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# Future prospects for sweetpotato processing in Papua New Guinea[1]

**Hui-Shung (Christie) Chang**

Associate Professor Christie Chang is a Principal Research Fellow at the Institute for Rural Futures, University of New England, Armidale, NSW, Australia. Email: hchang@une.edu.au.

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## Abstract

Food processing using local materials has the potential to create employment and income-generating opportunities for smallholder farmers and rural communities. In Papua New Guinea (PNG), the food manufacturing sector is small, and is dominated by a small number of foreign companies using primarily imported ingredients. To address these issues, the "Development of a food processing and preservation industry" was identified by the PNG government as one of the priority programs for agricultural development in the National Agricultural Development Plan. 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. The research involved an extensive literature review of sweetpotato processing research and development activities in PNG, as well as in China and Africa where such research and development activities have been the most extensive. Results showed that, given the current environment, promoting sweetpotato processing into commercially viable enterprises will be challenging. 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 for food processing and to investigate whether and how an efficient food processing industry can be developed.

Key words: agroenterprise development, agribusiness management, sweetpotato, Papua New Guinea

## 1. Introduction

Food processing using local materials has the potential to create employment and income-generating opportunities for smallholder farmers and rural communities. It also adds value, reduces freight costs, and increases the shelf life of fresh produce. More importantly, 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 increases along with urbanisation and economic development. In Papua New Guinea (PNG), the food manufacturing sector is small, and is dominated by a small number of foreign companies using primarily imported ingredients. The PNG government is well aware of these issues, with the "Development of a food processing and preservation industry" being identified as one of the priority program areas for agricultural development in its National Agricultural Development Plan (NADP) 2007-

2016 (Ministry of Agriculture and Livestock 2006). However, little directly relevant work had been done in this area at the time of writing.

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Although the NADP did not directly specify sweetpotato processing, or any other crops, there is a strong case for focusing on sweetpotato. Sweetpotato is the main staple crop in PNG and is grown by smallholder farmers across the country. 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 South Pacific countries, as well as to other root and tuber crops (for example, cassava, yam and taro).

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.

## 2. Methodology

In the project "Market diversification and processing for sweetpotato in Papua New Guinea: A pre-feasibility study", of which this paper is a part, we conducted an extensive literature review of sweetpotato processing research completed 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, while sweetpotato products were developed on-farm in collaboration with community groups. We also conducted social mapping of collaborating communities to track the dissemination of sweetpotato processing technology and to assess the community impact of the project. However, in this paper we focus our discussion on the literature review and the implications for PNG. Detailed information on technical trials, participatory product development and social mapping can be found in Chang and Mais (2014).

In the following section, we provide an overview of sweetpotato production and utilisation in the world. This is followed by discussion on relevant Chinese and African experiences, focusing on sweetpotato processing research and development and the role of government and international collaboration. We then consider the policy and business environment for agroenterprise development in PNG. Future prospects for developing a sweetpotato processing sector are assessed, followed by policy recommendations and concluding remarks.

## 3. Global sweetpotato production and utilisation

Sweetpotato has several advantages as a food crop. It requires fewer purchased inputs and less labour than other staple crops, such as wheat, rice and maize. It is adaptable to a wide range of agro-climatic conditions, including marginal areas, high altitudes, dry periods and poor soil. It has a flexible growing season which allows piecemeal harvesting over a three to10 month period and a tremendous capacity for producing high yields (up to 80 Mt/ha). It provides more edible energy per hectare than wheat, rice, maize or cassava. In addition, the ability of sweetpotato to establish ground cover very quickly enables suppression of weeds, control of soil erosion and maintenance of soil fertility (GTZ 1998). It has a reputation as a food security crop – that is, the one that a family relies on when the maize or rice fails. These attributes make it particularly suitable for smallholder farmers and rural households threatened by climate change, migration, civil disorder or diseases such as AIDS (CIP n.d.).

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 recent years, it has been seen as a functional food, with anti-carcinogenic, anti-oxidant, anti-inflammatory, and cardiovascular disease-preventing properties, and its low Glycemic Index helps stabilise blood sugar and reduce insulin resistance. Orange-fleshed sweetpotato (OFSP) with high beta-carotene is used to combat Vitamin A deficiency for children in Africa (Low et al. 2008).

### 3.1 Production

According to FAO, 115 countries produced close to 107 million tonnes (Mt) of sweetpotato in 2010 (UNCTAD 2012). The production is concentrated in 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 is 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 the African production.

In contrast to the declining trends observed in Asia in recent decades due to economic growth, sweetpotato production has increased in some African countries and in the United States.

