Resource and Crop Management Research Monograph No. 29

Marketing Opportunities for Starch and High Quality Flour Production from Cassava and Sweetpotato in Uganda

R.S.B. Ferris, A. Muganga, R. Matovu, S. Kolijn, V. Hagenimana, and E. Karuri

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Preface

The Resource and Crop Management Research Monograph series is designed for the wide dissemination of results of research about the resource and crop management problems of smallholder farmers in sub-Saharan Africa, including socioeconomic and policy-related issues. The range of subject matter is intended to contribute to existing knowledge on improved agricultural principles and policies and the effect they have on the sustainability of small-scale food production systems. These monographs summarize results of studies by IITA researchers and their collaborators in the IITA Resource and Crop Management Division (RCMD). They are generally more substantial in content than journal articles.

The monographs are aimed at scientists and researchers within the national agricultural research systems of Africa, the international research community, policymakers, donors, and international development agencies. Prepublication review and editing of each manuscript are conducted within RCMD.

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Abbreviations and acronyms

acre	a measure of land area, equivalent to 0.4 ha
ACDI	Agricultural Cooperative for Development International
ACIAR	Australian Centre for International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
c.i.f.	commercial, insured freight
CIP	International Potato Centre
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
CMD	cassava mosaic disease
CNp	cassava cyanogenic potential (a measure of the ability of a cassava plant to endogenously build up toxin precursors which, on contact, produce the human toxin hydrogen cyanide)
CPC	Corn Products Corporation
DFID	Department for International Development (UK)
DKK	kroner (Danish currency)
FAO	Food and Agriculture Organization of the United Nations
f.o.b.	free on board
GTZ	Gesellschaft für Technische Zusammenarbeit
HFS	high fructose syrup
IDRC	International Development Research Centre
IDU	Industrial Development Unit
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ISI	International Starch Institute
MS	modified starch
NARO	National Agricultural Research Organization
RSA	Republic of South Africa
UMS	unmodified starch
UNIDO	United Nations Industrial Development Oganization
UNPP	Uganda National Postharvest Program
USAID	United States Agency for International Development
Ush	Ugandan shillings

N.B. Throughout this text, maize and corn starch are used interchangeably.

Executive summary

Due to increasing competition resulting from globalization, Africa is losing the battle to supply agricultural products at competitive world market prices. Lack of efficiency and the inability to adapt to changing world markets mean that African farmers find it increasingly difficult to sell their products into traditional export markets and to service higher value markets. Moreover, this lack of market competitiveness makes African countries the final marketplace for surplus or low quality products from other exporting countries. The challenge for agricultural development researchers is, therefore, to enable African farmers to produce a wider range of agricultural products at prices and quality standards that are competitive with the world market.

Developing the small-scale processing sector is one approach to transforming low value crops into value-added products. This strategy also offers the opportunity to access new and higher value market opportunities. Successful crop processing industries in Asia, Latin America, and West Africa have shown that small-scale farmers can respond to new market opportunities and will invest in processing if markets support stable incomes. Examples of the dramatic effects that processing can have on local production and economic growth have been demonstrated in Nigeria with the rapid growth in *gari* production, in Thailand with the growth of the cassava-based animal feed industry, and in other countries in Asia with an emerging native starch and starch-based product market.

The aim of this project was to evaluate market opportunities in Uganda for transforming cassava and sweetpotato into higher value processed products. In Uganda, cassava and sweetpotato are considered famine reserve crops and processing has not been developed there as in other tropical countries. Much of the root and tuber harvest is consumed in the primary form after boiling or roasting. Processing techniques are limited to traditional methods. These generally produce low quality products that are constrained to low prices within the local marketing system.

Although the small-scale processing sector has not been developed, during the 1980s Uganda had an industrial plant to process cassava into starch. Unfortunately, this capacity was lost during the period of civil unrest and since that time Uganda has imported all its starch needs. This project, therefore, aimed to determine (1) current market demand for starch, (2) the merits of developing a small-scale processing sector compared with reestablishing factory-scale processing capacity, and (3) the technical and economic feasibility of small-scale starch processing technologies which would be appropriate in the Ugandan farming and marketing systems.

Results from the market survey indicated an approximate domestic yearly consumption in Uganda of *1,000–1,500* t of starch, *1,000–1,500* t of liquid glucose, and *400–500* t of dextrins. These markets have a combined yearly value of approximately $2–3 million. The major consumers of starch are in the pharmaceutical, food, and nonfood sectors. The nonfood industries include textiles, wood processing, and cardboard making. The level of starch consumption revealed in this survey was lower than suggested in previous reports. The difference may be because most nonfood processors were using cassava flour as a low-cost replacement for starch.

The survey found that virtually all starch was imported from India, Kenya, or European sources and the import prices in 1998 ranged from $400 to $800/t, cost, insurance, freight (c.i.f.) Kampala. A rapid market survey was also conducted in Kenya as it was suggested in previous studies that Uganda could export surplus starch into surrounding countries. The Kenya survey revealed there are two starch factories in Kenya, and that supply from Kenya was in the range of 20,000 t/yr. Kenya suppliers are already exporting into Uganda and Tanzania and, given the level of production and capacity to supply a range of starch products to the region, it would appear that Kenyan suppliers would increase market penetration into Uganda in the next 5 years. Interviews with Kenyan operators also suggested that the market for starch and starch products is becoming more competitive with the establishment of new starch trading companies in Nairobi and, therefore, the potential for Uganda to export into Kenya is unlikely, unless a specific link to the brewing industry is developed.

Analysis of the possibilities for the future supply of the Ugandan starch market indicated four options: (1) continued importation, (2) medium-scale factory processing, (3) small-scale starch processing, and (4) small-scale processing of high quality flour as a replacement for starch.

For most high-grade starch and high-grade starch products, the option for continued importation appears to be the most sensible. However, the fourth option, to produce high quality root crop flour, also has a number of attractions. For cassava, high quality flour could gain a premium price in the local food markets. High quality cassava flour is already used as a substitute for starch in the nonfood sectors and could be used as a partial replacement for wheat and maize flour in the food and animal feed processing sectors.

With regard to the option of scale, the Government of Uganda has already commissioned three reports on the technologies and funding required for factory-level starch processing. The cost of such an endeavor is in the region of $2–6 million, depending on the number of products to be manufactured, and several interviewees considered that it would be more cost effective to invest in factory operations in lower cost countries to supply Uganda, rather than develop local industrial capacity. This study, therefore, focused on the potential for small-scale technologies with regard to market intervention for root crop products.

To test the feasibility of local small-scale starch processing, equipment was imported from Vietnam and tested at the on-station and on-farm levels. The Vietnamese equipment proved to be simple to replicate and cost–benefit analysis from on-station trials found that starch could be produced for approximately $170–200/t, with an internal rate of return at approximately 30–40%. When this same technology was tested on-farm, the production costs were $300–$350 t, including the costs of loan and equipment repayment. These figures compare favorably with world market prices of starch between $200 and $600/t, c.i.f. Kampala. Tests to date indicate that farm-level production of starch is both technically and economically viable to supply the nonfood sector, although more product marketing is required to establish links with private-sector partners and to evaluate the sustainability of this agro-enterprise.

Supplementary studies found that starch processing was more profitable when conducted alongside flour processing which employs similar equipment, as waste from starch processing could be incorporated into flour. As margins are small, the sales of waste materials from starch are an important factor in the longer term sustainability of the process.

Introduction

This study was conducted to identify the domestic demand for starch in Uganda and to determine economic methods for supplying this market. The study compared four options for the supply of processed root crop products, but focused on the prospects for developing small-scale, rural agro-processing enterprises in Uganda to supply value-added products to urban consumer markets and industrial processors. The selected crops in this study were cassava and sweetpotato, which are major food security crops in Uganda, and the target markets were for starch and high quality flour. The long-term strategy of this type of research is to create and support agro-enterprise ventures, which contribute towards the growth of a more vibrant rural economy, providing sustainable employment and increased income for rural communities in Africa.

Unlike West Africa, Latin America, and Asia, where root crops are processed into a range of higher value products, in Uganda, root crops are considered a low value famine reserve and the harvest is used almost entirely for low value food products. Virtually all sweetpotato and approximately half of the cassava harvest are consumed at the village, after boiling or roasting. Cassava is processed into traditional products such as chips, flour, pancakes, beer, and gin; sweetpotato is processed to a lesser degree into dried slices in some northern areas of the country. For the purposes of this study, traditionally processed "chips" refers to a mix of cassava pieces and rough flour, made by pounding sun dried roots. Cassava flour is consumed after being mixed with water to produce a dough or mash; the flour is used either alone or mixed with millet flour to produce a more nutritious meal. Although market opportunities exist for cassava products, farmers are generally reluctant to grow more than they can easily sell or eat and the quality of processed products is generally low. Poor product quality and lack of processing equipment are significant barriers to increased sales of root and tuber crops, and these factors prevent farmers from gaining premium prices for their products and reaching new markets.

This study, therefore, investigated the market opportunities for higher quality, value-added root crop products to supply existing and new markets in the food and industrial sectors in Uganda. The project also evaluated improved small-scale processing technologies that would enable farmers to process improved quality products at increased volume and efficiency and obtain access to higher value markets.

Starch was selected as the target commodity, not only because it is a multiuse product with a rapidly expanding global market, but also because Uganda has a history of starch production. Until the 1980s, Uganda had an industrial capacity for starch processing that supplied the textile industry and there is much interest from the Government of Uganda in rehabilitating industrial starch processing. However, much has changed since the first years of independence. Uganda underwent a protracted period of civil unrest during the 1980s that badly disrupted the traditional industries, including cotton, and this led to the loss of associated markets in textiles and starch processing. The civil unrest was also responsible for loss and severe damage to the manufacturing skills base and infrastructure. This market survey, therefore, aimed to establish the size of the current starch market, major users, sources of supply, and market prices in Uganda. Information was also required on the types and quality of starch being used by the industrial sectors and the demand for starch-derived products such as glucose syrup and glues.

Although the survey focused on starch, it was recognized that there were a number of linkages in the production and marketing of starch and flours. Therefore, to provide more clarity in the market analysis and strategies for market intervention, both starch and flours were investigated within the market survey to ascertain the opportunities for supplying the local market with a range of products to supplement or replace imported goods.

Having established the demand for processed root crop products, the next problem is how to supply this market. In the 1970s and early 1980s, Uganda had an industrial capacity for starch processing which was built with Government funds. Since the end of the civil war when the main factory at Lira was destroyed, the Government has been unable to rehabilitate the project, and the private sector has been unwilling to invest in this industry despite generous Government incentives. An alternative approach to industrial starch processing is to initiate small-scale starch processing. This approach has been successful in Latin America and Asia, where small-scale entrepreneurs operate both independently and in conjunction with medium-scale processors.

Developing the small-scale sector offers several advantages compared with industrial development, including lower investment costs, greater locational options, lower production costs, and the use of rural resources, skills, and manpower. In Uganda, 85% of the population reside in the rural areas; employment opportunities are few and rural development slow. Although the Government has been successful in redeveloping some of the macroutilities such as roads, electricity, and civil security, development of the rural economy has been limited. The introduction of small-scale processing technologies offers the prospects of farmers moving beyond subsistence and stimulating demand for their crops. Similar strategies have been successful in other countries, such as Nigeria, Brazil, and China. The challenge is to adapt simple but robust technologies within the traditional farming systems of a country such as Uganda, and link the production of a primary commodity with new and higher value markets.

Objectives of the study

1. Review trends in the production of cassava and sweetpotato in Uganda.
2. Provide an overview of world production and major uses of starch.
3. Conduct a subsector market survey to determine the size of the starch market in Uganda, the major users, and the processes that require starch.

4. Evaluate technical options to supply identified market opportunities.
5. Identify and transfer small-scale starch and flour processing technologies and evaluate their technical and economic feasibility in Uganda.
6. Compare alternative strategies for market intervention to supply market needs.
7. Identify priorities for future areas of research.

Project strategy

The strategy in this project was to use a combination of market analysis and processing data to determine the most viable means of supplying the domestic starch market in Uganda. The project used a combination of primary and secondary data to review and analyze trends in both the production and prices of root crops and root crop products in Uganda. Secondary information was used to review the starch industry in Uganda and overseas. Market surveys were conducted to determine the current demand for starch in Uganda by gathering information on uses, costs, import levels, and sources of starch in terms of crop base and production site.

