KEY ISSUES IN SWEETPOTATO PROCESSING IN PAPUA NEW GUINEA

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ABSTRACT

The development of a food processing and preservation industry was identified by the Papua New Guinea (PNG) government as one of the priority programs in the National Agricultural Development Plan 2007-2016. Food processing using local materials was envisaged to have the potential to generate employment and income opportunities for smallholder farmers, and hence contributing to poverty reduction and food security. The PNG food manufacturing sector is small, and is dominated by foreign companies using primarily imported ingredients. The objective of this study was to assess the challenges and opportunities for developing a locally-owned food processing sector in PNG, using sweetpotato as a test case.

Sweetpotato was chosen because it is the main staple crop in PNG and is grown by smallholder farmers across the country all year round. Consequently, the socio-economic impact could be significant if an efficient sweetpotato processing sector could be established. The impact could be even greater if the associated technology spilled over to other food crops (cassava, yam and taro) and South Pacific countries. Research methods used included: technical trials to improve sweetpotato flour processing efficiency and flour quality; sweetpotato product development; and a review of sweetpotato processing R&D in PNG.

Results showed that, although there is a niche market for sweetpotato products, sweetpotato flour, as a raw material for commercial food processing, is not versatile functionally or cost competitive, compared with wheat and corn (for flour production), potato (for fries/chips), and cassava (for starch). Limited R&D resources can be better spent on improving the value chain of fresh sweetpotato roots. However, if the PNG government is determined to develop a food processing industry, sweetpotato processing can be used as a pilot both to build research and development capacity in food processing, and to develop an enabling environment necessary for small to medium size agroenterprise development.

Key words: *agroenterprise development, enabling environment, Papua New Guinea, sweetpotato*

1 INTRODUCTION

The PNG food manufacturing sector is small, and is dominated by foreign companies using primarily imported ingredients. “The development of a food processing and preservation industry” (Program Area 2) was listed in the Priority Program Areas for Food and Horticulture Crops Development in the National Agricultural Development Plan 2007-2016, aimed at generating employment and income opportunities for smallholder farmers, and improving poverty reduction and food security (Ministry of Agriculture and Livestock, 2006). In the 2014 Budget Strategy Paper, “Improving the enabling business environment for the agriculture sector and facilitating the development of the small and medium enterprises” was listed as one of six key policy priorities (Government of PNG, 2013). These two documents suggest that the policy environment seem favourable to small to medium size agroenterprise development. The objectives of this study were to assess the challenges and opportunities and derive policy implications for developing a locally-owned food processing sector in PNG, using sweetpotato as a test case.

Although the two documents did not direct specifically at sweetpotato processing, or any other crops, there is a case for developing a sweetpotato processing sector. Sweetpotato is the main staple crop in PNG, accounts for 43% of total food energy intake (Bourke and Vlassak, 2004). It is grown by smallholder farmers across the country, and supply is available all year around. Consequently, the socio-economic impact on rural communities could be significant if an efficient sweetpotato processing sector were established. The impact could be even greater if the associated technology spills over to other root and tuber crops (such as cassava, yam, taro), and potentially to other South Pacific countries. Developing the sweetpotato sector is an important pro-poor strategy to economic development (Fuglie, 2007).

2 METHODOLOGY

We conducted an extensive literature review of sweetpotato processing research in PNG, as well as in China and Africa where such research has been the most extensive and where the findings are most relevant to PNG. Technical trials were conducted on-station to assess the processing efficiency and quality of sweetpotato flour, based on the process suggested in Van Hal (2000). Sweetpotato products were developed on-farm in collaboration with community groups, following the territorial approach to rural agroenterprise development popularised by the CIAT (Ferris et al., 2006). We also conducted social mapping of collaborating communities to track the dissemination of sweetpotato processing technology and to monitor and evaluate the community impact of the project. In this paper, we summarise the results from on-station technical trials and on-farm product and market development. More detailed information can be found in Chang and Mais (2014).