**Table 1: World production of sweetpotato roots (in tonnes)**

| | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| Total World | 106,641,705 | 100,943,340 | 104,578,294 | 102,323,748 | 106,569,572 |
| Asia, including: | 88,430,581 | 83,124,117 | 85,702,879 | 84,182,639 | 88,511,139 |
| China | 81,039,000 | 75,600,000 | 78,830,000 | 76,772,593 | 81,175,660 |
| Indonesia | 1,854,238 | 1,886,852 | 1,876,944 | 2,057,913 | 2,050,810 |
| Vietnam | 1,460,900 | 1,437,600 | 1,325,600 | 1,207,600 | 1,317,060 |
| India | 1,066,500 | 1,067,200 | 1,094,000 | 1,119,700 | 1,094,700 |
| Japan | 988,900 | 968,400 | 1,011,000 | 1,026,000 | 863,600 |
| Philippines | 566,773 | 573,734 | 572,655 | 560,516 | 541,525 |
| Africa, including | 14,712,718 | 14,098,182 | 15,275,678 | 14,353,091 | 14,213,680 |
| Uganda | 2,628,000 | 2,602,000 | 2,707,000 | 2,766,000 | 2,838,800 |
| Nigeria | 3,462,000 | 2,432,000 | 3,318,000 | 2,746,817 | 2,838,000 |
| Tanzania | 1,396,400 | 1,322,000 | 1,379,000 | 1,381,120 | 1,400,000 |
| Angola | 684,756 | 949,104 | 819,772 | 982,588 | 986,563 |
| Kenya | 724,646 | 811,531 | 894,781 | 930,784 | 383,590 |
| Madagascar | 869,000 | 890,000 | 941,355 | 910,857 | 919,127 |
| Mozambique | 929,826 | 875,216 | 890,000 | 900,000 | 920,000 |
| Rwanda | 777,034 | 841,000 | 826,000 | 801,376 | 840,072 |
| Ethiopia | 388,814 | 388,814 | 526,487 | 450,763 | 401,600 |
| Latin America, including: | 1,961,714 | 2,104,017 | 2,057,497 | 2,162,830 | 1,966,398 |
| Brazil | 518,541 | 529,531 | 548,438 | 477,475 | 479,200 |
| Cuba | 303,000 | 414,000 | 375,000 | 437,000 | 384,700 |
| North America, including: | 744,046 | 819,741 | 836,662 | 883,207 | 1,081,720 |
| United States | 743,937 | 819,641 | 836,560 | 883,099 | 1,081,590 |
| Oceania, including: | 719,410 | 763,716 | 641,861 | 680,177 | 742,554 |
| Papua New Guinea[2] | 560,000 | 580,000 | 485,181 | 534,085 | 576,000 |

*Source: UNCTAD 2012.*

[2]These figures are much lower than the 3 Mt estimated by Bourke and Vlassak (2004).

The most significant increase has occurred in Uganda, from around 2 Mt in 1999 to 2.83 Mt in 2010. This expansion in production in Africa has been explained largely by strong population growth which has led to increases in demand (UNCTAD 2012). The United States produces relatively little sweetpotato (around 1.0 Mt in 2010) but production is increasing, due to increased awareness of the health benefits associated with sweetpotato. The United States is the leading global exporter, mainly to the European Union. Sweetpotato vines are also high in protein, vitamins and minerals, and widely consumed as a leafy vegetable in Asia, such as Taiwan, Malaysia and the Philippines, and in Africa, such as Guinea, Sierra Leone, Liberia, Uganda and East Africa (Islam 2006). In Vietnam, some varieties are selected and growing primarily for their vegetable tops, with little or no harvest of roots. In Taiwan some varieties are bred specifically for their desirable vine properties as a leafy vegetable (flavour, taste, crispness, tenderness). They are also used as animal feed. However, production data on sweetpotato vines are not reported. This means the importance of sweetpotato as a food crop could be much greater if production data included both vines and roots (Fuglie 2007).

### 3.2 Utilisation

Sweetpotato has many potential uses, including being used as a staple food, stockfeed and for processing into starch, dried chips and flour and associated food products (Fuglie et al. 2006).

Changes in sweetpotato use in developing countries from the early 1960s to 2009 are presented in Table 2. 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. The trend is 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 (Scott 1991).

**Table 2. Sweetpotato utilisation in developing countries[3]**

| | 1961-63 | 1973-75 | 1986-88 | 2009* | |
|---|---|---|---|---|---|
| | % | % | % | '1000 tonnes | % |
| 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 | 42.4 | 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 |

*Source: Scott 1991, except for 2009 (calculated by authors using FAOSTAT database)*

Two decades later in 2009, the proportions of sweetpotato used for food, stockfeed and processing were 54.2%, 39.0% and 0.04%, respectively (Table 2, last two columns). Clearly, the most significant change in 2009 has been the reduction in the proportion used in processing. This could be a result of sweetpotato

[3] Huang et al. (2004) pointed out that these figures, which are estimates at best, should be used and interpreted with caution. Reliable data are hard to collect because of the involvement of smallholder farmers whose production is often unreported. The concentration of sweetpotato production in China (75-85% of world production) could also distort the overall picture.

[4] Based on FAO statistics, this 42 Mt was used in China mainly for starch production. No processing use was reported in other countries.

losing its competitiveness to cassava as a raw material for starch production, especially in China[3], as alluded to in Fuglie et al. (2006).