Parallel to the market studies, processing equipment was fabricated and tested both on-station and on-farm to evaluate the feasibility of transforming cassava into starch and high quality flour. A starch extraction facility was developed at IITA–Uganda with the assistance of the Vietnamese national postharvest program. The starch facility was built to gather information on the design, costs, and suitability of small-scale starch extraction for village-level processing in Uganda. The starch processing equipment was given a preliminary test with a farmers' association to assess the financial viability of the system. Similar studies were made to develop technologies for high quality flour. Test samples of both starch and high quality flour were delivered to industrial processors with a view to establishing contracts for supply.

I

Uganda: geography and economy

Geography

The Republic of Uganda is located in East Africa. It is a landlocked country having borders with Kenya, Tanzania, Rwanda, the Democratic Republic of Congo, and the Sudan. The country has an area of 241,039 km², 18% of which are open water and swamps and 12% forest and game parks. In the central and western regions of the country, there is a bimodal rainfall pattern, with the heavier rains from March until May and lighter rains from September to December. The rainfall pattern shifts towards a unimodal rainfall pattern in the northern districts. Average rainfall is from 1,000 to 1,500 mm/year and the average temperature ranges from 15 °C by night to 28 °C by day.

Population. Based on information from the latest census (1991), the current Ugandan population is estimated to be 21 million people. The annual growth rate is approximately 2.5–2.7% and the population density is 85–90 persons/km². According to these figures, the population in Uganda will approach 30 million people by the year 2020. The rate of urbanization is increasing, with over 16% of the population (3.5 million) living in urban areas. Records show 4.2% of the population were living in the largest 150 urban centers in 1959 and 11.3% by 1991. For many people, the reason for moving to the cities was not to seek employment but to escape areas of civil unrest.

Economy

The economy in Uganda is predominantly agrarian, with nearly 90% of the population dependent on farming. Most farmers are small scale and grow crops on plots of 5–10 acres (2–4 ha) to support their families. The country is self-sufficient in food, although there are large supplies of food aid for areas of the country that suffer from rebel incursions.

During the period after independence, 1962–1970, Uganda had a flourishing economy with a gross domestic product (GDP) of 5% per annum. Between 1979 and 1985, Uganda faced a period of civil and military unrest resulting in the destruction of the economic and social infrastructure. Since 1986, the National Resistance Movement Government has introduced and implemented a recovery plan which is steering the country towards economic prosperity once again.

The new policies have aimed to minimize financial mismanagement, reduce the size of the public sector, and liberalize the economy. As a result of these reforms, economic growth has averaged 6% since 1986 and reached 10% in 1994. Although the rate of annual growth slowed slightly from 1995 to 1997, there is a steady positive trend, and this growth is supported by industrial growth which is increasing at a rate of over 10% per year. An important factor in the regrowth of Uganda was the decision in 1983 to allow the expelled Asians to return and reclaim their property. Although many returned only to sell their property, some 7,000 to 8,000 Asians have remained, and this group consists largely of industrialists, managers, and engineers.

Traditional export markets. Traditional export crops include coffee, tea, cotton, and tobacco (Table 1). The coffee boom which started in 1994 has shown a dramatic and sustained growth in exports from 2 million bags in 1993, with export earnings of $107 million, to over 3 million bags in 1996 with earnings of nearly $400 million.

As part of the privatization plan, the Commonwealth Development Corporation has rehabilitated six tea plantations, and export earnings in 1997 were more than $5.5 million. Cotton is an area of interest for this study as it is linked with the textile and starch markets. The cotton industry virtually collapsed during the period of civil unrest, from 470,000 bales in 1970 to 31,900 bales in 1990. Following investment from the World Bank, Lonhro, and other Asian and South African investors, it is thought that production will increase up to 160,000 bales with an export value of $40 million in 1998–2000. Unfortunately, the expected boom in cotton is yet to be realized and many of the problems have been caused by extremely poor weather associated with the El Niño of 1997/8 and the financial mismanagement in the procurement chain which led to widespread frustration among producers.

Nontraditional export markets. The return of stability and capital has also led to strong growth in the nontraditional export industries such as producing flowers, maize, beans, and spices. The export of fish and fish products has been an area of particularly high growth with the development of a number of fish factories on the shores of Lake Victoria. Unfortunately, the rise in income expectation has led to some individuals using pesticides and herbicides to increase their catch size and a spate of fish poisonings led to the European Union placing a temporary ban on fish importation from Uganda (FEWS 1999).

The importance of cassava and sweetpotato

In Uganda, cassava and sweetpotato are essential crops for food security and household income. Although both crops are exotic and were introduced only in the past 100–150 years, they have become integral to the cropping mix. In terms of national production, cassava now ranks second, after highland cooking banana, with

Table 1. Export by value of principal products, US$000s, 1990–1997.

Commodity	1990	1991	1992	1993	1994	1995	1996	1997
Traditional export crops								
Coffee	140,384	117,641	95,372	106,775	343,289	384,122	396,206	309,740
Cotton	5,795	11,731	8,218	5,505	3,485	3,129	14,961	29,197
Tea	3,566	6,780	7,721	11,141	11,804	8,698	17,059	33,577
Tobacco	2,941	4,533	4,204	7,011	8,269	7,397	4,626	12,150
Nontraditional exports								
Maize	3,318	4,188	3,894	23,319	28,666	19,302	17,885	19,407
Beans and other legumes	4,150	4,274	2,782	12,580	12,900	10,847	15,950	10,502
Fish and fish products	1,386	5,313	6,498	8,943	10,403	17,541	45,030	29,980
Cattle hides	4,072	3,363	3,375	5,228	10,549	8,886	7,666	7,729
Sesame seed	5,234	10,517	6,478	2,776	1,548	5,282	9,303	1,520
Soybean		468		2,056	756	880	2,913	240
Soap				1,302	1,739	2,630	2,241	1,977
Electric current	1,218	923	1,537	728	2,245	2,414	4,164	11,688
Cocoa beans	504	374	281	714	586	442	4,105	887
Goat and sheep skins	2,064	968	664	619	344	38	1	0
Hoes and hand tools	109	445	462	381	1,018	2,160	813	185
Pepper		197	210	350	444	88	73	63
Vanilla		176		328	674	7	809	4
Live animals	106			285	150	33	113	26
Fruits				265	238	267	34	154
Groundnut		121	34	251	365	393	15	21
Banana		162	208	173	658		910	16
Roses				158	531	34	2,809	1,114
Ginger		121	105	132	20	27	61	12
Gold		9,648	49	89	244	23,197	64,090	80,590
Other products (1)	2811	2320	4,675	10,122	19,034	56,124	95,156	56,690
Total								
Traditional export crops	152,686	140,685	115,515	130,432	366,847	403,346	432,852	384,664
Nontraditional exports	24,972	43,578	31,252	70,799	93,112	150,592	274,141	222,805
All products	177,658	184,263	146,767	201,231	459,959	553,938	706,993	607,469

Source: Statistics Department, Ministry of Finance, Planning, and Economic Development, Entebbe.

a production of approximately 2.5 million t and sweetpotato fourth, with a production of approximately 2 million t. Farmers have adopted cassava and sweetpotato in preference to indigenous crops because of their ease of propagation and ability to produce stable yields in areas of marginal soil fertility, under variable rainfall, and low input management techniques. Cassava and sweetpotato are also relatively tolerant to pests and diseases and both crops have been successful in the drier areas of Uganda which do not support banana production.

Production trends for cassava and sweetpotato

Cassava production. In addition to a reliable agronomic performance, cassava is also popular as it is efficient to produce in terms of labor costs and roots can be harvested or stored in the ground over a period from 6 months to 3 years. Because of this highly flexible harvest date, farmers can sell roots when they need cash and for many farmers cassava is considered a "landbank." Cassava can also be processed into a number of traditional products, such as chips, flour, pancakes, beer, and gin and therefore is less prone to the famine–glut marketing cycles associated with more seasonal crops, such as maize and sorghum. In the past 30 years, cassava production in Uganda has risen from 2 million t in the 1970s to over 3.5 million t in the early 1990s. Despite the suitability of cassava for the local farming system, production in Uganda has recently suffered from a virulent form of cassava mosaic disease (CMD). This has caused widespread crop losses, particularly in the period from 1988 to 1992.

As a result of this disease epidemic, cassava production has fallen significantly and in some areas of Uganda losses of up to 80% have been reported (Otim-Nape 1997a,b). Although the severity of the CMD epidemic in Uganda is not fully reflected in the Ministry of Agriculture production data (Fig. 2), the cassava production data indicate a decline from 3.5 million t in 1989 to a level of 2.25 million t in 1996.

To overcome the CMD epidemic, the national cassava program, in collaboration with several development agencies, including the Gatsby Charitable Foundation, the Department for International Development, UK (DFID), and the United States Agency for International Development (USAID), has initiated major multiplication projects to resupply Ugandan farmers with resistant cassava planting material (Ferris et al. 1997; Opio Odongo and Otim-Nape 1999). The resistant varieties, which were developed by NARO and IITA, have been multiplied and distributed throughout the country and it is expected that cassava production will return and exceed the level of 3.5–4.0 million t within the next 5 years. One of the reasons for the rapid recovery in yield is that farmers are being resupplied with new, improved varieties.

In a monocrop, the older varieties when not affected by CMD produce from 6 to 8 t/ha in farmers' fields, whereas new varieties produce from 10 to 15 t/ha. The rapid increase in yield in the primary multiplication areas is already having a strong downward effect on cassava prices at the markets and it is anticipated that prices for cassava and cassava products will stabilize at levels that are near to or below the 10-year average.

Sweetpotato production. Sweetpotato is favored due to its ability to grow two crops per year in the bimodal rainfall pattern. As with cassava, growing sweetpotato is labor efficient and the crop requires little maintenance once the canopy has become established. After harvest, the tubers have a shelf life of 2–3 weeks and this provides sufficient time for transport over relatively large distances, even within the fragmented bulking and marketing systems in Uganda. Production has steadily increased to nearly 2.5 million t since 1986 (Fig. 1). This increase has, to a large extent, filled the food supply gap caused by the CMD epidemic and loss of cassava production.

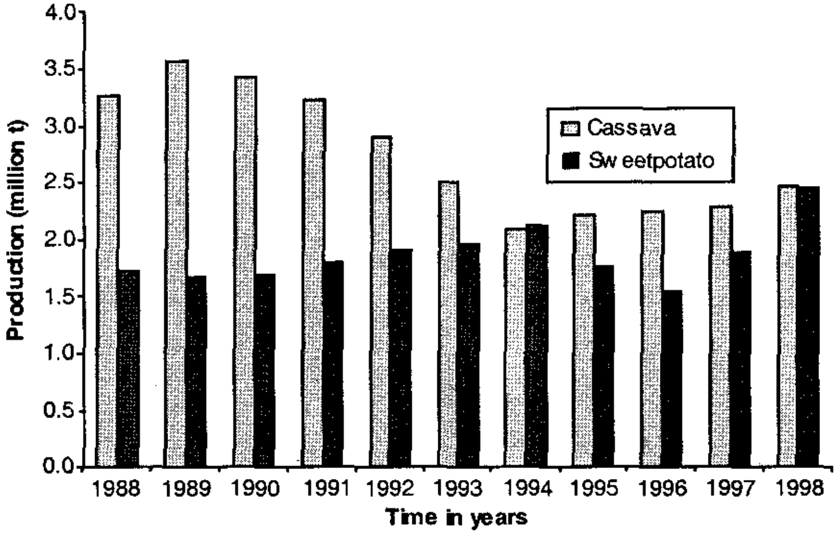

Figure 1. National production of cassava and sweetpotato (million t).
Source: Ministry of Agriculture, Uganda.

Future trends in root crop production in sub-Saharan Africa

It is predicted that root crop production will increase by approximately 2.75–3% per annum in sub-Saharan Africa over the next 20 years (Table 2, Scott et al. 2000). Given this expected rise in production, which is based on population and economic growth factors, the food security role of these crops will become increasingly important. However, a key question is whether cassava and sweetpotato will remain subsistence crops in countries such as Uganda, or whether such crops can play a more important role in economic development. Prospects for a transition from a food store to a leading economic commodity are unlikely, unless new market opportunities can be identified and farmers can supply surplus production into expanding and/or higher value markets, as has been achieved in West Africa, Latin America, and Asia.

Table 2. Production trends for cassava and other root and tuber crops up to 2020 (000,000 t).