3 SWEETPOTATO AS A FOOD CROP

As a food crop, sweetpotato offers several advantages. It requires fewer purchased inputs and less labour than other staple crops such as wheat, rice, maize or cassava. It is adaptable to a wide range of agro-climatic conditions, including high altitudes, marginal areas, dry periods and poor soil. In addition, sweetpotato has the capacity to establish ground cover very quickly enables early weed suppression, controls soil erosion and helps maintain soil fertility (GTZ, 1998). It provides more edible energy per hectare than wheat, rice, maize or cassava. It has a reputation as a food security crop – that is, the one that a family relies on when the maize or rice fails.

Sweetpotato may not be the most nutritious staple crop compared with cereal crops, but it has the highest nutritional value as a vegetable. Sweetpotato roots are high in carbohydrates and dietary fibre. They are also rich in vitamin B and C and minerals like potassium, magnesium, phosphorus and zinc (WHfoods, n.d.). In addition, the orange-fleshed varieties contain high levels of β-carotene, a pre-cursor for vitamin A, and are heavily promoted to combat vitamin A deficiency in sub-Saharan Africa (SSA). Being low

Glycemic Index (GI), sweetpotato is a beneficial food for diabetics; it can help stabilise blood sugar levels and reduce insulin resistance. Sweetpotato vines/tops, often under-valued and unreported in government statistics, are also high in protein, vitamins and minerals (Islam, 2006) and are widely consumed as a leafy vegetable.

According to FAO, 115 countries produced close to 107 million tonnes (Mt) of sweetpotato in 2010. Production was concentrated is Asia (82.3% of global production) and in Africa (14%). China is the world's largest sweetpotato producer, with 76.2% (81 Mt) of global production in 2010. This was followed by Uganda (2.84 Mt), Nigeria (2.84 Mt), Tanzania (1.4 Mt) Indonesia (2.05 Mt) and Vietnam (1.32 Mt). Together, Uganda, Nigeria and Tanzania represent half of total African production. In contrast to the declining production trends observed in Asia due to economic development in recent decades (Huang et al., 2004), sweetpotato production has increased in the United States and some African countries. Expanding production in Africa has been explained largely by strong population growth and subsequent increases in demand (UNCTAD, 2012). Although a small producer (about 1 Mt), sweetpotato production is increasing in the US due to increased awareness of its health benefits, particularly its low GI, high fibre and low fat content. The US is the leading global exporter of sweetpotato, mainly to Europe (UNCTAD, 2012).

Sweetpotato has several potential uses, including as a fresh food, a stockfeed, and as a raw material for food processing. The main sweetpotato food processing options are: starch, dried chips/flour, and new food products (Fuglie et al., 2006). Changes in sweetpotato use in developing countries from the early 1960s to 2009 are presented in Table 1. The data show that sweetpotato use in fresh form declined from 77.6% of total production in the early 1960s, to 52.4% in the late 1980s. This trend was largely counter-balanced by an increase in the use of sweetpotato as stockfeed, from 11.7% of total production in the early 1960s to 36.1% in the late 1980s. By comparison, there was little change in sweetpotato used for processing into new food products, with a minor increase of 4.5% to 5.4% recorded over the same period.

Table 1. SP utilisation in developing countries (Scott, 1991)

	1961-63	1973-75	1986-88	2009*	
				1000 Mt	%
Fresh food	77.6	70.2	52.4	55,380	54.2
Stockfeed	11.7	19.0	36.1	39,790	39.0
Processing	4.5	4.8	5.4	42	0.04
Seed/replanting	0.3	0.2	0.2	294	0.3
Waste/others	5.9	5.8	5.8	6,637	6.5
Total	*100*	*100*	*100*	*102,143*	*100*

* Calculated by authors using FAOSTAT database.

Two decades later in 2009, the proportions of sweetpotato used for food, feed, processing were 54.2%, 39.0% and 0.04%, respectively (Table 1, last two columns). The most significant change by 2009 was the reduction in the proportion used in processing. This was mainly a result of sweetpotato losing its competitiveness as a raw material for starch production, especially in China (Fuglie et al., 2006).