### *3.2.1 As a fresh food*

Sweetpotato is the seventh most important food crop (by volume) in the world, after maize, rice, wheat, potato, cassava and barley. Data from FAO indicate that in 2009 the world average per capita consumption of cereals was 146.7kg per year, with wheat (66kg), rice (53.3kg) and maize (17.1kg) being the top three cereal crops. The world average per capita consumption of starchy roots was 61.1kg per year, with potato (32.6kg), cassava (14.3kg) and sweetpotato (8.3kg) being the top three root crops. This means sweetpotato is normally not consumed as a main staple, with only few exceptions such as Papua New Guinea (260kg/person/year) and the Solomon Islands (180kg/person/year), as well as regions in Southern China, West Papua in Irian Jaya, the central coast of Vietnam, and the northern islands of the Philippines (Prain n.d.). Other major consumers of sweetpotato are: Rwanda (73kg/person/year), Burundi (89kg/person/year) and Uganda (73kg/person/year).

This consumption pattern reflects differences in agro-climatic conditions and the stage of economic development of each country and/or region. For subsistence economies in the developing countries, the consumption pattern is determined largely by agro-climatic conditions. However, as an economy develops, agriculture becomes more market-oriented. In more advanced economies, food consumption is largely determined by economic factors, such as income, relative prices, and quality/nutrition, as well as socio-demographic factors, such as age, gender, location (rural vs urban), occupation, ethnicity, and prestige[5]. As income rises, there is a general tendency for food consumption to move away from starchy roots and towards cereals. Within both the cereal and starchy roots, there is generally a move towards more nutritious, more versatile and better tasting choices (Scott et al. 2000). There are also tendencies for food choice to move towards diversity and higher quality, more convenient and easy-to-prepare products. This is evident by the consumption patterns observed in developed countries both in the West (e.g. Australia, New Zealand and USA), and in the East (e.g. Japan, Korea, Taiwan, Hong Kong, Singapore). This means that, despite its agronomic superiority and reported health benefits, the demand for sweetpotato will declines as a staple food as income rises and as urbanisation intensifies.

Differing consumption patterns of sweetpotato between PNG rural and urban areas have been observed by Gibson (2001a,b). Annual per capita consumption of sweetpotato was found to be 299kg and 42 kg in rural and urban areas, respectively. In a recent consumer survey in Port Moresby, Chang et al. (2014) found that rice is the most preferred staple food, followed by sweetpotato and cooking bananas. 55% of the respondents chose rice as their most preferred staple food while 40% of respondents chose sweetpotato. The main reason for choosing rice is its availability while it is taste / preference for sweetpotato. For changes in sweetpotato consumption, 23% of respondents indicated that they are eating more, while 29% are eating less and 48% are eating about the same, compared to a year ago. The main reasons for eating more are a change in taste/preference for health reasons and an increase in family size, and the main reasons for eating less are affordability and different taste and preferences of children who prefer rice and potato.

### *3.2.2 As a stockfeed*

Both sweetpotato roots and vines are commonly used for raising pigs in countries and regions such as China, northern and central Vietnam, the island of New Guinea (Papua New Guinea and West Papua), the Philippines, Cuba and Uganda (Peters 2004). Sweetpotato roots have several shortcomings as stockfeed. First, they contain little protein: crude protein content commonly ranges from 1.3 to 4% on a dry weight basis. This problem can be overcome by supplementing a sweetpotato-based diet with rice bran, fishmeal, soybean cakes, sweetpotato vines, cassava leaves or commercial feeds. However, farmers often lack sufficient resources to purchase these ingredients (Peters et al. 2002). Second, fresh

[5]In Japan and Taiwan, for example, sweetpotato has been associated with poverty (coined as a "poor man's food") and harsh wartime and post-war conditions (Bourke n.d.). Although sweetpotato was a significant food item in the 1940s and 1950s, consumption has declined in these countries in line with industrialisation, to become negligible in recent decades.

sweetpotato roots contain trypsin inhibitors, which reduce protein digestibility in uncooked roots and slow animal growth. Third, the digestibility of sweetpotato starch is also poor. Starch and protein digestibility can be improved by cooking sweetpotato roots and small farmers in China and Vietnam cook sweetpotato roots daily to feed their pigs, but it is labour-intensive and costly. In PNG, roots are fed to pigs uncooked. Another inefficiency in the sweetpotato-pig system is wastage following harvest since sweetpotato roots and vines do not store well.

The importance of sweetpotato as an animal feed varies widely by scale of operation and by region. In Asia, more than 80 % of pig production involves small-scale "backyard" producers using sweetpotato and other low cost locally available feedstuffs. However, these producers are generally less efficient than specialised producers who rely on commercially formulated feed. These findings indicate both a challenge and an opportunity. Fuglie et al. (2006) argued that, while small-scale producers face increasingly stiff competition in pig production, improving the sweetpotato-pig production system, which favours small-scale production, may be a way for policy makers and scientists to support "pro-poor" agricultural development.