		Additional output/2020	
Major region	1993	Baseline	High growth
Sub-Saharan Africa	88.06	80.48	95.98
SE Asia	42.35	5.6	5.95
Latin American countries	30.51	12.42	19.98

Source: Scott et al. 2000.

NB. Cassava, roughly 95%, 5% other roots and tubers.

Price trends for cassava and sweetpotato

The price information shows a series of peaks for cassava and sweetpotato over the past 10 years (Fig. 2). These price fluctuations were the result of poor harvests caused by adverse weather. The peak in 1992/3 was caused by a regional drought, the peak in 1994 by the Rwandan crisis, although (interestingly) only sweetpotato prices were affected. This was probably the result of a strong demand for food that could be shipped and stored. As fresh cassava cannot be stored for more than 2–3 days, it was not purchased. In 1997/8, the dramatic price rises were caused by a combination of drought in 1996/7, the CMD effect on cassava production, and the El Niño event which caused widespread flooding across East Africa in 1998.

When the price data are compared with the 10-year average, it is apparent that the market recovered relatively quickly after peak prices, i.e., within a season, as either farmers increased production in response to favorable prices or production simply recovered owing to improved weather. The improved supply caused a decline in prices and stabilization. During the 1998/9 season, farmers experienced a 10-year high in prices rapidly followed by a 10-year low. It is most unlikely that price changes were a reflection of farmers responding to market opportunities. The data show that the price simply stabilized at the 10-year price and this supports the view that farmers grow only what they know can be easily consumed or sold in the local market. The variations in price are, therefore, a function of adverse weather causing crop losses rather than farmers planning to supply highly priced markets. When nominal price data were deflated over a 10-year period, the underlying trend reveals (Fig. 2) that farmers are not gaining from increased prices for their goods over time. This suggests that in the long term, increases in production for countries such as Uganda, which have not developed alternative markets for root crops, will be driven by population growth and demographic shifts rather than farmers increasing production to supply more lucrative and expanding market demands.

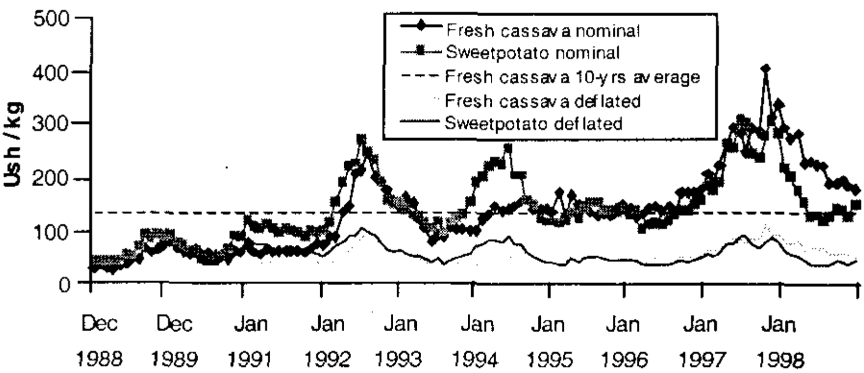

Figure 2. Trends of nominal and deflated fresh cassava and sweetpotato prices in Kampala district, December 1988 to December 1998.

Farmers' ability to adjust to changes in the market

As part of a national baseline survey for cassava (IITA, unpublished data), farmers were questioned about cassava sales, access to market information, and their ability to react to changes in the market. Most cassava farmers sold a range of products including fresh cassava, processed cassava chips, flour, beer, and gin. Farmers indicated they had little access to official sources of market information but most had a reasonable knowledge of local prices. Market supplies were dependent upon the season and favorable conditions. In poor weather, farmers with surplus production have no problems with sales and traders buy from their farms at relatively good prices, as occurred during the 1997/8 season (a). Alternatively, when the crop is generally good, and farmers face low prices due to oversupply, they are required to transport goods to more distant markets and sell produce often at base prices, as occurred in 1998 (b). Most farmers indicated they were unable to respond quickly to changes in demand and were prone to unstable market prices as they had few avenues in which to diversify their risks.

In 1998/99 season (a), the prices of cassava and cassava products fell dramatically across the country. In the districts of Lira and Apac, prices for dry cassava chips fell from $200/t to less than $50/t within 12 months. Farmers were forced to sell at the lowest price or opt not to harvest. Lack of market information combined with lack of access to new technologies means that even progressive farmers, who may wish to adopt new processing technologies to supply higher value markets, are not able to buy such equipment and thereby develop strategies to address market forces.

To counter these problems, IITA and the International Potato Center (CIP) have established a number of processing sites in collaboration with the Uganda National Postharvest Program (UNPP) and NGOs/farmers' associations to test the commercial potential for processing cassava and sweetpotato into higher quality and higher value products. For cassava, the processing sites are focusing on methods to produce higher quality chips, flour, and more recently, starch. One lesson from this research has been that for farmers to have long-term success, they need to have a flexible marketing strategy. As market prices change for a specific commodity, farmers need to be able to adjust their outputs to supply the best option, including fresh cassava, cassava chips, flour, animal feed, brewing cassava into beer, distilling the beer into gin, or seeking potentially higher profits via starch and secondary processed goods.

Compared with cassava, the market options for sweetpotato are less clear. Although cassava is already processed and traded in Uganda, sales of sweetpotato are almost exclusively confined to fresh tubers. To explore the market possibilities for processed sweetpotato products, CIP has set up experimental sites in Soroti and Lira districts to promote the sales of sweetpotato chips and flour. The CIP/UNPP scientists are also promoting the use of sweetpotato flour in confectionery products such as bread, cakes, and cookies in an attempt to stimulate demand for flour. The current status is that market options for sweetpotato products remain limited. Sweetpotato chips are not commonly traded beyond household sales and sweetpotato flour is an untested product. Techniques for processing sweetpotato into starch have not been tested in Uganda and at this stage, market options are therefore theoretical. In this situation, CIP has taken the pragmatic approach to test a range of potential market options including:

- Increased production of orange-fleshed tubers for processing into confectionery products, as a means to develop markets for high Vitamin A products.
- Market testing of sweetpotato chips, flour, and starch.
- Development of products such as sweetpotato jam and ketchup.
- On-farm testing of sweetpotato leaves as an animal feed for pigs.

Options for starch within the marketing mix of cassava processors

Having a successful marketing mix is closely associated with being able to adapt to prevailing market conditions. In 1997/8, the retail price of cassava flour was approximately \$400–550/t; which was similar to the price for imported starch (\$400–600). At that time it was more economic to process flour and import starch and prospects for marketing local starch appeared bleak. However, the situation in 1999 is quite different, and farmers are selling cassava at low prices < \$50/t. This fall in cassava prices makes flour a less attractive option for farmers, but makes cassava a more competitive raw material for processing into starch.

Although the raw material is now at an attractive price for starch processing, little is known about the starch market in Uganda. There has been no analysis of the options for processing starch in Uganda; there are no reliable data on the size of the market, the potential buyers, and the quality of starch they require. Therefore, this study set out to gather more detailed information on the starch market in Uganda and to determine whether local processors could compete with imported starch.

II

Starch properties, methods of production, and products

Starch is a highly versatile, renewable natural resource which is used in virtually all industrial sectors. In the natural state, starch is used as a binder, stabilizer, surfactant, texturizer, and bulking agent. Starch is also processed into a range of products including adhesives, sweeteners, and other more specialized products, such as biodegradable plastics and superabsorbent polymers. Essentially, starch is a carbohydrate polymer of glucose found as a nutritive reserve in plants. Starch is composed of two types of polysaccharide molecules, one linear (amylose) and the other branched (amylopectin). In natural starch, these molecules are closely associated in structured microscopic granules, and in cassava starch, amylose content typically lies within the range of 16–18% relative to amylopectin (Bagalapolan 1988).

Starch properties

Starch quality is determined by a number of characteristics including physical, chemical, and rheological properties. The physical and chemical quality factors include color, odor, pH, flow properties, granular size, shape, molecular weight, and amylose content. The most important rheological characteristics of starch pastes include gelatinization temperature, viscosity, swelling capacity, gel clarity, and freeze–thaw stability or resistance to retrogradation.

Physical and chemical properties

Grade A starch is a bright white color and the degree of whiteness can be assessed using either a simple visual score or by testing with a spectrophotometer. A simple test to assess visual contamination is by observing a starch suspension which is pressed between glass plates, the contaminant particles being viewed against a white sheet. Odor caused by fermentation on drying or moldiness from poor storage is undesirable. Starch pH should fall within the range of 4–7 for edible starch; high quality cassava starch is typically within the range of 6.3–6.5. Flow properties are measured by the amount of powdered starch that will pass through a sieve within a determined time period. High flow rates indicate higher quality and low flow rates indicate a high moisture content or lumpiness. Starch granules vary in size; for cassava, the range is from 5 to 40 μm. Granule shape can be determined by viewing under a scanning electron microscope. Cassava starch granules are mainly round, with a flattened surface on one side containing a conical pit. Molecular weight is determined by the amylopectin content, and the ratio between amylose and amylopectin is an important basic characteristic that affects starch performance. All of these parameters are used to classify starch into grades that relate to quality, price, and application.

Rheological properties

The rheological properties are of most interest to processors as starch is generally used as an aqueous suspension. The behavior of starch on pasting, cooking, and in various forms of processing, determines product quality. Most forms of starch modification are involved with changing the rheological performance of a starch and tailoring rheological characteristics to increase process efficiency and end-product quality.

Gelatinization temperature. When an aqueous suspension of starch is heated, water molecules around the granule disrupt the hydrogen bonding and enter the granules which then swell. This swelling and the absorption of water are an irreversible process termed gelatinization. The gelatinization process leads to the preparation of a viscous suspension and this determines the temperature at which a starch paste takes on the desired processing qualities. Due to the differences in starch granules' size and their heterogeneous structure, gelatinization does not occur at a specific temperature but across a temperature range. For cassava, this is from 58 to 70 °C.

Various methods of modifying starch, such as cross-linking, reduce the gelatinization temperature, whereas the addition of surfactants, such as potassium palmitate, which prevent the penetration of water into the starch granules, increases the gelatinization temperature. These modifications stabilize the viscous behavior of the paste, making it more resistant to damage by acids, heat, or shear forces, and thus enhance the performance of starch during processing. There is some evidence that certain varieties of cassava have different gelatinization temperatures and according to Bagalapalan (1988) a lower gelatinization temperature is associated with reduced cooking quality.

Viscosity. When an aqueous concentrated suspension of starch is heated to the gelatinization temperature, starch granules swell by rapidly absorbing the available water. As the starch granules absorb water, solubles are leached from the granules into the aqueous phase. When the available volume of water has been absorbed, these solubles diffuse back into the granules until an equilibrium is reached. This complex structural matrix is highly dynamic and viscosity can be altered by changes in water content, temperature, mechanical forces, and pH. As with the gelatinization temperature, various forms of physical and chemical modifications affect starch viscosity. For example, starch viscosity is increased by esterification or etherification.

The most common method for measuring starch viscosity is by using a Brabender Visco-Amylograph. This instrument measures changes in the viscosity of a standardized starch suspension when it is subjected to a predetermined heating and cooking cycle. A Brabender Visco-Amylograph curve provides five key data points.

1. Peak viscosity represents the highest viscosity that starch paste can reach.
2. Viscosity at 95 °C, which in relation to peak viscosity gives an idea of the ease of cooking the starch.
3. Viscosity after cooking at 95 °C for a certain period, which reflects the stability of the paste.
4. Viscosity of the paste after cooling to 50 °C, which is a measure of the setback, i.e., the thickening or stiffening effect produced by cooking.
5. Final viscosity after stirring for a definite period at 50 °C indicates the stability of the cooked paste.

Swelling capacity and solubility. Swelling capacity can be defined as the maximum increase in volume and weight which starch undergoes when allowed to swell freely in water. Solubility is a measure of the solutes which are leached from starch granules when tested for swelling capacity. Swelling capacity of starch is dependent upon the strength and nature of the associate forces within the network of the starch granule. Factors affecting the associative forces include (1) amylose:amylopectin ratio, (2) molecular weight of the fractions, (3) degree of branching, (4) conformation, and (5) length of the outer branches of the amylopectin. Starches fall into three groups, according to the level of association. Cereal starches have the highest degree of association and the lowest swelling power and solubility, followed by root starches and tuber starches. The swelling power can be altered by acid modification or hypochlorite oxidation which weakens the granule network, causing a higher swelling capacity. Cross-linking increases the bonding between starch molecules and this lowers the swelling and solubility.

