetpotatoes unless a reliable supply is present.

As stated previously, the potential for OFSP to stimulate demand for sweetpotatoes, based on nutritional attributes overriding purely economic considerations, remains to be seen.

Low (1995) states that men are largely responsible for producing commercial plots of SP in South Kenya. Their involvement in producing SP roots for the market depends on having access to roads and transport, and the availability of labor—having more than one adult woman in the house. The capacity of smallholder farming households to meet an expansion of demand is constrained by household labor availability, and by competing demands for this labor. This could limit the growth of supply in the future.

Substitution - sweetpotato vs. cassava, maize, potato, wheat

Technical and economic aspects of substitution of SP flour for wheat and other flours have been covered in previous sections (4.2 and 2.5). In summary, sweetpotato can substitute in varying percentages for other flours in a range of traditional and 'western" food products. Generally, levels of substitution are higher for non-sweet products, and lowest for bread, where texture is particularly sensitive to reductions in wheat flour levels. Where bread is eaten as a semi-sweet snack item, this may not be the case, however.

Omosa (1997) produced price series for the years 1989-92 for sweetpotatoes (fresh roots) and wheat flour in Nairobi and Kisumu. A price series for sweetpotato flour also is extrapolated based on expected conversion rates (not given). Under this scenario, sweetpotato flour would have been at a roughly similar price, or more expensive, than wheat flour in Nairobi, but would have been cheaper than wheat flour, on average, during 1991-2 (but not 1989-90) in Kisumu. This demonstrates that sweetpotato is most competitive with other flours closer to the sites of crop production, where fresh roots costs are lower. A similar situation was found in Indonesia with sweetpotato vs. wheat flour in Kenonggo, East Java (Peters and Wheatley 1998).

Omosa (1997) provides no comparisons with cassava flour, however. Cassava is a more common staple food in many of the regions where sweetpotatoes are grown, and produces roots with a higher dry matter (and lower sugar) content. Cassava roots are generally cheaper than those of sweetpotatoes, even in rural areas. Although they do contain cyanide, this is usually reduced to innocuous levels through the drying/milling process itself. Thus, sweetpotato is most likely to be the preferred wheat flour substitute for products where the sweet taste characteristic is an advantage, with cassava flour having the advantage for other products where a more neutral flour is sought.

Potato dry matter contents are generally lower than those of sweetpotato and other root crops, and thus will not compete as a source of flour other than for specific food industry applications where the specific functional qualities of potato starch are needed. Omosa (1997) found that there was no competition between fresh potato and sweetpotato roots at the level of urban household consumption.

RECOMMENDATIONS FOR FUTURE DIRECTIONS FOR SWEETPOTATO PROCESSING/POST-HARVEST RESEARCH IN SUB-SAHARAN AFRICA

Information gaps

Very little demand side information exists. Omosa's 1997 study of sweetpotato consumption is nearly 10 years old, and remains the best source of information. Given the relatively minor importance of sweetpotato in the urban diet, it is probably difficult to justify further dedicated studies of this type, but it might be possible to take advantage of other, more general, food surveys to include specific questions on sweetpotatoes in the future.

Similarly, there is a dearth of macroeconomic analysis on sweetpotatoes in East Africa, again probably due to the limited role the crop plays in the diet, and the relatively small proportion of the crop that is marketed beyond the purely local production region.

Much of the literature suggests that post-harvest R&D should emphasize options for incorporating sweetpotatoes as a raw material in a range of value-added food products. In this area, there is adequate information on technical aspects of using SP in these products, and on the consumer acceptability of those products (generally good). What is missing is information on:

- Best technological options and operating conditions—at appropriate scales—for producing intermediate products (flour, boiled, mashed SP) at competitive prices and acceptable quality.
- Structuring a sustainable supply chain from farm to (urban) consumer for these food products, that includes existing food industry firms (SME and larger scales).
- Financial viability and size of such market opportunities.

OFSP represents an exciting option for differentiating sweetpotatoes from other root crops and flours, and for overcoming the 'inferior good" connotations of the crop, based on a compelling nutritional advantage (associated with an easily recognizable visible indicator—orange color). The literature documents the acceptability of the orange-fleshed varieties, and the products made from them, and confirms the nutritional benefits obtained from regular consumption of food products that incorporate flour and boiled, mashed OFSP roots. To complete the picture, more information would be welcome on:

- Food industry perceptions of OFSP, and its interest/willingness to use it as raw material. Do they see marketing advantages for products containing OFSP? Will they pay more for it than for normal SP?
- The costs of the nutritional and promotional campaign needed to introduce OFSP in an area, and how this can be sustainably continued, if necessary, after the life of a specific project or campaign.