### *3.2.3 As a raw material for food processing*

Dehydration is the most common way of processing sweetpotato, and it has been traditionally practiced by farm households in the major sweetpotato producing regions of Asia and Africa (Woolfe 1992). Besides allowing improved preservation, the drying and processing of sweetpotato into chips, flours and starch offers marketing opportunities such as:

- reducing bulkiness and losses due to high perishability of fresh roots (although roots can be left in the ground for some time, they risk weevil attacks and infestation by other pathogens);
- increasing shelf life;
- facilitating storage and transport;
- enhancing nutritional value, as the nutrients are concentrated in the dried food products (Hagenimana et al. (1999) showed that sweetpotato flour proved to be the most effective way of increasing carotenoid content, compared with boiled and mashed sweetpotato and raw and grated sweetpotato); and
- potential for use as an ingredient for many marketable processed products.

All of which may contribute to improving household food security and income.

The major industrial use of sweetpotato is starch production. Starch has wide usage in the manufacture of many food and non-food products (Fuglie et al. 2006). In food industries, starch is used to impart "functional" properties to processed foods such as thickening, binding, filling, texture, and taste. Starch is also converted into sugars and sweeteners, especially important is the use of corn starch to produce high-fructose syrup for soft drinks. Uses of starch in non-food industries include textile, paper, plywood, adhesive, and pharmaceutical products. Starch is also used to make beverage and fuel alcohol. Worldwide, the biggest user of starch is the sweetener industry (Fuglie et al. 2006). Asia accounted for about one-third of world starch production, nearly half of which is from cassava and sweetpotato. While Thailand is the major producer of cassava starch, China is the major producer of sweetpotato starch (Fuglie et al. 2006). In Europe, maize, wheat, and potato are the main sources of starch.

Raw material cost is key to the competitiveness of starch, since it accounts for 70-80 % of total processing cost. Another key determinant of starch processing costs is the starch conversion rates. Starch conversion rates are around 60-65 % for cereals (maize, wheat, and rice), 22-25 % for cassava, 8-12% for potatoes and 10-15 % for sweetpotato (Wheatley et al. 1995). One way to improve cost competitiveness and increase the starch extraction rate is to select high starch-yielding varieties (Fuglie et al. 2006). Another cost factor is processing efficiency, which depends on the technology used and the scale of production, which in turn affect capital and labour costs. Trade in starch among Asian countries is heavily dominated by cassava starch because of its cost advantage (Fuglie et al. 2006).

### *3.2.4 Potential industrial uses of sweetpotato*

Research carried out at the International Potato Centre has shown that more than 100 industrial products could be produced from sweetpotato, such as lactic or polylactic acid used in the manufacture of biodegradable plastics, bioethanol, and anthocyanins for food colouring and additives. To date, however, their application is yet to be developed. Overall, the industrial potential of sweetpotato remains largely unknown and yet to be fully exploited (UNCTAD 2012).

## 4. Sweetpotato R&D

In the following section, we review the research and development and extension activities supported by various agencies to promote sweetpotato processing in China, Africa and PNG.

### 4.1 China

Public research on sweetpotato processing in China began in the early 1980s. This research was part of the Chinese government's broader effort to increase farmers' income and create employment opportunities in the relatively underdeveloped provinces in mountainous regions where there was a heavy reliance on sweetpotato as a staple food. Significant resources were devoted to finding new uses and developing postharvest technology for sweetpotato. Unlike potato processing technology, these processing technologies could not be readily imported from overseas. Although some progress was made in product development and some equipment for extracting starch from sweetpotato was developed by local scientists, starch quality was poor and the processing cost was high. External help was required to progress further.

In 1987, the Sichuan Academy of Agricultural Sciences began to collaborate with the International Potato Centre (CIP) on postharvest utilisation (Fuglie and Hermann 2004).[6] This collaboration lasted nearly two decades. Initially, collaboration focused on introducing and improving machinery for small-scale starch extraction and noodle making. In the mid-1990s, the resulting improved technology was extended to, and adopted by, machinery manufacturers and sweetpotato processors. With this proven success in noodle making, research and development activities were expanded to include product development and processing of instant noodles, snack foods, and flour products (Wheatley and Song 2002).

However, by the late 1990s the households and small enterprises that had adopted sweetpotato processing technology for starch/noodle processing faced growing competition from larger-scale food manufacturing in China's rapidly advancing market economy. As a result, research by Chinese and CIP researchers turned increasingly toward questions of scale and efficiency (Huang et al. 2003). In particular, scientists sought to develop technologies that would make small-scale sweetpotato processors more productive and competitive. As competition issues became more acute, CIP-supported research expanded from production to include aspects of organisation and management of processing enterprises and the marketing of sweetpotato processed products (Zhang 1999).

In addition to international collaboration, the Chinese government also played a key role in turning around the Chinese sweetpotato sector in the 1990s, in particular by its support of research into processing technologies and its implementation of the "one-dragon" policy. The one-dragon policy is the Chinese approach to supply chain coordination (Wei and Zhang 2004). It links farmers' groups (rural associations) to well-established food manufacturers: the dragon head enterprises (DHEs).