Paste clarity. A suspension of starch in water is opaque and gelatinization increases transparency. Paste clarity is related to the state of dispersion, i.e., the level of dilution and the retrogradation of a sample. The term retrogradation refers to the deterioration in quality of a sample over a period of time. Cassava starch has a high swelling power and a low retrogradation tendency, and therefore has good paste clarity that is preferred for products requiring clear thickening agents as used in soups and pie fillings.

Freeze–thaw stability. On cooling, the molecules in a starch paste become less soluble and suffer retrogradation, i.e., a loss in quality. The effects of retrogradation include curdling of sauces on thawing, staling of baked products, and the formation of a skin on the surface of a starch gel. For many processed food products, it is desirable to have an elastic starch paste that does not undergo retrogradation on freeze–thaw cycles. Cross-linking starch and the addition of surfactants can considerably improve the ability of a gel to withstand freeze–thaw cycles.

Table 3. Estimated world starch production (1992) (000 t).

Region or country	Maize	Sweet-potato	Cassava	Wheat	Potato	Other	Total	% World production
North America	13,450	–	–	200	55	20	13,725	41
USA	13,200	–	–	50	50	20	13,320	40
Canada	250	–	–	150	5	–	405	1
Latin America	1,000	–	330	–	–	–	1,330	4
European Union	3,400	–	–	1,400	1,200	–	6,000	18
Eastern Europe	300	–	–	–	300	–	600	2
Africa	–	–	20	–	–	–	20	<1
Asia	3,020	4,165	3,442	165	400	30	11,222	34
China	–	4,000	300	–	–	–	4,300	13
Japan	2,500	120	–	150	400	–	3,170	10
Thailand	–	–	1,800	–	–	–	1,800	5
Indonesia	–	–	800	–	–	–	800	2
India	200	–	350	–	–	–	550	2
Vietnam	–	–	90	–	–	–	90	<1
The Philippines	75	–	17	–	–	–	92	<1
Malaysia	–	–	70	–	–	–	100	<1
Taiwan	45	15	15	15	–	30	90	<1
South Korea	200	30	–	–	–	–	230	1
Australia	50	–	–	300	–	–	350	1
Total	21,220	4,165	3,792	2,065	1,955	50	33,247	100
Percent share	64%	13%	11%	6%	6%	0%	100%	

Source: Ostertag 1996.

Starch production and products

World starch production, markets, and products. In 1997, world production of starch was approximately 35 million t with a global market value of approximately $14 billion. As most industries have some application for starch, consumption is closely linked with industrial development (Lynam 1987, Table 3). The USA is the largest starch producer, accounting for over 40% of world production, and is also the highest starch consumer, using over 50% of world production. Europe produces nearly 20% of world production, followed by China (13%), and Japan (10%).

Starch production and consumption in China run somewhat counter to the general market trends and China is unusual in that almost all the starch is produced from sweetpotato, whereas in the USA, Europe, and Japan, maize is the major substrate. In most of the world, starch is processed using industrial techniques, whereas in China, starch is extracted using traditional village methods.

The main starch markets in China are for local noodle production with some supplies for monosodium glutamate. On the global market, starch supplies the industrial food and nonfood processing markets. Nevertheless, China is the second largest starch producing country with an annual yield of over 4 million t (Marter and Timmins 1992).

Table 4. Starch source distribution in global market (excluding China).

Starch type	Percentage
Maize (Corn)	80
Potato	8
Cassava	6
Wheat	4
Rice and others	0.5

Source: ISI 1998.

Sources of starch

Starch is commercially extracted from maize (corn), sweetpotato, cassava, wheat, rice, potato, and to a lesser extent from sorghum, arrowroot, sago palm, and banana. Starch from each source has slightly different functional properties, such as the gelatinization temperature, viscosity, and swelling capacity; however, they all have similar chemical reactions and are usually interchangeable. In cassava and sweetpotato, up to 28% of the root fresh weight is starch, whereas in cereal crops this figure is approximately 75% of the grain.

Using chemical fertilizers and efficient methods of crop production, 7–10 t/ha starch dry matter can be produced. Industrial starch plants in Thailand expect to extract 25% of the fresh weight of cassava as starch and seek efficiencies which increase the rate of extraction up to 26–27% (Pers comm, Rupert Best). In the traditional rainfed, low input systems of countries such as Uganda, the level of starch extraction from cassava may be significantly less, i.e., in the range of 10–15% extraction with a yield of 1.0–2.0 t/ha of starch.

Apart from the rather specialized Chinese market, maize is currently the major commodity used for starch extraction, representing 80% of the world market (Table 4). Dent and flint maize/corn varieties are used to make cornstarch for food, animal feed, and industrial products. According to figures from the International Starch Institute, Denmark, in the commercial world market, potato represents 8%, cassava 6%, wheat 4%, and rice and other products supply 0.5% of the starch market. In Uganda, the most likely source for starch is cassava as this is a cheaper product than maize and the process of wet starch extraction can be done with relatively unsophisticated processing equipment at small- and medium-scale levels.

Across the world there is strong competition in prices for the different types of starch and industrial users can switch to the cheapest source of starch for most processes. In the past 20–30 years, many industries have shifted to maize starch due its low price and high quality, which have been achieved through increases in efficiency of both production and extraction. There is also a trend towards the use of more specialized modified starches. As the maize-based starch industry leads in the development of modified starch products, this has strengthened the market share for maize starch producers.

Table 5. Uses of starch and starch products in the food sector.

Native starch	
Baby food	As a nutrient and a thickener
Cream biscuits	As a binder in the cream
Meat products	As a binder, reduces drip during smoking of meats
Sausages	As a binder
Extruded and fried snacks	Provides crisp, even browning and hampers penetration of oils
Modified starch	
Ketchup	As a thickener
Soups	As a thickener
Sauces	Improves appearance
Mayonnaise	As a thickener
Noodles	Increases viscosity, consistency, mouthfeel
Subproducts	
Baking	
Maltose	Improves moisture retention and color control
Dextrose	Improves crust and dough properties
Low fat foods	As a sweetener
Beverages	
Beer maltose	HFS is an excellent fermentation substrate
Soft drinks	HFCS DE 42 and DE 55 are used as sweeteners
Alcohol	Very high DE glucose syrups are used as fermentation boosters
Confectionery	
Marmalade/Jam	DE 63 increases sweetness and shelf life
Ice cream	As crystal and texture controller
Dairy cream	As a stabilizer/sweetener
Fruit fillings	As a sweetener
Canned fruit	As a sweetener

Starch products and uses

Traditional uses of starch were for (1) thickening, filling, and bulking agents in food products, (2) binding and finishing agents in the textile and paper industries, and (3) the manufacture of gums and glues. The development of the starch conversion industry led to a major expansion in glucose and fructose production and, more recently, there has been a significant growth in the use of starch for nonfood products such as biodegradable plastics and textiles. Modern techniques enable starch to be extracted at high levels of purity and relatively low cost. This makes starch an attractive raw material for industrial processing, See Tables 5 and 6 for starch-based products used in the food and nonfood sectors.

Native starch. Native starch is the basic starch product that is marketed in the dry powder form under different grades for pharmaceutical, human, and industrial consumption. Native starch has different functional properties depending on the crop

Table 6. Uses of starch and starch products in the nonfood sector.

Native starch	
Pharmaceutical drugs	Binder
Paper	Sizing
Textiles	Binder
Animal feeds	Binder and nutrient
Modified starch	
Paper	Binding agent, filler, coating agent, coloring agent
Textiles	Sizing, filling and finishing, printing/color applications
Cardboard	Adhesives
Plywood	Adhesives/dextrins
Corrugated board	Glues/dextrins
Fermentation products from glucose	
Ethanol	
Lactic acid	
Citric acid	
Gluconic acid	
Derived products from glucose substrates	
Diapers	Superabsorbent polymers
Foundries	Core binder in castings
Concrete	Retarder in concrete
Detergent	Redeposition inhibitor of dirt
Agriculture	Coating of seeds to improve germination
Dusting powders	To reduce moisture
Water	For flocculation purposes
Oil drilling mud	Increases viscosity and reduces fluid loss
Plastics and polymers	
Biodegradable plastics	
Polyester plastics	
Nonwoven textiles	

source, and specific types of starch are preferred for certain applications. Native starch can be considered as a primary resource that is also processed into a range of starch products. The are five major categories of starch and starch products, (1) unmodified or native starch (UMS), (2) modified starch (MS), (3) glues/dextrins, (4) sweeteners, and (5) starch-derived products (Table 7).

Modified starch. Modified starch (MS) is native starch that has been changed in its physical and/or chemical properties. Modification is achieved by transforming native starch through a range of processes including heat treatment, changes in pH, or by subjecting starch to enzymes and additives. Although MS resembles native starch in appearance, modification enhances the performance of the starch by improving specific functional qualities such as gelatinization temperature, paste clarity, viscosity, and film forming ability.

Table 7. Major classifications of starch types and products.

Unmodified starch	Modified starch	Dextrin
Cornstarch	Pregelatinized starch	Thin boiling starch
Cassava starch	Oxidized starch	British gum
Sweetpotato starch	Esters	Yellow dextrin
Wheat starch	Ethers	White dextrin
Potato starch	Cross-linked starch	
Sweeteners	Starch derivatives	
Maltodextrin	Fermented products	
Glucose syrups	Detergents	
Fructose syrups	Biodegradable plastics	
Dextrose	Textiles	

The main types of modification are:

- Gelatinized starch made by passing a starch suspension over a heated rotating drum followed by cooling and drying.
- Dextrin types made from dry chemical treatment.
- Wet chemical treatment including thin boiling, acidified, and oxidized starches.
- Modifications which involve catalysts and processes for cross-linking, esterification, and etherification.

The food industry uses an increasing amount of modified starches. Acid-modified starches have a lower viscosity, higher gel strength, and improved clarity compared with native starch and these products are used in cakes and gum confections. Oxidized starch, made using hypochlorite, provides gels of low strength but improved clarity and these are used for candy production. Cross-linked starches have reduced stringiness and are best suited to pie fillings and canned pie fillings. Esterified starches are highly stable and do not retrograde on repeated freeze–thaw cycles. These are used in frozen dessert products and pudding starches. Acetylated starch has good stability at low temperatures and is used in canned, frozen, baked, and dry foods.

Adhesives and dextrins. Adhesives can be classified as glues or pastes. Glues are more liquid than pastes and possess some form of mobility, i.e., glues can be pumped, whereas pastes have poor mobility or none. Cooking starch in water and adding a preservative will produce a simple form of starch paste. These pastes are used for bill posting or sticking labels to bottles. The addition of salts such as calcium chloride at specific temperatures or borax significantly improves the adhesive properties. Clays and bentonites can be added as extenders and bleaching agents help to reduce film color. Dextrins are a more refined type of adhesive that is made by reacting starch with acid and heat or enzymes. They have a lower viscosity than simple adhesives, which permits their use at higher concentrations and makes their films dry faster with a stronger bond. They are classified as White dextrin, Yellow dextrin, or British gum. Dextrins have a wide range of applications, ranging from plywood and paper bonding to envelope seals and furniture making.

Sweeteners. The starch conversion industry cracks the long starch polymers into individual glucose units to produce glucose syrup, dextrose, and fructose, all of which are commonly referred to as sweeteners. The conversion of starch into sweeteners is probably the largest single market for starch, and it is estimated that more than half of the starch produced in the world is converted into glucose and fructose. In the USA, more than 70% of all starch is converted into sweeteners which are used in the manufacture of soft drinks and confectionery products.

Glucose. Glucose is produced by three standard processes, (1) acid hydrolysis, (2) acid–enzyme hydrolysis, and (3) enzyme–enzyme hydrolysis. All of these reactions reduce the starch polymer chain into a mixture of monosaccharides, disaccharides, and intermediate products by cutting the glucosidic bonds. The product of hydrolysis is therefore a mixture of glucose and intermediary products and the quality of the mixture is characterized by the Dextrose Equivalent (DE) number. Commercial sweeteners are classified according to the DE number of the syrup, hence, maltodextrins are those syrups with a DE of less than 20. Glucose is the common name for the liquid syrup with a DE above 20, and dextrose for the solid sugar.

Maltodextrins are used in a variety of foods including soups, fruit-flavored mixes, cakes, and biscuits. Maltodextrins are preferred to glucose due to their lower hygroscopicity, bland taste, and ability to give body without adding too much sweetness. Glucose is used throughout the confectionery industry and is generally preferred to sucrose. It is used in the preparation of canned products, tomato juice, and a wide range of confectionery. It is also used as the base for the manufacture of alcohols, gluconic acid, acetone, citric acid, sorbitol, and ethylene. Glucose is used by the pharmaceutical industry in syrup formulations.