Finally, there remains scope for more attention to animal feed uses of the crop. This could be especially important if processing involves sorting/grading SP roots, with a significant volume of rejects requiring some productive utilization. The only detailed study found for pigs, for example, was of one small area in Uganda carried out in 1997. A more general study of the potential for improving pig production efficiency is warranted.

Priorities - OFSP

The TSNI project in Mozambique and the VITAA project elsewhere across East Africa have convincingly demonstrated that OFSH can bring significant and beneficial public health improvements through increasing dietary vitamin A intake, especially in vulnerable children. Although OFSP was not traditionally consumed in the project area, it was well accepted by the local population (once introduced)—i.e. there was no acceptability barrier for these novel OFSP varieties.

In Mozambique, these very positive results were achieved through a proactive nutritional education and promotional campaign, and support to planting material multiplication and market development. For OFSP to realize the potential for a major public health impact at the level of both rural and urban populations, these associated activities will also need to be scaled up and out across the region. Research to develop and assess less intensive, lower cost methods of reaching target groups would be worthwhile.

In the medium term, it will be important for all parties to monitor and evaluate the impact of these efforts, and to put in place feedback mechanisms that will allow the methodology to be adjusted in the light of experience over time.

Further technical research to identify, evaluate and promote new OFSP varieties suited to different edaphoclimatic conditions (i.e. similar to local varieties where possible) is important. OFSP varieties with high dry matter content will assist the use of OFSP in processed products, including bakery goods. The excellent consumer acceptability of "golden bread" and other OFSP-containing foods augurs well for future bakery and even food industry use, if conversion rates can be maximized, and costs reduced. The next step is to take these experiences beyond the pilot stage to full commercial implementation, once supplies of fresh root raw materials are sufficient. The Family Concern project is attempting to make the necessary supply chain links with the private sector, and this should be carefully monitored. Other experiences elsewhere in Africa will be valuable. Case studies at this level should be well documented.

Similarly, technical research to ensure that orange color and beta-carotene content are maintained during processing (as far as is possible) is important. The use of dried sweetpotato offers prospects for incorporating very high levels of beta-carotene in food products if processing losses can be minimized. The nutritional advantages and good consumer acceptability (if promoted) could provide scope for OFSP to avoid the need to be price competitive with wheat flour or cassava, unlike white-fleshed sweetpotato.

From a market and business perspective, OFSP offers a "unique selling point" that other competing raw materials (fresh roots, flours) do not have. This does enable OFSP to compete on factors other than price (an option not really possible for non-OFSP varieties, see later). The very positive results of studies of the nutritional value of baked and other foods made with OFSP raw materials provides ammunition to approach a number of food industry sub-sectors, as the Family Concern project appears to be doing in Kenya. The experience now being gained in that project will be critical in assessing if OFSP does indeed have a role in the food industry over and above that occupied by non-OFSP. The pilot experience of the Family Concern project does seem to have identified a number of factors that will be critical in obtaining long-term interest of the food industry, e.g. continuity of supply. The reports do not, however, provide details of prices and margins through the nascent market chain, as it develops. This will be critical to establishing the potential sustainability of the chain, as well as the share of value added which is captured in rural areas. It will also be interesting to see how much industry is prepared to invest in promoting the nutritional advantages of their new raw material—they should have an incentive to do this.

Attention should also be paid to use of OFSP by small food businesses (bakeries, street sellers, market stall holders and other players) in villages or small towns, based on the positive experiences from Mozambique and elsewhere. An efficient and effective combination of nutritional education/promotion, and small business development around OFSP could be possible with a relatively small investment of resources—perhaps a model could be developed based on a number of pilot experiences. The education/promotion component would also, of course, benefit on-farm consumption of OFSP among the rural community at large.

Priorities for non-OFSP

Currently, sweetpotatoes continue to be consumed in their fresh state across rural and urban Africa. Use in processed products may occur at farm/household level, but in the market is limited to a few isolated examples, usually associated with support from research and development projects (as reviewed here). Animal feed use of the roots is also limited to subsistence farm-level situations.

The key question is, is it worthwhile to continue to expend R&D effort and resources on expanding the utilization of sweetpotatoes, especially processed products derived from the roots, for those varieties that are not orange-fleshed—i.e. where no nutritional advantage exists? In these situations, sweetpotato largely stands or falls on the basis of costs, compared to competing sources of flour and starch such as wheat, cassava and maize. The literature suggests that non-OFSP will find it difficult to compete with other sources of starch and flour on a purely cost basis, since the fresh roots are more expensive per kilogram than cassava, and have a lower conversion rate. Nevertheless some potential advantages of non-OFSP exist:

- Short crop production cycles allowing more than one harvest/year, resulting in higher biomass and root yield/ha/yr compared to other root crops that may have higher fresh root yields per harvest, but only one harvest per year. This advantage would need to be expressed in terms of price for it to be apparent to potential users/processors.
- A higher sugar content than other root crops, potentially allowing processors (bakers) incorporating sweetpotato flour in "sweet" products to reduce added sugar (and hence the cost of other ingredients). This is reported in some papers, and would give non-OFSP an advantage over cassava or wheat flour for some bakery products and some types of consumers. It would however, make the flour less suited to non-sweet bakery goods such as bread.
- Plant breeders in Africa have identified some very high dry matter, non-sweet cultivars/varieties that could potentially compete on a dry matter production/ha basis with cassava. However, yields have often been determined only on small, experimental plots in 'research station'. Performance of these varieties will need to be assessed and proven in a range of edaphoclimatic and farm-level conditions.[8]
- Vine production, or combined root and vine biomass yield. Especially for animal feed uses, the potential of sweetpotatoes has not been explored yet in Africa.

Despite the above positive elements, it appears difficult to foresee an obvious potential for non-OFSP to carve out a direct role in the human diet than goes much beyond current utilization patterns. The food industry needs positive reasons to adopt a new raw material (e.g. SP flour), since this involves risk, effort and expense. Their attitude is likely to be "Why bother?"

While OFSP has a valid nutritional response to this question, and thus a selling point that other flours lack (especially if backed with promotional efforts at consumer level), non-OFSP lacks this driving force. This is even more the case if potential flour users also have to make the flour themselves. Other users (e.g. bakers) could use fresh roots (e.g. boiled mashed SP added directly in bakery products) but this entails significant additional labor and costs.

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[8] Note that plant breeders are also developing higher yielding/high dry matter content cassava and maize varieties, so this is essentially a red queen race between crops.

In the end, wider use of non-OFSP is likely to boil down to cost relative to the existing raw material (wheat flour) and other potential substitutes (maize and cassava). Based on the data reviewed here (admittedly 10 years old at least) non-OFSP was consistently the highest priced option, except in the main SP production areas at harvest time. For this situation to change, it would require:

- Much higher non-OFSP yields and dry matter contents.
- Much more consistency in production (continuity of supply for any processing industry).
- Change in long term wheat grain and flour price trends (and food aid policy?).

So, if wheat prices in East Africa start increasing, and non-OFSP varieties with high dry matter yields demonstrate potential to produce a price-competitive flour, then a focus on this option could be worthwhile. It is likely that the prime beneficiary of such a situation would be cassava and/or maize, with non-OFSP taking a secondary role, however.

Under this scenario, a relevant research agenda would be:

- Optimizing sustainable root yields for high dry matter content varieties in high potential production areas (including multiplication of planting material and other production issues).
- Evaluating efficient and cost-effective chip and flour production technologies, based on current experiences, with emphasis on small-medium scale (not micro) options. Balancing cost against product quality is a key consideration.
- Facilitating trials with potential industrial users/clients, and the establishment of sustainable supply chains.

One drawback of sweetpotatoes often mentioned by bakers in the references reviewed here is the problem of additional labor and expense incurred if using fresh boiled and mashed SP. This raw material appears to produce a higher quality baked product than flour, but is more difficult for a bakery to incorporate into existing work practices (based on use of flour only). One way around this could be to structure the production of boiled/mashed SP roots as a stand-alone business, supplying a number of bakeries in a given area. The economic viability of such a small business would need to be tested, but it would potentially improve the attractiveness of SP to bakers, while offering a new employment option for women/farmer groups, for instance.

However, these are only worthwhile if the yields and conversion rates that are possible in a given area put sweetpotato roots in striking distance of the price of competing flours. But if non-OFSP is only a competitive source of flour in a few specific locations, due to special local circumstances, then this effort may not be justifiable.

The other potential major priority for non-OFSP is animal feed. This has been quite neglected by CIP and its partners to date in Africa, despite a considerable body of research from Asia showing the potential of sweetpotato roots and levels combined with other locally available feed resources, to be an efficient and low cost pig feed. Cattle, as a high status livestock, received the lion's share of attention in East Africa. But research in Uganda (Peters, 1998) shows that pigs are widely distributed, if ignored. Their low status is even advantageous, since they are not stolen by Karamajong raiders like cattle, and therefore represent a much more secure store of value.

Research on animal feed—and especially pig feed—use of sweetpotato roots and vines should be carried out, especially:

- Trends in markets for pork.
- Formulation and evaluation in on-farm trials of feed rations including sweetpotato roots and vines (paper of D. Peters presents a design for this).
- Trials of locally appropriate methods to increase sweetpotato root digestibility—cooking, fermentation etc (adapting Asian technologies).
- Socio-economic studies of pig production in E Africa.

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