Under the one-dragon policy, DHEs were selected based on their size, financial profile, market position and technological leadership. Their main role (as the dragon head) was to lead the way for agricultural industrialisation through market development, technology innovation, and supply chain management and to drag its tail (the rural associations and their farmer members) to prosperity (Lingohr 2007). Rural associations, on the other hand, supplied raw materials to the DHEs, also often performing primary processing (for example of crude starch) to supply to the DHS. In return for their participation in the one-

[6]Other areas of collaboration included the development of new technologies to eliminate viral diseases in sweet potatoes. The techniques included new methods to identify viruses in sweet potato roots, and better systems for multiplying improved virus-free plant varieties. By the early 1990s, these efforts helped boost sweet potato production by over 30% and expanding cultivated area to over 600,000 ha in Shandong Province (CGIAR n.d.).

dragon policy, both DHEs and rural associations were rewarded with preferential tax rates, low-interest loans, subsidies, equipment, training and technical advice. According to Lingohr (2007), there were four, six and 15 DHEs for sweetpotato alone at the national, provincial and county levels, respectively.

This development indicates the increasingly larger role large-scale modern food manufacturing companies are playing in sweetpotato processing in China. It also illustrates the importance of a value chain approach to industry development.

### 4.2 Africa

Sweetpotato is undergoing a resurgence in Africa, motivated by the capability of the crop to withstand climatic shocks and increasing rainfall variability, the food security value of sweetpotato in emergencies and their buffering role under changing prices of cereal crops. Since the early 1990s, CIP and partner institutions have undertaken a range of research projects in Sub Saharan Africa (SSA) on sweetpotato utilisation and processing. The overall aim of this program has been to increase the role of sweetpotato in urban and rural diets, maximise nutritional benefits and enhance the income of rural producers (Thiele et al. 2009). The overall program involves research in the following areas:

- Varietal selection for different end uses;
- Including sweetpotato roots, and derived intermediate products, in a range of commonly consumed foods;
- The technical aspects of processing and product quality;
- The economics of production and processing;
- Consumer and market acceptability studies;
- Orange-fleshed sweetpotato (OFSP);
- Varietal variation and selection;
- Levels of β-carotene /Vitamin A in fresh roots and processed products;
- Evaluation of public health/nutritional benefits of OFSP promotion at community level; and
- Market chain and enterprise development action-research based on sweetpotato.

African research has a strong focus on OFSP mainly because of its potential to combat vitamin A deficiency. According to CIP (n.d.), Vitamin A deficiency threatens an estimated 43 million children under age 5 in SSA and contributes to significant rates of blindness, disease, and premature death in children and pregnant women. Only 125 grams of most orange-fleshed sweetpotato varieties is required to meet the recommended daily intake of vitamin A for children and non-lactating women.

Wheatley and Loechl (2008) reviewed the research undertaken on sweetpotato postharvest utilisation and processing in East Africa in the past two decades to assess outcomes and to identify future research and development priorities. Some of this research focused on fresh root quality and postharvest storage and the development of market chains. However, most attention was given to processing fresh roots into more stable intermediate products (such as dried chips and flour) and their use in a range of locally important snack food such as mandazi and chapatti. In recent years, significant efforts were made to assess the health benefits of OFSP.

The findings of Wheatley and Loechl (2008) are very relevant to the current situation in PNG, and are summarised below:

- Fresh use: sweetpotato was still predominantly used in its fresh form as a supplementary food crop for on-farm or local consumption;
- Fresh root marketing: in the 1990s, only a small percentage of production was traded (5%) and urban markets did not appear to be growing because of strong demand constraints for sweetpotato roots. However, more recent studies found some growth in urban market demand for sweetpotato in line with rapid urbanisation, the 'supermarketisation' of agricultural production, and the advent of OFSP varieties. It was noted that promotional campaigns associated with OFSP were instrumental in driving this growth;
- Starch: sweetpotato is widely used in Asia for starch extraction and animal feed. However, the potential for starch in East Africa was not considered high, based on the absence of any compelling functional advantages of sweetpotato starch and the high raw material cost;

- Animal feed: stockfeed uses were considered to have some potential, especially for intensive cattle production (fodder including vines), pigs and small ruminants, but there was a lack of basic information on this option;
- Processing fresh roots into food products: small-scale rural or urban processing enterprises were assessed to be technically and economically feasible. However, only very limited commercial development employing these technologies had occurred to date, usually within the supportive environment of development projects;
- Orange-fleshed sweetpotato varieties: OFSP had been demonstrated as capable of providing sufficient vitamin A to counteract nutritional deficiencies. Fresh roots and processed products made from OFSP have proven acceptable to consumers when accompanied with a nutritional promotion campaign. However, there were indications that, without such an associated effort, uptake of OFSP varieties in non-intervention areas would have been more limited; and
- The 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) had the potential to improve demand for sweetpotato.

The key message from the review was that although there is a role for OFSP in helping eliminate Vitamin A deficiency, improving the cost-competitiveness of non-OFSP as a 'raw material' for the food industry (that is, flour, dried chips, and starch) would require significant investments in productivity improvements and root dry matter content in the field. Furthermore, with limited research funds, any further investment in sweetpotato processing research had to be weighed against the potential returns on research and development from improving on-farm productivity and postharvest, while taking into account other crops that also required similar investments.