Crystalline dextrose. This is made by concentrating refined glucose syrup under vacuum to an 80% solids content that is cooled and then crystallized. Dextrose is used in baking as a fermentable sugar; it also acts as a flavor and fragrance enhancer. In the dairy industry, dextrose is used in frozen desserts to control excess sweetness. Dextrose is also is used by the pharmaceutical industry for intravenous feeds and formulations.

Fructose. Since the development of fructose processing, fructose syrups have largely replaced glucose. Fructose is 1.7 times sweeter than sucrose and 4 times sweeter than glucose and is therefore more economical in large-scale processing. Fructose is converted from glucose enzymatically, using heat-stable glucose isomerase. The isomerase enzymes are obtained from specific types of *Steptomyces* which yield thermal-stable isomerase (Bagalapolan 1988). In the starch conversion industry, high fructose syrups (HFS) are sold as standard products which are categorized by their DE numbers. Common products include HFS 42%, HFS 55%, and HFS 90%.

The major use of HFS 55% is for soft drinks and HFS 42% is used in canned fruit preserves, ice cream, bakery products, jam, candy, and various other confectionery products. Demand for HFS has grown dramatically in the past 15 years, because of their excellent functional qualities and low price compared with sucrose (cane/beet sugar). Starch-based sweeteners currently compete with sucrose in all areas except dry mixes and nonhygroscopic sweeteners, such as required for table sugar.

Starch derivatives. In addition to the market for sweeteners, glucose is also used as a primary product for fermentation into a range of products, such as ethanol, lactic acid, and gluconic acid. These fermentation products can then be further processed into industrial products such as solvents, detergents, drilling mud, explosives, biodegradable plastics, nonwoven textiles, and polystyrene products. This industrial product range, particularly the biodegradable plastics and textiles, is expected to grow significantly in the next decade. The reason for this growth is based on the fact that the primary resource, starch, is perceived as a natural, renewable, and ecologically sound resource and this "credibility factor" will be the marketing tool for sales of these processed products (Ostertag 1996).

III

Cassava starch: markets, qualities, applications, and methods of extraction

The major markets for cassava starch are textiles, paper manufacture, dextrin production, food products, and conversion syrups. Cassava starch has four main qualities, high gel clarity which is superior to all starches except that from potato, excellent thickening characteristics, a neutral flavor, and desirable textural qualities (Blanchard 1995). It is also attractive to industrial users as it is low cost and, for many applications, less cassava starch is required than maize starch to achieve a particular function.

Textiles

Cassava starch is used in three aspects of textile processing: sizing, finishing, and printing operations.

Textile sizing. Sizing involves coating yarn with a smooth film of starch to enable it to withstand the abrasive and flexural stresses during the spinning and weaving processes. Size films are applied to the spun yarn as a thin coating. Typically, the amount of starch solution or "size" added to the yarn represents 5–15% of yarn weight. The starch effectively cements the yarn filaments and prevents "fuzz balls" caused by single filament breakages. Starch acetates, a form of modified starch, are mainly used in warp sizing because of their good yarn adhesion properties and improved tensile strength.

Textile finishing. Most fabrics are subjected to finishing operations. These are intended to improve their stiffness and to add weight. For example, often a fabric is finished by immersion in a dilute solution of cooked starch. Afterwards, it is passed through a roller press to remove excess solution and dried on steam rollers. Cassava starch is softer and "naturally" more transparent than maize starch and consequently is preferred for finishing fabrics. Hypochlorite oxidized starches which have excellent clarity are used for finishing cottons, particularly those with high color prints as this type of starch does not dull colors.

Textile printing. Starch is mixed with the coloring agent as a thickener to produce a clean, sharply defined pattern. Cassava starch is often mixed with wheat- or cornstarch to provide a good working consistency to the dye mix.

Paper manufacture

Although paper is mainly wood pulp, starch is added to paper as a binding and coating agent. Starch is used at four stages in the manufacture of paper.

Wet end application. Cellulose fibers require to be strengthened before they can be made into paper sheets and starch is added to the paper mix as a binding agent to increase the tearing and bursting strength. As it does in textiles, starch not only binds the cellulose fibers but also reduces surface fuzz, increases stiffness, and improves the strength which is required by high-speed mechanical processing of the paper sheets.

Size press applications. This process applies a film of starch to the raw paper to (1) improve the appearance, (2) inhibit ink penetration, (3) form a hard surface for writing or printing, (4) reduce surface picking, and (5) prepare the surface for subsequent coatings. All types of native starch are used in this process, although better results can be obtained by using oxidized starches or starch acetates. Cationic cassava starch is an excellent surface sizing agent.

Calender/roller application. During the processing of paper, starch films are added to the paper surface via a series of rollers. The type of starch used depends on the type of paper, but for heavy papers, native or thin boiling starch is used. In base coat applications, low viscosity starch is used and oxidized starches are used for final coatings to control problems associated with paper curl.

Paper coating. A final coat of starch is used as an adhesive in pigmented coatings. Cassava starch is the preferred product for this purpose because it is simple to prepare, has high adhesive properties, stable viscosity, high mechanical strength, and is low cost.

Dextrins

Cassava starch is often preferred in adhesive production as the adhesives are more viscous, work more smoothly, and provide stable glues of neutral pH. The glues are easily prepared and can be combined with synthetic resin emulsions for enhanced performance. Cassava paste is also neutral in taste and odor. Cassava dextrin is therefore preferred as a remoistening gum for stamps and envelope flaps because of its adhesive properties and agreeable taste and smell.

Food industry

Because of the clarity of the gel, cassava is preferred for use in soup mixes and in confectionery products that require a clear gel or thickener, such as soups, pie fillers, and pudding mixes. Cassava is also the preferred starch for the production of tapioca, i.e., starch pearls, for reasons of clarity.

The bland flavor of cassava starch makes it highly suitable for products with a delicate flavor or aroma. Cassava starch is also more readily digested than potato starch and for this reason is preferred in the manufacture of baby food. Cassava starch is also particularly suited to the production of expansion or "puffed" products because of changes in the expansion properties of the material on gelatinization. Traditionally processed puffed products include *Kerapok*, a type of cracker made in Asia, and *Pan de bono,* a type of bread made from fermented cassava starch in Colombia.

Pregelatinized starch has good solubility, digestability, and ease of preparation. The main market for pregelatinized starch is the "instant pudding" market and cassava starch provides the highest quality puddings. Similarly, cassava starch is used in instant noodles, and this is a rapidly expanding fast-food market in China and much of Asia.

Starch used in the manufacture of glucose syrup must be of high purity with a low protein content and in this respect cassava starch is again preferable to other unmodified starches.

Genetic diversity within cassava starch

There is increasing interest in the use of native starch in industrial processing due to its higher ecological credibility, especially for use in food products, compared with chemically modified maize starches. Unfortunately, studies to date have shown that there are few differences in the quality of starch among cassava varieties. However, Blenchard (1995) suggests that much of the diversity in starch from maize has been achieved through genetic manipulation and more targeted breeding of cassava could achieve similar results.

Methods of starch extraction from cassava

Cassava varieties fall into two main categories, "bitter" and "sweet" cassava, depending on the cyanohydrin content of the roots. In general, bitter cassava has a higher cyanohydrin content than sweet cassava and requires some form of processing before it can be eaten safely. For processing purposes, bitter varieties are most frequently used whereas sweet cassava is preferred for the boil-and-eat market.

Extraction of starch from the cassava roots can be divided into five main stages: preparation, rasping/pulping, purification, dewatering and drying, and finishing. For cassava, the process of starch extraction is relatively simple as there are only small amounts of secondary substances, such as protein, in the roots. When roots are selected for starch extraction, age and root quality are critical factors. Cassava roots need to be processed almost immediately after harvest as the roots are highly perishable and enzymatic processes accelerate deterioration within 1–2 days. A first-rate starch can be obtained using only water, and this makes the processing of cassava flour and starch particularly suitable for developing countries and rural industries.

In many countries, the supply of cassava roots for starch processing is made on a contractual basis between a processor and outgrowers. Roots are purchased on the basis of percentage starch and this can be established by simple techniques such as snapping the root and judging the maturity of the crop by the color and the force needed to snap the root. The processor is seeking a mature, white, nonfibrous root. Starch content can also be determined on a gravimetric basis using displacement to gain an idea of density or by chemical means. In most cases, however, processing is conducted on the basis of root weight and payment is made on final starch yield.

Peeling and washing. In small-scale processing, the peel (skin and cortex) is removed and only the soft central part of the root is processed. When the roots are fresh, it is relatively simple to cut them with a knife to the depth of the skin and then cut or peel away the outer cortex. This leaves clean smooth tubers for processing. The roots are either heaped or stored in water and can be washed by hand to remove any remaining dirt before rasping.

At the medium- to large-scale levels, a number of mechanical devices can be used for the processes of peeling and washing roots. The most common type is a mesh-coated cylinder that is partially immersed in water. As the cylinder is rotated, the roots inside the mesh drum wash against brushes and against each other; abrasion and washing remove skin and debris. Alternatively, roots can be cleaned and peeled within a large rotating screw, fitted with paddles. As the screw slowly rotates, the roots are moved along a 15 m axis and the action of abrasion removes the outer papery skin. As the roots move along the axis, water is sprayed at high pressure onto the roots to remove any dirt. At the factory level, the whole root is used for starch extraction. Since the inner part of the peel represents 8–15% of the root weight, using the whole root significantly increases the extraction efficiency compared to manual methods that discard the peel.

Rasping and pulping. To maximize the efficiency of starch extraction it is necessary to rupture all the cells to release the starch granules. Typically, after one or more gratings, between 70 and 90% of the starch is liberated from the cells.

Rasping can be done by hand but this process is usually power driven and the scale of throughput determines the quality and effectiveness of the rasping machinery. At the small-scale level, there are several types of rasping machines, depending on the local design. Most raspers consist of a wooden or metal rotating cylinder which has saw blades set into the cylinder longitudinally.

Roots are fed onto the cylinder that rips apart the cellular structure of the roots to produce a fine mash or slurry. At the factory level, roots are first cut using a rotary knife to reduce the size of the roots to 3 cm cubes and these smaller sections are then pulverized in a rotary rasper or hammer mill. Water is added at this stage to produce a slurry that is forced through slot filters to further break down the cells and release the starch granules.

Screening. Separating pulp from starch requires water and a filter. At the small-scale level, starch screening is carried out by hand. The pulped cassava mash is placed onto a screen or simply tied into a cloth and the starch is pressed through the muslin/nylon screen by hand, using a washing action. This batch system is relatively slow and the extraction rate can be as low as 10–15% of fresh weight (Kolijn et al. 1998). In small-scale production, waste pulp contains significant amounts of starch and this can either be used as animal feed, or simply remixed into flour for food. The screening process can be improved by using rotating cylindrical screens that are immersed in water or by the use of mechanized shaking screens.

In larger factories, screening is replaced with a multistage filtration process. Roots are rasped or pulverized and the *thippi* or large fiber fraction is separated by using sieve bends or DSM screens. The coarse waste is dewatered and dried for animal feed. The slurry or "milk" from the first and second rasping and washing is passed through a multistage filtration process in which conical centrifugal extractors purify and wash the starch. Centrifuges are arranged in rows with a diminishing screen size along the row.

The extraction gradient separates the coarse and fine fibers from the slurry. Waste from the extractor bank is fed to a separate system for dewatering and waste extraction. This waste is dried and sold as a finer feed for animals. After passing through the "light milk" extractors, the milk is batch fed into a high-speed centrifuge that concentrates the starch density to provide "heavy milk", with a moisture content of 40%. There are two main industrial processes for starch extraction, the Alfa Laval and the Dorr Oliver (Bagalapolan 1988). For more information on industrial processing, cyclone separators, and high-speed starch centrifuges, see the Alfa Laval website at www.alfalaval.com.

Settling and purification. At the rural level, starch is settled in tanks. After rasping and washing, settling takes approximately 6 hours and when the starch has settled, supernatant water is removed by opening stoppers on the sides of the tank. Starch is washed by adding clean water and agitating the mixture, before allowing it to resettle. Processors add sulphuric acid to improve starch whiteness and alum to increase the rate of sedimentation. In Brazil, the batch-type settling tanks have been modified into an S-bend channel system which makes possible continuous processing and settling.