4 SWEETPOTATO PROCESSING RESEARCH IN PNG

Unlike in Western countries, there is little awareness among the general public of PNG of using sweetpotato as a vegetable (as opposed to a starchy staple food). Likewise there is little awareness of the potential to use sweetpotato as a raw material for processing into bakery products, noodles or snack foods, as is common in Asia and Africa.

Sweetpotato processing research and development was institutionalised in PNG when the Food Processing and Preservation Unit (FPPU) was established in 1984, with the goal of developing a food processing sector in PNG (Cegumalua, 2007). Work at FPPU focused on developing products for downstream processing, and on training and assisting

entrepreneurs in progressing further into commercial scale agroenterprises. FPPU was reviewed, and was subsequently shut down, in 2007. The review found that the program had failed to achieve its original objective (Cegumalua, 2007). First, there was little uptake of the processing technology by entrepreneurs and trainees. Of those few individuals who were interested in adopting the technology, most did not succeed because of insufficient technical knowledge. Those who managed to go into processing business failed to develop into fully-fledged commercial enterprises either because of lack of necessary capital or business management skills to scale up. Most continued to operate at the cottage industry level, selling their produce in informal markets. Second, the building and processing equipment of FPPU had deteriorated over the years, and eventually became un-operational, due to poor management and lack of financial support from the government.

After the closure of FPPU, most processing research was conducted at the National Agricultural Research Institute (NARI). NARI research focused on evaluating sweetpotato varieties and their suitability for producing sweetpotato flour. Research also focused on using composite sweetpotato/wheat flour to produce derivatives such as cakes, donuts, pancakes, biscuits, and noodles. Similar research was also conducted with other food crops such as cassava, yam and taro. The main objective was to substitute imported wheat flour with locally produced flours as much as possible while maintaining the integrity of products that were derived from the composite flours. Those experiments were not as successful as expected.

Sweetpotato flour is functionally very different from all-purpose flour, for example, it is gluten-free, sweet and has a strong flavour (Peters and Wheatley, 1997). This restricts the use of sweetpotato flour as a substitute for wheat or other flour. Even partial substitution (at a level of 10–15%) of wheat flour with sweetpotato flour can change the taste, smell, and texture of products, such as bread, enough to have them marketed as different products. The potential for sweetpotato flour in making bread is limited, but flat unleavened products such as pancakes, puddings, and chapattis can be made with higher proportions of sweetpotato flour. This is also true for a much wider range of products, mostly with a sweet taste, including donuts, biscuits, muffins, cookies, brownies, noodles, pies, and baby foods (Woolfe, 1992; Peters and Wheatley, 1997).

These results suggested that rather than imitating wheat-based products, more attention should be given to developing recipes that suit the unique characteristics of sweetpotato, and use locally available materials.

4.1 On-station sweetpotato flour processing

4.1.1 Factors influencing processing efficiency and flour quality

The most important quality characteristics of sweetpotato flour are moisture content, protein, starch and β-carotene content, as well as microbiological quality, colour, taste, and odour. The quality of sweetpotato flour is defined in the African Standard CD-ARS 827:2012(E) (ARSO, 2012), as shown in Table 2.

Table 2. Compositional requirements for sweetpotato flour (ARSO, 2012)

Parameter	Requirement (In % on dry matter basis)	Method of test
Total ash	< 3.0	ISO 2171
Moisture	< 12.0	ISO 712
Crude fibre	< 5.0	ISO 5498
Acid insoluble ash	< 0.15	
Total sugar (as sucrose)	> 6.0	ISO 2173
Starch	> 60.0	ISO 15914
pH of aqueous extract	4.5-7.0	ISO 1842
Cold water solubles	< 12.0	ISO 941

Survey of literature showed that sweetpotato flour of a desirable quality can be made at the household/village level using simple technology (Wheatley et al., 1995; Van Hal, 2000). Sweetpotato flour processing involves the following steps: selection of fresh roots, weighing, trimming, washing, peeling, slicing/shredding, soaking (bleaching/blanching), pressing, spreading, drying, grinding, sifting, weighing and packaging (Van Hall, 2000). Although not a complex process, each of these steps has some bearing on the final quality and processing cost of the flour, especially the selection of fresh roots.