### 4.3 PNG

Sweetpotato processing research and development was institutionalised in PNG with the establishment of the Food Processing and Preservation Unit (FPPU) in 1984, whose goal was to develop a food processing sector in PNG (Cegumalua 2007). FPPU was jointly managed by the Department of Agriculture and Livestock (DAL) (later the Fresh Produce Development Agency (FPDA)) and the University of Technology (UniTech). FPPU was used by DAL/FPDA for product research and development, and by UniTech for teaching food technology students. Under FPDA, the work at FPPU focused on developing successful products for downstream processing and also on assisting entrepreneurs with progressing further into commercial scale agroenterprises. Several products were developed successfully and a number of entrepreneurs were trained. Many more received technical assistance over the counter.

FPPU operations were reviewed in 2007. The review found that the program had failed to achieve its original objectives, despite there being both potential for food processing to develop in PNG and significant interest (Cegumalua 2007). First, there was little uptake of the processing technology by entrepreneurs and trainees. Of those few individuals who did adopt the technology, most did not succeed since they lacked sufficient technical knowledge. Those entrepreneurs and trainees who managed to sustain their business failed to develop into fully-fledged commercial operators because they lacked the necessary capital and 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 were not properly maintained, partly due to poor management and partly due to financial constraints, making its operations unsustainable.

In 2007, after having been in existence for more than 20 years, FPPU was shut down. Interestingly enough, just before the FPPU was shut down, the National Agricultural Development Plan 2007-2016, released in 2006, specifically identified "Developing a food processing industry for staple food crops and vegetables" as one of PNG's development priorities (Ministry of Agriculture and Livestock 2006). 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. The main objective was to replace wheat flour with sweetpotato flour as much as possible, without affecting the integrity of composite flour or

derivative products. This research was made possible by a number of externally funded projects, including:

- a sweetpotato marketing, postharvest and processing project funded by ACIAR[7] (Chang and Irving 2013);
- a yam project funded by the University–Industry Cooperation Foundation of Kangwon National University of South Korea;
- a cassava flour project, funded by the Agricultural Incentive Grant Scheme (AIGS) under the Agricultural Research and Development Support Facility (ARDSF) funded by AusAid; and
- the NARI-EU-ACP-S&T Program (Building Human Resource Capacity in Science and Technology for Agricultural Development in Western Pacific Countries) funded by the European Union.

### 4.4 Global research priorities

CIP conducts regular global surveys of key informants to help establish its research and development priorities and programs (Fuglie 2007). Surveys have been conducted in 1987, 1990, 2005 and more recently 2012/2013.The 2005 survey identified the following priority needs of sweetpotato farmers in developing countries:

- control of viruses (through varietal resistance, quality planting material and crop management);
- small-enterprise development for sweetpotato processing;
- improve availability and quality of sweetpotato planting material;
- select/breed cultivars exhibiting high and stable yield potential;
- select/breed early-bulking cultivars;
- reform agricultural and food policies; and
- improve potato storage methods.

Regional differences in priority needs for sweetpotato were noted. These reflected differences in the role of sweetpotato in respective rural economies, as well as differing capacities of the respective agricultural research systems. For example, respondents from China, with its relatively strong agricultural research system, placed greater importance on long-term research strategies to improve utilisation of genetic resources and pre-breeding, as well as meeting the growing market demand for industrial starch and diverse consumer food products. Respondents from SSA, on the other hand, placed higher priority on shorter-term applied and adaptive research. This included tailoring cultivars and crop management methods to local environmental conditions, and developing propagation systems to disseminate new varieties and reduce crop losses from viruses.

Based on the survey results, Fuglie (2007) concluded that sweetpotato will continue to play an important role in meeting the food, fodder, and income needs of the world's poorest and fastest-growing populations. Further research to address those priority needs, as part of a "pro-poor" development strategy, will help improve the livelihoods of farm households in many developing countries.

## 5. The role of government in rural agroenterprise development

Rural agroenterprise development is an important component for pro-poor growth strategy due to its potential to contribute to rural development and poverty reduction by increasing the demand for agricultural commodities, as well as diversifying income sources, for smallholder farmers (Lundy et al. 2002; Ferris et al. 2006; UNIDO and GTZ 2008; Da Silva and Baker 2009). However, for this to happen there must be an enabling environment that encourages smallholder farmers to participate in

[7]ACIAR have funded several research projects in Papua New Guinea in the last decade, focusing primarily on improving sweetpotato production through variety evaluation, composting, and pest and disease control (viruses and weevils) (ACIAR n.d.). However, increasing attention has been given to issues related to marketing, postharvest management and processing of sweetpotato.

agroenterprises and markets. Potential areas for the state to intervene and provide necessary support to agroenterprises have been identified by Christy et al. (2009).

First, there are "essential enablers" that the state must provide to ensure the efficient functioning of markets for private enterprises. These include the rule of law (such as property rights and their enforcement mechanisms), infrastructure provision (roads, bridges, ports, electricity supply, water supply, telecommunications) and a trade policy conducive to small- and medium-sized agroenterprises. Second, there are "important enablers", which the state can and often does provide. They include research and development, financial services, and standards for, and regulations on, products and production processes. Third, there are "useful enablers" that are sufficient but not necessary conditions for markets to function well. These include reducing red tape and ensuring the ease of doing business, strengthening business development services and facilitating market/value chain linkages.