Preliminary drying. To improve the rate of drying, high-speed centrifuges are used in the larger factories to concentrate the starch slurry to a moisture content of 30–40% before drying by evaporation.

Drying. Sun drying is the cheapest form of water removal; solar dryers are used in all small-scale operations and by many medium-scale mills. After settling, the wet starch is spread out either into baskets or directly on to cement floors or floors covered with a plastic sheet. The starch is generally crumbled before or during drying to break up the cake. An important advantage of sun drying is the bleaching effect but there are problems associated with dust and bacterial contamination.

Drying yards. These consist of a furnace at one end of a long floor. The heated air is channelled under the drying floor. The area nearest the furnace is hottest and distance from the heat source reduces the heat. The starch is moved from the coolest area towards the heat source to dry. This system requires that the starch is continually moved by operators towards the heat source and removed before gelatinization takes place.

Oven driers. A range of ovens can be used to dry starch. The simplest is a fire that is placed below racks. The fire is separated from the racks by brickwork, similar to an oven. This system can be enhanced by insulating the chamber walls and improving on the air circulation within the chamber. To make the shift from batch to continual flow systems, there are several types of continual process ovens including drum driers, belt driers, and tunnel driers.

Flash driers. For the larger types of factory, the most rapid means of drying is via pneumatic driers. The starch is fed from the concentrators to the air blast shaft and heated to approximately 150 °C. The starch is dried in the drying column whilst being pneumatically conveyed from the entry point to the top of the drier; a column may be 20–50 m in height. Insufficiently dried particles are separated and fed back into the system and the dry powder is transferred via a cyclone to a starch filter.

Finishing and packaging

Crude starch often consists of large lumps and these need to be pulverized and dry-screened in a process known as bolting. Larger mills have bolting equipment whereas smaller starch manufactures use rollers. After rolling, starch is usually refiltered through dry screens to remove any remaining fibers. The starch is then stored in nylon bags, preferably with a plastic liner to prevent rewetting.

Differences in processing according to scale are summarized in Table 8. For more details on starch processing, see www.starch.dk (tapioca starch extraction).

Table 8. Summary of methods of starch extraction by scale of operation.

Activity	Small-scale < 1 t/day	Medium-scale > 1 < 10 t/day	Large-scale > 10–100 t/day
Preparation	Wash roots by hand	Wash mechanically	Wash mechanically
Preparation	Hand peel roots with a knife	Peel mechanically	Peel mechanically
Extraction	Rasp/grate roots either by hand or with a small rasper	Rasp mechanically, add water to slurry and possibly rerasp	Cut and rasp. Add water to slurry and rerasp/hammer mill. Finally pulverize through slot filters
Purification	Filter starch by hand through a cloth to separate starch and coarse fibers	Separate starch, fibers, and dirt using basket type centrifugal filters	Dewater slurry through a linear dewatering centrifuge and remove coarse fibers
Purification	Settle starch in tanks	Introduce water and re-filter along a bank of cyclone separators	Rerasp and add water
Purification	Remove supernatant water and wash wet starch with clean water. Agitate and allow to resettle	Each separator in the bank has a smaller size filter to progressively remove dirt and fibers	Introduce water and re-filter along a bank of cyclone separators
Dewatering	Remove water from tank by decanting the supernatant water	Concentrate starch in high speed centrifugal separators to reduce moisture content to 40%	Concentrate starch in high speed centrifugal separators/concentrators to reduce moisture content to 40%
Drying	Remove starch to a bed or tray for sun drying	Dry wet starch using solar drying yards or drying tables, alternatively heat dry using continuous processes such as drum/belt driers	Flash dry using pneumatic heating columns
Finishing	Roll dried starch to reduce lumpiness	Bolt in roller mill	Bolt in specialized mill
Grading	Grade, if possible	Grade	Grade as required
Packaging	Pack dry starch in 50/100 kg sacks	Pack in bags 50 kg/1 t	Pack dry starch in big bags (1 t)
Waste products	Animal feed/reprocessed into other food products such as flour	Animal feed	Animal feed

IV

Starch production in Uganda

Uganda is a landlocked country more than 1,000 km from the coast. Importation of a low cost, bulky commodity such as starch via the Kenyan port of Mombasa is expensive. To overcome these problems, a medium-scale cassava-based starch factory was built in 1967 to supply the growing industrial sector in Uganda at that time.

The Lira starch factory

The factory was located in Lira as part of a decentralized development scheme established during the regime of Dr Milton Obote (Fig. 3). The factory was managed by a parastatal organization, known as the Lango Development Company and owned by the Ugandan Development Corporation (UDC) and Lango District Council. The factory was sited in the heart of the cassava belt, and cassava was supplied from a 200 ha farm and an outgrowers scheme. The factory output was 5 t of starch/day, which supplied the textile and paper industries. After processing, starch was transported by rail to the industrial towns of Tororo, Jinja, and Kampala.

During the period of civil unrest and forced repatriation of the Asian community, the Lira starch factory was severely damaged, rebuilt, and then destroyed. Perhaps more importantly, the markets associated with textiles and paper also declined dramatically and much of the Ugandan textile industry moved to Kenya.

Following the civil unrest, the Government of Uganda commissioned several studies with a view to rehabilitating the Lira starch factory. However, the Lira project is yet to find a strong public/private sector partnership that can raise sufficient capital to revitalize the factory. The first plans to rehabilitate the Lira factory were outlined in a report by the Industrial Development Unit (IDU 1987). In this report, it was planned to rebuild a factory unit to produce 10 t of starch/day with 4 t being converted to glucose and 1 t to dextrin.

A second feasibility report was undertaken by the United Nations Industrial Development Organization (UNIDO) in 1991. The findings from the UNIDO report suggested that reopening the Lira factory was a viable business proposal and would have significant social benefits in this economically neglected part of the country (UNIDO

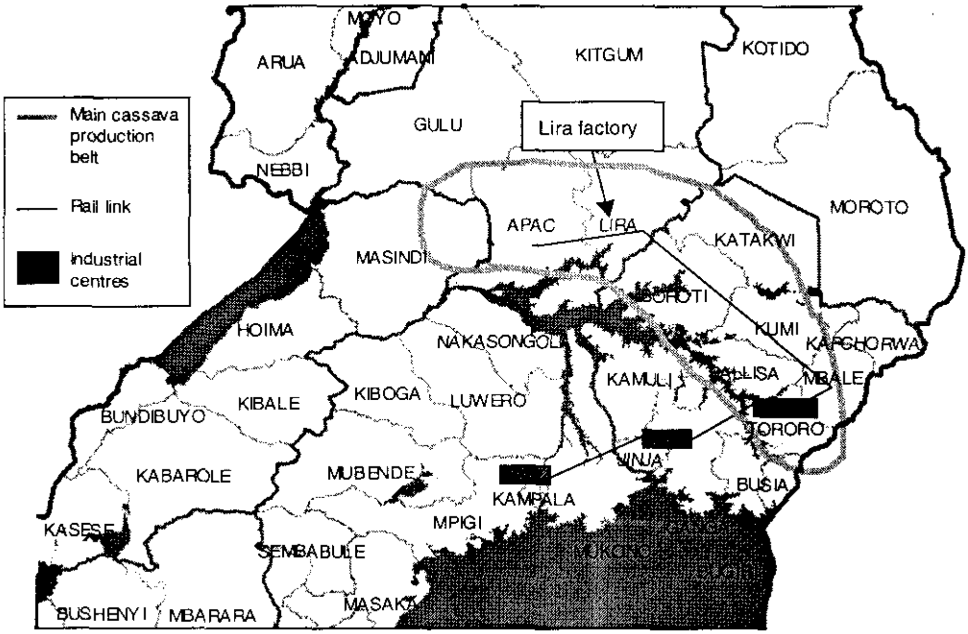

Figure 3. Site of the Lira starch factory and areas of industrial activity.

1991). The plan for starch production was based on a factory operation involving a 3-shift system to produce 15 t of starch/day. The factory production would include 6 t of industrial starch, 1.5 t of pharmaceutical grade starch, 6 t of liquid glucose, and 1.5 t of dextrin. In 1991, the starch had a projected sales price of \$777/t and the project had an internal rate of return of 40% over 10 years. The social benefits of the factory would include the provision of a long-term market to absorb local surplus cassava production and employment in an area that has few job opportunities. In view of this report, the East African Development Bank and the Ugandan Government made a financial pledge of \$2.5 million towards the rehabilitation plan. It was envisaged that the private sector would provide the additional \$3.5 million required to finance the project. However, the private sector did not respond favorably and no funding was made available to meet the rehabilitation project.

In 1995, the International Starch Institute (ISI) was commissioned to produce a third report for the rehabilitation and modernization of the Lira factory (ISI 1995). This report suggested that the project concept was feasible, but that more details were required in both market analysis and the means of financial support. The ISI report was critical of previous technical advice and suggested that the starch be produced only from wet processing and not by a combination of wet and dry processing as proposed in previous reports. The ISI also suggested that the funding and management of the factory might be best addressed through a joint venture between Ugandan and

European investors who would provide the capital and managerial skills necessary to successfully redevelop the project. The report did not explore the possibilities of investment from Asia or the Republic of South Africa (RSA) that may offer a more likely source of finance and skills in Uganda than Europe, due to the presence of many Asians in Uganda and the starch processing skills in the RSA. Asian entrepreneurs are major stakeholders in Ugandan industries and much of the starch currently used in Uganda is imported from India. The Asian business community is well placed for access to reliable market information, to raise funds from local financial institutions, and to gain support from the industries using starch.

Much of the ISI report provides technical details for starch processing and the levels and quality of raw materials needed for efficient processing. The economic viability of the project was based on a predicted demand for starch that was related to GNP. According to this calculation, it was suggested that Uganda would have a starch consumption level in the region of 5,000 t/yr by the year 2000, with Kenya at 6,000 t/yr, and Tanzania at 4,200 t/yr. The price of starch in 1995 was $450 f.o.b. Mombasa, with an expected c.i.f. Kampala price of $550/t. Total cost of the rehabilitation of Lira starch factory was 60 million Danish kroner (DKK) ($8–9 million) and the project plan had an internal rate of return of 30%, with a payback time of 4.2 years. The factory would aim to produce 30 t/starch/day from 48,750 t of fresh material. This figure represents 2% of the national cassava production. Approximately 40% of the starch would be sold in Uganda with a plan to sell surplus to Kenya, Tanzania, South Africa, Europe, and the Far East.

The ISI report concluded that a detailed market survey should be made to confirm their figures and that more detailed market information was essential before investors should consider starch processing in Uganda. In 1998, whilst this study was being undertaken, a group of Ugandan investors purchased the derelict premises of the Lira starch factory for a figure reported as 100 million Ugandan shillings (Ush). According to the new proprietors, it will cost approximately $5–6 million to rehabilitate the factory. The new owners, "Lira Starch Ltd", carried out a rapid market survey and estimated that demand for starch in Uganda was 2,500 t/yr in the food, textile, and pharmaceutical industries. However, the survey found that a large part of the demand was for starch products such as HFS and dextrin rather than UMS. The marketing strategy proposed by the new owners is to produce a range of products including standard UMS, high grade UMS, dextrin, and HFS to exploit the full range of starch markets in the country.

According to the operating plan, fresh cassava will be the main raw material although dried cassava may be used when necessary. As suggested by the IDU report, the processing plant would be supplied from a cassava farm, which should supply up to 60% of the raw materials. It is intended that outgrowers supply the remaining 40%. At present, the local investors are soliciting funds for refurbishment or replacement of the buildings and equipment (*New Vision,* 15 April 1999).

V

Starch market survey

The starch market survey was undertaken to provide a more detailed estimation of starch usage in Uganda and to compile a list of users, products, and processes that include starch and starch products. Information for starch import prices and sources of supply was recorded from a range of sources to assess the accuracy of market information. A preliminary study was also conducted to rapidly assess the starch market in Kenya, with a view to assessing opportunities for the export of starch from Uganda.

The purpose of gathering this information was to determine the size of the starch market and to evaluate current market opportunities for starch processing in Uganda and the prospects for starch marketing in the longer term.

Methodology

The main survey targeted the manufacturing and service sectors in Uganda including the pharmaceutical, food, textile, paper, plywood, laundry, tobacco, and paint industries. The survey was conducted in the towns of Kampala, Jinja, Mukono, and Mbale, and districts of Tororo, Mbarara, Rakai, and Kasese. In Kenya, the survey conducted interviews with two starch factories and 21 starch-using companies in Nairobi.