Dry matter content and flour yield are the most important factors influencing processing cost. Both are affected significantly by the choice of variety. Sweetpotato roots are classified into two general types in terms of dry matter content and colour: dry-fleshed cultivars with mealy, light yellow or white flesh, and moist-fleshed cultivars with soft, gelatinous, bright orange flesh. Yields reported in the literature range from 17 to 38%, as moisture content can vary from 65-80%, depending on variety, but they are most likely to be in the range of 25-29% (Van Hall, 2000). Therefore, careful consideration must be given to the selection of the raw sweetpotato roots.

For any given variety, sweetpotato roots must be sorted based on their size and shape, while removing roots with rots, insect damage, excessive mechanical damage, and excessive soil or other foreign materials. Peeling takes more time when the roots are too big, too small, or irregularly shaped. Excessive culling and trimming to remove undesirable parts of roots will increase wastage, reduce yield, and increase labour costs (Gakonyo, 1993).

4.1.2 Results from flour processing trials

Altogether, six batches of sweetpotato flour in different volumes, and using three different varieties, were produced. Data collected included: (1) the time taken to carry out each of the various processing steps; (2) variable costs of raw material, labour, water and electricity; (3) extraction rate/flour yield; and (4) proximate contents of flour.

Key results were:

- On average, it took 28 hours to process 100kg of fresh roots, including 20 hours of drying time in the oven.
- Extraction rate/flour yield varied between 17-20%, depending on varieties, quality of fresh roots, and drying time.
- Results from proximate analysis from 4 samples tested (Table 3) showed average readings for protein, at 3.26%; moisture, at 6.34%; fat, at 1.67%; ash, at 1.93%; and fibre, at 1.82%.
- Average variable cost of flour was K7.80/kg. This is high compared to the retail price of wheat flour at K3.8-4.5/kg and of rice at K3.45-4.0/kg at the local supermarkets. Similar results were found in other studies (e.g. Peters and Wheatley, 1997) that sweetpotato flour has to be 50%–90% cheaper in order to compete with wheat flour and replace it in any significant volume. However, if sweetpotato roots could be sourced locally or from the farm, the average variable cost would be reduced to around K5.0/kg.

Table 3. Proximate analysis results from 4 samples (in %)

Variety	Milled	Tested	Protein	Moisture	Fat	Ash	Fibre
One-moon	04.10.12	23.10.12	2.58	8.25	3.75	1.00	2.00
Wahgi Besta	29.11.12	9.12.12	3.24	7.50	0.75	2.50	1.50
Wahgi Besta	11.12.12	18.12.12	4.22	2.85	0.67	2.48	3.26
Kerot	22.04.13	29.04.13	3.00	6.75	1.5	1.75	0.50
Average			3.26	6.34	1.67	1.93	1.82

These results suggested that only by sourcing inexpensive raw materials and through very efficient processing can sweetpotato flour be cost competitive with wheat flour. To reduce raw material costs, consideration must be given to improving yields to lower the cost of

production, selecting/breeding varieties with high dry matter, identifying processing sites that are near the source of supply, and improving postharvest management to reduce product losses during transit and storage. To reduce processing cost, more research is also required to determine the desirable moisture content, the optimal combination of temperature and drying time, and the effect of leaving the sweetpotato unpeeled on the quality of flour and its derivatives.

4.2 On-farm sweetpotato product development

The territorial approach to rural agroenterprise development popularised by the CIAT (Ferris et al., 2006) involves the following activities:

- develop partnerships, territorial diagnosis and joint planning;
- identify market opportunities for small rural producers;
- analyse market chains;
- design and implement rural agroenterprise business model;
- strengthen business development services; and
- advocate for improved marketing and trade policies.

In this paper, due to time and other resource constraints we presented results from partnerships development, territorial diagnosis, the spread of processing technology, and impact assessment.

4.2.1 Developing partnerships

Two rural communities were invited to participate in this research: the first group was members of a farmer co-operative (co-op) based in Sibi village, and the second group was from Gebansis village. Our main contact persons were the project coordinator of the co-op and a community leader for the latter group. Sibi village is located in a mountainous area 600 meters above sea level, and is an hour drive away from the Lae City – the second largest city in PNG. Gebansis is more conveniently located near the main road and is 30 minutes drive to the Lae City. The different locations and makeups of the two groups allowed us to compare results and develop locally appropriate intervention strategies.