In the following section, we assess the business environment facing agroenterprises in PNG.

### 5.1 Policy environment

In PNG, the "development of a food processing and preservation industry" (Program Area 2) is listed in the Priority Program Areas for Food and Horticulture Crops Development in the National Agricultural Development Plan 2007-2016, with the objective "to develop food processing and preservation for commercial and cottage industries" (Ministry of Agriculture and Livestock 2006).[8] The first strategy listed under Program Area 2 is to "conduct a feasibility study to establish guidelines for product development, the demand, volume, quality and price", "provide the development plan and a business plan for establishing the food processing and preservation industry in the country", and "determine upstream requirements for the raw materials and supply to the processing industry".

In the 2014 Budget Strategy Paper (Government of PNG 2013), "Improving the enabling business environment for the agriculture sector as well as small to medium enterprises" is listed as one of six key policy priorities, along with macroeconomic stability, health, education, infrastructure, and budget alignment. The microeconomic reform agenda for improving the enabling business environment encompasses:

- encouraging state-owned enterprises (SOEs) to be efficient, with a particular focus on the telecommunication, electricity and transport sectors;
- enforcing the competition and consumer protection law so that markets operate competitively and fairly;
- building the productivity of the tourism and agriculture sectors, especially in rural and remote areas of PNG;
- reducing the cost of doing business and removing regulatory impediments to private sector growth;
- facilitating the development of the small and medium enterprise sector; and
- encouraging the operation of the informal economy and the transition of the informal economy to the formal economy.

These two policy documents suggest that the policy environment may be favourable to developing small-scale sweetpotato processing.

### 5.2 Business environment for sweetpotato processing in PNG

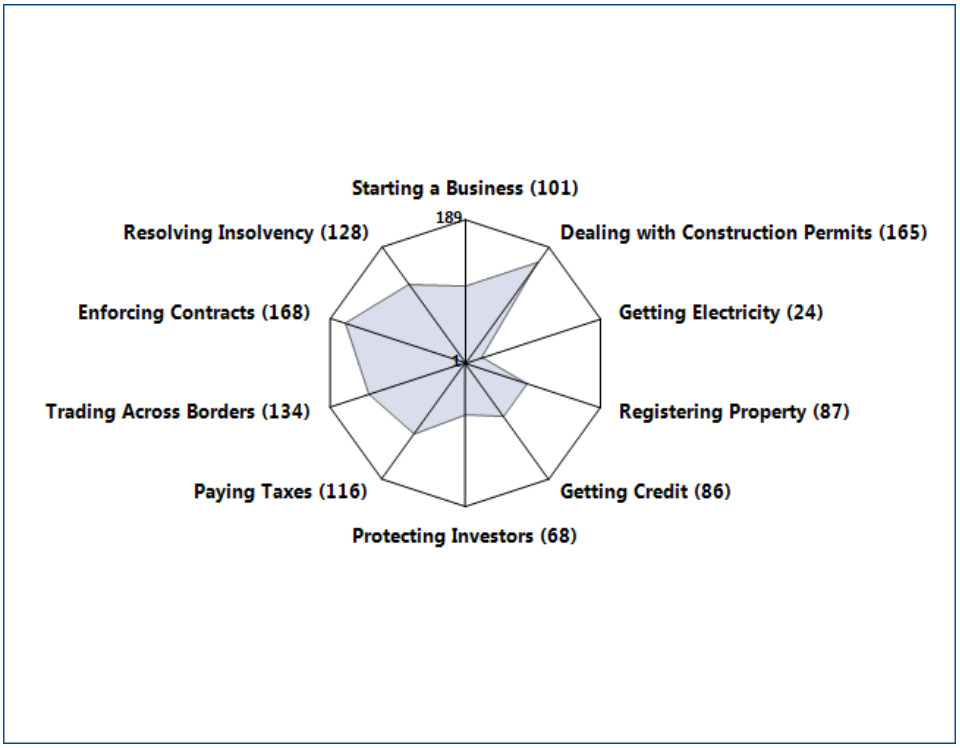
The Doing Business Index was developed by World Bank Group (2003), based on ten indicators. They are: starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting investors, paying taxes, trading across borders, enforcing contracts and resolving insolvency. Based on Doing Business 2014, PNG is ranked 101/189 for starting a business and 168/189 for enforcing contracts (Figure 1). Interestingly enough, PNG is ranked 24/189 for getting electricity even though it requires 4 procedures and takes 66 days to get connected. Furthermore, PNG has one of the lowest electrification rates in the Pacific with approximately 10% of households having access to

[8]The other two program areas are: Program Area 1: Improved food production and Program Area 3: Market development and promotion.

electricity. There are significant shortfalls for business requirements and frequent blackouts. The household burden of not having access to electricity impacts disproportionately on women.

As Christy et al. (2009) point out that the Doing Business Index for a country may not be applicable to rural areas that are not included in the survey, or to sectors that have specific requirements such as agriculture and agro-industries.