In Uganda, factories were sampled from the business registers of the National Statistics Department, the Uganda Manufacturers Association, and the Business Listing of the *Monitor* newspaper. Companies were also visited, based on anecdotal information of starch usage and information gained from other interviewees. In most cases, initial visits were made, then interviews were arranged although much of the information required secondary verification.

Tables 9 and 10 list Ugandan factories and institutions that use starch and starch products in their processing. Interviews with company representatives were conducted using a formal questionnaire (Annex 2). Those companies interviewed that did not use starch are listed in Annex 3.

Table 9. Factories and institutions that use starch in Uganda.

Institution*	District	Type	t/yr	Cost/t (1998)	Source
Pharmaceutical sector					
1. — A —	Kampala	n.a	40–50.00	n.a	n.a
2. — B —	Jinja	BP	60–120.00	$800	Holland
		UMS	n.a	$450–650	India Kenya
Food sector					
3. — C —	Kampala/ Mbale	UMS	24.00	$400	India
4. — D —	Tororo	UMS	24.00	$400–600	India Kenya
5. — E —	Kampala	n.a	n.a	n.a	n.a
6. — F —	Kampala	n.a	0.22	n.a	n.a
7. — G —	Jinja	UMS	360.00	$400–600	India Kenya
8. — H —	Kasese	MS	1.15	n.a	n.a
9. — I —	Kampala	MS	1.80	n.a	n.a
10. — J —	Kampala	UMS	24.00	$400–600	India Kenya
Nonfood sector					
11. — K —	Mbale	n.a	n.a	n.a	n.a
12. — L —	Jinja	UMS	240.00	$400	India
13. — M —	Kampala	UMS	50–100.00	$400	India
14. — N —	Kampala	Liquid starch	0.02	$1.5–2.00/l	n.a
15. — O —	Kampala	Liquid starch	0.03	$1.5–2.00/l	n.a
16. — P —	Kampala	Liquid starch	0.05	$1.5–2.00/l	n.a
17. — Q —	Kampala	Liquid starch	0.01	$1.5–2.00/l	n.a
18. — R —	Kampala	Liquid starch	0.01	$1.5–2.00/l	n.a
19. — S —	Kampala	Liquid starch	0.05	$1.5–2.00/l	n.a
20. — T —	Kampala	Liquid starch	0.03	$1.5–2.00/l	n.a
Total confirmed usage			945.37		

n.a = not available. * Names deleted to preserve confidentiality.

Use of starch and starch products by major industrial sectors in Uganda

The results, based on the information from 80 companies, revealed that 30% of the respondent companies used starch; within this group 80% used maize starch, 10% MS, and 10% cassava starch. The starch users in Uganda were divided into three main categories pharmaceuticals, food, and nonfood.

Each of these sectors used between 200 and 500 t of UMS or MS/year. This suggests that the national consumption of starch in Uganda is probably within the range of 1,000 to 1,500 t/yr (Table 10). Assuming a value of $500/t, the starch market including UMS and MS has a value of between $500,000 and $750,000/year.

Table 10. Factories and institutions that use starch-derived products in Uganda.

Institution*	District	Type	t/yr	Cost/t (1998)	Source
1. — AA —	Kampala	Glucose syrup	n.a		
2. — BB —	Kampala	Dextrin	10		
3. — CC —	Jinja	Glucose syrup	n.a		
Food sector					
4. — DD —	Kampala	Glucose syrup	800–1000	$600–700	Kenya Yugoslavia India
5. — EE —	Kakira	Glucose syrup	216	$520–590	Kenya
6. — FF —	Kampala	Glucose syrup	240	$610	
7. — GG —	Kakira	Glucose syrup	n.a		
8. — HH —	Kampala	Glucose syrup	n.a		
9. — II —	Kampala	Glucose syrup	35		
10. — JJ —	Kampala	Glucose syrup	300	$600–700	Kenya
Nonfood sector					
11. — KK —	Kampala	Dextrin manufacturer	n.a		
12. — LL —	Jinja	Dextrin	60	$200	
13. — MM —			150		
14. — NN —	Jinja	Dextrin	60		
15. — OO —	Kampala	Specialist dextrins	18	$1,000–2,000	
Total sweeteners			1500		
Total dextrins			300		

n.a = Not available. * Names deleted to preserve confidentiality.

The use of sweeteners in the pharmaceutical industry was not determined, but the food industry indicated that consumption of glucose syrups and HFS was in the range of 1,500 to 2,000 t/yr (Table 10). Assuming a value of $600/t for liquid glucose, this market has a value of approximately $9,000,000–$1,200,000/yr. Dextrin usage was probably underestimated in this survey but can be estimated to be within the range of 500 and 750 t/yr. When a value of $300–$500 is assumed for pastes, adhesives, and dextrin, this market may have a value of $200,000–$300,000/yr. The combined value of these markets is $2–3,000,000/yr.

Pharmaceutical sector. Information from the pharmaceutical sector found that multinational companies did not procure starch locally as they manufactured their products overseas and only packed and retailed in Uganda. Starch prices from the local pharmaceutical manufacturers suggests that both high grade and UMS were used in the preparation of medications. Although pharmaceutical suppliers use liquid glucose in the manufacture of syrup formulations, the level of syrup usage was not revealed.

Food sector. The food industry used a combination of UMS and MS costing \$400–\$800/t and a substantial amount of liquid glucose or HFS. Specialized companies in Europe supplied MS, and although one price was quoted at the unlikely figure of \$60/kg, i.e., \$6,000/t, only small quantities were purchased to meet the needs of specific processes.

Nonfood sector. The Ugandan textile industry uses maize starch. The amount used by the textile factories was approximately 300–350 t/yr and other nonfood processors, including plywood and cardboard box industries, used 100–200 t/yr. Much of the starch used by plywood and paper processors was in the form of dextrin. Starch for the nonfood sector was imported from India and Kenya at a cost of between \$400 and \$650/t. The level used by the textile factories would have been significantly higher if these companies used only starch in their processing, but low-cost flours often replaced starch, and this distorted the market profile.

Sources of starch procurement

Results from the survey indicated that 10% of the recorded amount of starch was purchased from retailers in Kampala, of an unknown source. However, 90% of those interviewed said they imported starch from Kenya and India with some procurement from European sources. They indicated a number of problems associated with importation into Uganda, including delays in transit and delivery, high transportation costs, and the need for a high capital stock, which had cash flow disadvantages. On review, it appears that the range of importation sites was rather limited from this study and that most buyers were purchasing from either Kenya or India.

During the survey, the buyers did not mention the Internet as a source of procurement and this may be a lost opportunity, particularly if clients are seeking occasional and perhaps low quality goods. Most major starch producers and also starch support industries selling processing equipment have web pages which can be accessed with relative ease using a standard web search engine. A simple search will reveal a number of sales points, offering a range of products, including standard grade starch and starch lots. There are even offers for low-cost, "off-grade" or low quality starch that might be of interest to nonfood processors. The ISI has also initiated a market place on their web page for producers, traders, and consumers to facilitate starch trading, www.starch.dk

Indigenous starch production

During the survey, only one local Ugandan starch producer was identified. It was claimed that the capacity of this factory was approximately 30 t/month, i.e., one t/day. The factory was in full production from 1989 until 1994 and supplied dextrin to the brewery and edible oil industries. The starch factory was provided with chemicals from the purchasing factories to make and supply the glue. Currently the factory is producing only 1 to 2 t of starch/month, or less, to supply a local pharmacist and the brewery. Information from the factory indicated that over the past few years, demand had favored maize starch rather than cassava starch.

The factory produced maize starch at 2,000 Ush/kg ($1,481/t), and cassava starch at 1,500 Ush/kg ($1,111/t), (exchange rate $1 = Ush 1,350, 1998). Low output was attributed to poor market demand, although lack of demand may have been more related to competition from imported goods, that are either cheaper, of higher quality, or modified (Table 11).

Starch prices

Due to the increasing global demand for starch and the use of high volume industrial processing, world market prices for starch are highly competitive. Nevertheless, prices vary according to the country of production, source of starch, quality, and changes in currency value. As shown in Table 11, cassava is generally the lowest cost starch as it is produced in countries with low labor costs.

Table 11. Market prices and suppliers of starch and derived products.

Country	Product	Cost ($/t)	Source	Year
Thailand	Cassava starch	$320	f.o.b. Bangkok	1988
	Cornstarch	$350–370	f.o.b. Bangkok	1988
Thailand	Cassava starch	$210	f.o.b. Bangkok	1999
	Cassava starch	$135*	f.o.b. Bangkok	1999
	Cornstarch	$320–350	f.o.b. Bangkok	1999
	HFS	$350	f.o.b. Bangkok	1999
Brazil (R & M International)	Native cassava starch	$320	f.o.b. Brazil	1998
USA (Ramblin Corp)	Cold H_2O soluble cornstarch	$340–360	f.o.b. USA	1998
India (Anil)	Cornstarch	$400	c.i.f. Mombasa	1998
	Cornstarch	$303	c.i.f. Mombasa	1999
	Cassava starch	$230	f.o.b. Mombasa	1999
Kenya	Cornstarch	$600	f.o.b. Eldoret	1998
Kenya	Cornstarch	$620–660	c.i.f. Kampala	1998
Kenya	Cornstarch	$548	f.o.b. Eldoret	1999
Kenya	Cassava starch	$564	f.o.b. Mombasa	1999
Pakistan (Habib Arkady Ltd.)	Liquid glucose	$450	f.o.b. Pakistan	1999
	High fructose syrup	$400	f.o.b. Pakistan c.i.f. prices = + $65/t	1999
Uganda (Rakai)	Cornstarch*	$1,481	c.i.f. Kampala	1998
	Cassava starch*	$1,111	c.i.f. Kampala	1998

*May–June 1999 prices

Kenya Corn Products Corporation Ltd. is the starch factory nearest to Uganda and the prices for Kenyan corn starch in 1998 ranged between $590 and $660/t c.i.f. Kampala. Cassava starch from India in 1998 was quoted at $400/t c.i.f. Kampala. In 1998, the standard world market price for maize starch ranged from $300 to 400/t.

More recent information from Thailand indicates a significant fall in cassava starch prices to a price below $200/t f.o.b. Bangkok 1 January 1999. However, according to the Thai Tapioca Trade Association Bulletin of April–June 1998, the new target for 1999 is to export 500,000 t at a price below $200/t. This fall in price is the result of the devaluation of the Baht, caused by the currency crisis and general recession in southeast Asian economies.

The Kenya starch market

One of the strategies proposed in the ISI starch feasibility study was to sell surplus Ugandan starch production into Kenya and Tanzania. To gain an insight into the Kenyan starch market, a rapid survey was undertaken in Nairobi and Mombasa. In Kenya, starch and starch products are produced and supplied by two companies, Kenya CPC Ltd. based at Eldoret, and Tapioca Ltd. based in Mazeras near Mombasa. Kenya CPC Ltd. produces and/or imports and wholesales corn starch, glucose syrup, and more specialized starch-based products.

According to anecdotal information, the cassava starch processor, Tapioca Ltd., does not operate at full capacity or on a year-round basis, and often imports starch for local retailing. At the time of this survey the cost of corn and cassava starch was approximately $550/t.

In 1997, Kenya CPC supplied a range of starch and starch-derived products to the textile, paper, cardboard, brewing, and food industries. These included UMS, MS, and desired products such as glucose and HFS. The approximate sales volume for all products was 19,000 t in 1997 falling to 17,000 in 1998. It is clear that Kenya CPC not only supplies these products to a broad range of manufacturers, but that the company has a relatively high capacity for supply. Kenya CPC is supplying starch products to the domestic market and is also exporting to both Tanzania and Uganda.

According to the Kenya survey report, until recently Kenya CPC held a virtual monopoly for starch processing and supply in East Africa. However, three new companies, Anil Starch of India, Ghalam of Israel, and Meelunie of Holland, are now marketing starch from Kenya to the region and this has increased the level of market competition.

From the sample of 21 companies surveyed in Kenya, 19 were located in Nairobi, and 20 were privately owned. These enterprises included the paper, food, textiles, beer, meat, pharmaceutical, and adhesive manufacturers. The products made by these companies included corrugated paper, cartons, medicine, glue, beer, fruit juices, sauces, soups, baking powder, sausages, and soap products. All the factories interviewed used corn starch, but 15 of the 21 respondents indicated they would be prepared to try cassava starch if the quality was high and prices competitive.