4.2.2 Territorial analysis

A social mapping method was used to assess the resources available at the communities. Two maps were produced for the first group: one for Sibi village and one for the Middle Erap community of which Sibi village is a part. The focus of the village map was to identify the main roads, mountains, rivers, and any other relevant geographic features in relation to the resource centre of the co-op located in Sibi village. The community map focused on identifying the locations and names of villages in the community, and the location of community resources such as schools, health clinics, churches, resource centre, drum oven, fish ponds, rice fields, and pineapple fields. Chinese taro (*Xanthosoma sagittifolium*) was identified as the major food crop. Coffee and cocoa were the major cash crops, and were widespread in the community. Like most rural PNG, there was no electricity service in the community, but few households had generators and solar power. Both the main road and feeder roads were in poor conditions and were impassable after heavy rains. There was one wood-fired drum oven in the community.

Similar mapping exercise was undertaken in Gebansis village. The village had good roads and easy access to the Lae urban centre, and electricity connection was available for those who could afford it. Banana was the staple food crop while cocoa was the main cash crop. Gebansis village had a cocoa co-op. Several households were out-growers for a poultry company (Tablebirds). Three wood-fired drum ovens were identified.

4.2.3 Product and market development

Basic training on flour processing and baking was provided to both groups, and sweetpotato flour was distributed to Sibi and Gebansis participants along with recipes. Participants were encouraged to work together and to experiment with making sweetpotato products and

develop their own recipes. Several weeks after the training, a number of sweetpotato products had been developed. The Gebansis group had made sweetpotato strips, cassava/sweetpotato cake, fried sweetpotato balls, sago/sweetpotato fries, donuts, cookies (with pumpkin and banana), and boiled sweetpotato flour balls. For the Sibi group, more interesting new products were developed using ingredients that were available in the village. These included: donuts, pastry (pumpkin, potato), scones, fried flour, sweetpotato cookies, banana cakes, peanut cookies, ukoi (with pumpkin and pawpaw), strawberry flavoured cookies, steamed banana cakes, bread, cassava donuts with locally made desiccated coconut, pizza bases, and buns with various flavours.

Fifteen households in Sibi and seven households in Gebansis were involved in developing these products. In most cases, half a dozen experiments were required to arrive at a product of acceptable quality. Some products were sold in the villages and were well-received. Demand was high and profits were significant. Training in marketing, costing, hygiene and packaging was provided to participants who were active in product development. Marketing trials to sell a few selected products to schools and government agencies in the Lae City are to be conducted later to get consumer feedback before commercial roll out.

4.2.4 Tracking the spread of sweetpotato processing technology

Six months after the project started, social mapping again was used to track the spread of the sweetpotato processing technology, focusing on the social networks through which sweetpotato knowledge was disseminated, agents of change, individuals who received the knowledge second-hand, and their relationship to the change agent. We found that in Gebansis, social networks were mainly kinship-based, and were largely limited to people who were related to the community committee chairman. In contrast, in Middle Erap community, social networks extended beyond Sibi village to include neighbouring villages who were also members of the co-op. The project coordinator of the co-op, being employed from outside the district, appeared to be more objective and inclusive in her decision making. Given that rural communities are diverse and their social and political structure is complex, the participatory methodology employed in this project helped us gain significant insights into the workings and power relationships of these rural communities, which has bearing on knowledge dissemination aimed at improving livelihood. More details on social mapping can be found in Sar et al. (2013).