**Figure 1. Papua New Guinea's ranks on Doing Business**




*Source: World Bank Group (2013).*

GTZ (2003) identified 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.

When the assessment is made against the ten preconditions as identified by GTZ (2003), PNG fares rather poorly. Issues that are most relevant to PNG are: functioning and effective infrastructure (particularly electricity and transport), access to effective and efficient support services and resources, adaptive management capacity and entrepreneurial competence within business and enterprises, active participation in and ownership of development processes by well-linked stakeholders and ongoing learning from success and failure by all stakeholders.

Infrastructure problems have long been recognised as one of the major constraints to economic development in PNG (ADB n.d.; AusAid 2007; Wilson 2008; Global Development Solutions 2008). Although the PNG government, international aid agencies and development banks have invested heavily in the transport infrastructure in PNG for many years, much is yet to be done (ADB n.d.; AusAid 2007). Issues of capacity, business support services and business links were clearly identified by the review of FPPU by Cegumalua (2007) and the review of the food processing training program by Chang and Irving (2013). This means the current business environment in PNG is not favourable, and the PNG government must do more in improving the business environment for agroenterprise development.

## 6. Future prospects for sweetpotato processing in PNG

The potential for sweetpotato processing in rural development and poverty reduction in developing countries is well recognised. However, the development of a sweetpotato processing sector in PNG faces significant challenges. As a staple food, per capita sweetpotato consumption has declined and is expected to decline further as income increases and urbanisation intensifies. As a stockfeed, sweetpotato has some shortcomings, such as a lower dry matter and relatively indigestible roots (due to the presence of trypsin inhibitors). Its use could eventually be replaced by commercially formulated feed as the scale of production increases. As a raw material for food processing, sweetpotato is not as versatile and not cost competitive as wheat and corn (for flour production), potato (for fries/chips production), and cassava (for starch production).Some of these issues are being addressed through international collaborative R&D projects.

However, to achieve sustained productivity and competitiveness improvements, these efforts must be better coordinated, and much more support and investment is required in strengthening business development services and market/value chain development to build capacity in entrepreneurship and business management.

- *Research and development*. While international collaboration has been helpful and must continue, the PNG government should take a more active role in developing a strategic plan for the development of a food processing industry (initially using sweetpotato as a pilot), and in securing longer-term technical support and collaboration with CGIAR partners such as ACIAR, CIAT and CIP to improve the cost competitiveness of sweetpotato as a raw material for processing through variety selection, postharvest management and value chain coordination.
- *Business linkages*. The importance of value chains in improving sectoral competitiveness has increasingly been recognised as agricultural development strategies shifted from a production-oriented approach to a broader systems perspective that emphasises agri-food chain coordination, value creation and the institutional setting under which chains operate (Konig et al. 2013). Chain coordination is especially important for the agribusiness sector that is characterised as facing high levels of risk and uncertainty. These characteristics stem from the fact that agricultural production is affected by seasons, weather, and pests and diseases, which result in variations in quantities, quality and prices from season to season. Perishability of agricultural products and long distances to markets also make chain coordination a necessity in order to ensure consistency in quality and supply. This means smallholder farmers must be better integrated into value chains.
- *Business development support*. To help small-scale farmers and emerging enterprises integrate into value chains will require support services that change production-oriented mindsets and build new skills in assessing and meeting marketing opportunities. Local agribusiness development services (LBDSs) include technical training and advisory services, financial services, market information services, extension and technology transfer, and business linkages and networking. Given the diversity of the operating environment facing small-scale farmers and entrepreneurs, a

mix of strategies as in pluralistic extension systems, may be required (Heemskerk and Davis 2012). These strategies may include reforming public extension systems (building capacity and balancing public and private service provision), developing the capacity for private LBDSs, and developing agribusiness centres for service provision and learning.

## 7. Conclusions

Sweetpotato has many uses: as a fresh food, as a stockfeed, and as a raw material for flour and starch production. Nearly half of global production is consumed fresh, nearly 40% is used as stockfeed, and less than 5% is used for processing. The main reason for the low level of processing worldwide is that sweetpotato as a raw material for food processing is not competitive with its main rivals. The exception to this trend is China, where there is strong support from the national government and years of international collaboration in improving on-farm productivity and capacity building. Much can be learned from the Chinese, and also African, experiences in sweetpotato product and process technologies, as well as in research priority setting. These experiences can serve as a starting point for adaptation to conditions in PNG.

Given the current environment in PNG, promoting sweetpotato processing into commercially viable enterprises for smallholder farmers and entrepreneurs will be very difficult. However, if the PNG government is determined to develop a food processing industry, as indicated in the National Agricultural Development Plan 2007-1016 and the 2014 Budget White Paper, further research into sweetpotato processing, and related product development, can be used as pilot both to build capacity for food processing, and to investigate whether and how an efficient food processing can be developed in PNG. If this is the case, current research and development activities must be better coordinated, and much more support and investment is required in strengthening business development services and market/value chain development to build capacity in entrepreneurship and business management.

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