4.2.5 Monitoring and evaluation

The research team visited Sibi village nine months after the project started to assess the impact of the training activities on the community, their experience with sweetpotato processing, and to find out more about the constraints and opportunities for village-level processing. Several issues were identified:

- Product development – development costs were high because it took time and several experiments before satisfactory results could be achieved. Using local ingredients had reduced costs and encouraged creativity.
- Equipment – availability of equipment and tools was a serious issue for the community because there was only one drum oven in Sibi village. However, members of the community were looking into alternative ways to baking, such as using dish ovens, steaming, and frying. More research is needed to identify food processing equipment that is practical for rural communities where there is no electricity access.
- Costs of ingredients – the availability and costs of ingredients, such as oil, sugar, eggs, and wheat flour, was also an issue.
- Labour intensity – it was tedious and time-consuming to make sweetpotato flour. Participants were interested in finding alternative methods for sun drying and solar drying of sweetpotato.

- Access to sweetpotato processing training and flour – some interviewees complained about not having had access to training or flour because they were not part of the community or network that was involved in the project.

Some of these results are similar to what was found by Chang and Irving (2013). They found that although there was interest in food processing in rural communities, the uptake of technology after training was often poor. Major constraints to adoption were: labour intensity, and lack of access to equipment (such as milling machinery, baking ovens, and kitchen utensils), ingredients (such as milk, sugar, butter, and eggs), and basic services (transport, clean water, electricity, credit, and technical support).

Further research is required to address the socio-economic constraints to technology dissemination and adoption, and to identify locally appropriate technology (equipment and tools) for rural households with limited resources and budget. Given that leadership is the most significant enabling factor in the spread of technology and initiation of change in rural communities, it is crucial to identify individuals who have the social capital and commitment to broaden the existing kinship networks to include the wider community, as well as being proactive in problem-solving, rather than relying on outside help.

Overall, the project has produced significant results with respect to flour processing and product development, as well as raising community awareness of sweetpotato processing. Sweetpotato products have been sold in both Gebansis and Sibi villages with good outcomes – demand was high; profits were significant; and a quick income source. These results showed that marketing opportunities exist for good quality, low cost sweetpotato products that are made from locally available materials using family labour.

5 KEY ISSUES AND POLICY IMPLICATIONS

Lack of access to basic services (transport, water and electricity) and basic equipment in rural communities were recognised in this paper, and by Chang and Irving (2013). Problems with capacity, business support services and business linkages were clearly identified in the review of FPPU by Cegumalua (2007). In addition, GTZ (2003) outlined ten preconditions that are necessary for successful intervention in rural development through agro-enterprise development:

- an enabling environment that provides for an attractive investment climate and fosters dynamic entrepreneurship;
- adequate mechanisms and structures that address local needs;
- active private sector institutions and linkages;
- functioning and effective infrastructure (hard and soft);
- access to integrated and open markets;
- access to effective and efficient support services and resources;
- adaptive management capacity and entrepreneurial competence within business and enterprises;
- local organisations, groups and associations (representing the poor) as building blocks;
- active participation in and ownership of development processes by well-linked stakeholders; and
- ongoing learning from success and failure by all stakeholders.

Most of these are lacking in the current business environment in PNG.

The main policy implication was that the PNG government should play a central role in supporting agroenterprise development by considering the following policy interventions (Ferris et al., 2006):

- encouraging diversification and adding value locally in rural areas;
- promoting participatory methods that directly involve local chain actors in decision-making and develop local capacity;
- stimulating collective action and involvement of rural economic organisations with a solid business and market orientation;

- strengthening the market for business support services and its coordination;
- generating and promoting technologies related to small-scale agricultural production;
- improving service infrastructure such as water and electricity supply; and
- Investing in research and development to reduce raw material costs.

6 CONCLUSION

Food processing has the potential to create employment and diversify and increase income for smallholder farmers and rural communities by adding value to local produce. In the longer term, a well-functioning food processing sector is crucial for the sustainability of the farming sector, as the demand for value-added and processed products can be expected to increase as the economy develops. This means there is a good case for investing in rural agroenterprise development.

However, promoting small to medium-scale processing agroenterprises in PNG will be challenging, due to the current operating environment and resource and capacity constraints. For starters, limited resources should be spent on improving the value chain of fresh sweetpotato roots to reduce the raw material cost. However, if the PNG government is determined to develop a food processing industry, sweetpotato processing can be used as a pilot both to build research and development capacity in food processing, and to develop an enabling environment necessary for small to medium size agroenterprise development.

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