Although it is difficult to provide firm figures on the size of the starch market in Kenya from such a rapid sample, sales records indicate a supply of at least 20,000 t/yr. Taking into account exports to Uganda at an estimated level of 1,000 t which was captured from the Uganda survey and supplies of approximately 5,000 t to Tanzania, it can be assumed that Kenyan industries are consuming somewhere in the region of 12,500–15,000 t/yr. This range takes into account supplies from the three new starch companies into the domestic market. This market has a value in the range of $7.5–12.5 million.

The level of starch production indicates that Kenya has the necessary capacity and is already supplying starch and a full range of starch products to manufacturers in the region. This finding suggests that unless a starch factory in Uganda is particularly price competitive, it will face strong and probably insurmountable competition for sales outside Uganda. Also, the presence of marketing agents for the three international starch companies suggests that prices in Kenya will become more competitive in the future and that sales within Uganda will also become more competitive.

Fresh competition from South African starch manufacture

Although cassava starch is produced only intermittently in Kenya due to high internal costs, a new company in South Africa, CS Manufacturing Ltd. (CSM) opened a new cassava-based starch factory near Pietersburg, Northern Province. The factory has a capacity to produce 60 t of starch/day. Reports from the company suggest that cassava grows well in South Africa and that the yields are higher than in South America or Thailand.

According to the marketing department of CSM, South Africa uses approximately 90,000 t of starch/year, primarily in paper, corrugated board, and food products, and so the CMS factory could supply approximately 20% of this domestic market. The South African starch market has an annual value of R150 million, ($30 million). The effect that this new player will have in the African starch market is unclear, but if the marketing has been done well and production costs are indeed low, then the South Africans may provide a new local competitor in East Africa.

Starch replacement

One of the more interesting findings from the survey was the number of companies in Uganda that have resorted to substituting flour for starch in their processing. The survey data indicated that most nonfood processors use cassava flour as a partial or total replacement for starch (Table 12). According to the textile manufacturers, flour serves the same purpose as starch, is cheaper, and locally available.

Table 12. Factories replacing starch with cassava or maize flour.

Site*	Location	t/yr
— U —	Mbale	2000–2500
— V —	Jinja	720
— W —	Jinja	60
— X —	Jinja	58

* Names deleted to preserve confidentiality.

Reports from one of the major textile mills in Uganda revealed that it had virtually stopped using starch because of its high cost but instead uses a considerable amount of flour as a substitute. The factory uses a combination of maize and cassava flour with a local purchase price of 300–450 Ush/kg ($222–333/t) for cassava flour and 350–450 Ush/kg for maize flour. The factory uses local flour to reduce production costs and the cost of the textiles as the factory supplies low-cost textiles in response to market demand. Currently the textile mill is competing with imported secondhand clothes and is therefore forced to sell into a low-cost market. The largest textile factory in Uganda uses a combination of starch and cassava flour. One t of cassava flour costs $250–350 compared with a delivery price of $400–650/t for imported starch, so using flour provides a considerable saving in production costs (Table 13).

The widespread use of starch–flour mixtures or the substitution of flour for starch was a complicating factor for the survey team. In several cases, it was necessary to revisit factories to confirm actual starch usage, as factory employees were reluctant to discuss starch replacement.

Flour prices relative to starch prices in Uganda

Although the replacement of imported starch with locally available flour has several advantages in terms of lower price and availability, the price factor is not always constant. In the 1997/8 seasons, the prices of local flour were relatively high because of the adverse effects of the seasonal and longer term weather patterns on crop production. At the peak period of 1997, prices of maize and cassava flour were considerably higher than international starch prices and at that time it would have been unrealistic to consider

Table 13. Starch and flour usage by major industrial sectors.

Industry	Starch t/yr	Glucose t/yr	Dextrin t/yr	Total starch products t/yr	Maize flour t/yr	Cassava flour t/yr	Combined total t/yr
Pharmaceutical	100–200	n.a.	10	200	0	n.a	200
Food	450–550	800	n.a	1,300	300	n.a	1,600
Nonfood	300–500	n.a.	140–200	580	60	2,000	2,640
Price/t ($)	400–800	600–700	200–400	–	400	200–400	–
Total (t)	950	800	316	–	360	2,000	–
Estimated range (t)	1,000–1,500	1,000–1,500	300–500	2,300–3,500	500–1,000	2,000–2,500	4,500–6,500

n.a = not available

Table 14. Retail prices of starch and various flours in Uganda, 1998, fourth quarter.

Item	Consumer price range/kg (Ush)	$ Costs/t
Cassava flour	170–300	110–200
Maize flour	400–800	270–530
Wheat flour	800–1,500	530–1,000 (270–300 t*)
Maize starch	2,000–500	1,300–1,600
Cassava starch	1,500–2,000	1,000–1,300
Spray/aerosol starch	4,500–6,000	n.a

*price of imported flour. n.a not available.

anything other than starch importation. However, in 1998/9, prices of cassava and sweetpotato fell to below the 10-year average (Fig. 2) and therefore the low cost of root crops made local starch manufacture considerably more attractive. The information in Table 14 shows that cassava flour prices have stabilized at lower prices in recent months and with the recent fall in the value of Ugandan shillings against the US dollar, cassava flour can be purchased at considerably lower prices than most imported starch products. The question of availability is unclear and it is assumed that taking 2–3% of the total production for starch processing would not lead to a dramatic shift in prices.

Differences in starch consumption in this survey compared with the ISI values

The findings from the Uganda survey indicated a domestic starch consumption of 1,000–1,500 t/yr, which was considerably less than the range of 4,500–5,000 t predicted by ISI. The disparity between the predicted and survey figures may be related to the structure of the Ugandan economy that is more dependent on trade than manufacturing. Consequently, GNP figures used by the ISI may not be an accurate measure of manufacturing capacity. However, it is more likely that the ISI figure did not take into account the high level of flour substitution. The combination of starch and flour used for industrial processing in Uganda provides an estimated consumption figure in the range of 4,500–6,500 t/yr as predicted by ISI.

The findings from Kenya indicated a market at 15,000–25,000 t/yr that was 2 to 3 times higher than the ISI prediction of 6,000 t. The reasons for the differences between these two figures may be a result of regional supply from Kenya and also the more industrialized nature of the Kenyan market, but further studies are required to confirm the consumption and export patterns.

Starch quality as required by the users

When questions were asked on starch quality characteristics, all users required a product that was white, fine, and odorless. For imported starch, the priority factors that determined purchase were price and delivery time. When interviewees were asked for their requirements for *locally produced starch,* the response was quite different. All users indicated that if they were to purchase locally made starch, quality would be their highest priority. The second most important factor was reliable supply; less than half of those interviewed suggested that price would be the second most important factor.

The specific request for quality in locally manufactured starch rather than price suggests either that interviewees assumed prices would be low, or they lacked confidence in the expected quality of the local product. Nevertheless, the two textile producers stated that they would be interested to test locally made cassava starch or high quality flour, but would purchase the product only if the starch quality was the same as imported starch and the price was highly competitive, thus implying their preference for low-cost cassava flour.

Market potential for high quality cassava flour in the food sector

In addition to supplies of high quality flour to the nonfood sector, a recent market survey was conducted by Gensi et al. (2001) to evaluate the prospects for the incorporation of cassava flour into bakery products. The cassava flour survey revealed that 74% of confectionery manufacturers in Kampala and Jinja had, at some time, tried cassava flour in their products, but that all had subsequently stopped using it because of the poor quality. The bakeries found that, although costs were reduced when cassava flour was used, products were found to be of a significantly lower quality due to problems with cassava flour color, odor, and contamination. A similar finding was observed in this survey. When bakeries were informed about methods to replace wheat or maize flour with high quality cassava flour, a number indicated that they would be interested to test high quality cassava flour, particularly for biscuit manufacturing (Table 15).

Table 15. Confectionery manufacturers response to cassava flour.

Name	Output loaves /day	Cost of wheat/t	Tried cassava flour	Results	Interested to try HQCF
1. — AB —	4,000 l/day	$640	Yes	Products poor quality	Yes
2. — BC —	300 l/day	$648	Yes	Very poor quality flour	Yes
3. — CD —	26 t wheat/m	$638	No	—	No
4. — DE —	1,000 l/day	$635	No	—	Yes
5. — EF —	1,5,000 l/day	$635	No	—	No
6. — FG —	1,200 l/day	$630	No	—	No
7. — GH —	1,400 l/day	$630	No	—	No
8. — HI —	n.a	$640	No	—	Yes
9. — IJ —	n.a	$590	No	—	Yes
10. — JK —	n.a	n.a	No	—	No
11. — KL —	n.a	$570	No	—	No
12. — LM —	n.a	n.a	No	—	Yes
13. — MN —	n.a	n.a	No	—	Yes

n.a = not available. = not tested. * Names deleted to preserve confidentiality.

VI

Market opportunities for cassava and sweetpotato products

Cassava

The market survey indicated that there are prospects for replacing imported starch with locally produced cassava starch or flour, if the quality is good and prices are competitive. Given the high level of starch substitution within the nonfood sector, there are considerable opportunities to supply high quality cassava flour to industries including those producing textiles, plywood, fiberboard/cardboard, and to low grade paper manufacturers.

With regard to the food market, traditionally processed cassava flour is already sold in the retail market and several retailers sell cassava flour at 350–450 Ush/kg and mixtures of cassava and millet flour at prices of 1,000–2,000 Ush/kg. The flour used in the retail trade is traditionally processed and therefore higher quality cassava flour is likely to gain a premium price in this market. According to Gensi et al. (2001), there are also reasonable prospects for increased sales of higher quality cassava products in the food sector, particularly for the manufacture of low grade biscuits where gluten content is less important than in bread production.

Sweetpotato

No trading in sweetpotato starch or flour was identified in this survey and there appears to be a clear divide in the cassava and sweetpotato markets. Whilst cassava products are already widely traded in Uganda and East Africa, sweetpotato is traded only as a fresh product. The major problems for sweetpotato products include the quality after processing, as the chips develop a brown color on drying and the flour has a sweet taste. Further studies on product development are required before sweetpotato products are likely to show market potential.

CIP, in collaboration with Makerere University and UNPP, is currently exploring possibilities for sales of value-added sweetpotato products, such as sweetpotato-based jam, orange sweetpotato flour, and leaves for animal feed. The sweetpotato jam is at the pilot stage and is being sold in Kampala for 2,000 Ush/450 g. There are other products, such as ketchup, which are sold in other countries. A considerable amount of training is being done to show processors how to use sweetpotato flour in a range of confectionery products (Owori 2001).

Market options for processed root crop products

Having established that markets for cassava starch and flour exist, the next issue is to determine which type of delivery system can best supply these markets. From the survey information it was concluded that there are four main options:

1. Starch importation.
2. Medium-scale factory starch production.
3. Small-scale starch production.
4. Replacement of starch with high quality cassava flours.

To evaluate these options, there are a number of aspects that must be considered. These are (1) product price, (2) product quality, (3) technical feasibility for supply, (4) investment costs for local processing, (5) returns on investment, (6) availability of raw materials, (7) ability to supply markets on a regular basis, (8) possibility for substitution, (9) socioeconomic benefits in terms of national revenue and employment, and (10) potential problems. A summary comparison of these aspects is detailed in Table 16 and the following section provides a discussion of the advantages and disadvantages of the four options.

Starch importation

Due to the lack of manufacturers in Uganda, almost all processors import maize/cornstarch because of its high quality, competitive price, and year-round availability. Although there is a cassava processing starch factory in Mombasa, (coastal Kenya), no companies in Uganda reported that they were using their products. Starch prices on the international market are relatively low and due to the competitive nature of this market, prices are likely to remain relatively stable in the near future. The devaluation of the East Asian currencies made Thai starch particularly low cost in dollar terms, in 1999 particularly. Figures from Thailand indicated prices as low as $135/t. Given these prices, overall market stability, no requirement for fixed cost investment, and the erratic nature of local crop prices, continued importation of starch is a highly attractive option. In addition to low costs, the external starch suppliers can provide a full range of products tailored to specific needs.

Factors limiting starch importation for Ugandan buyers include the cost of transportation, delays in transit, and cash flow problems which are associated with stockpiling or payment for advance orders of starch. Because of cash flow problems, some industries supported the idea of local starch production.

Table 16. Comparison of the four identified market options:

Marketing aspects	Importation	Factory starch and subproduct processing	Village-level starch/flour processing	Village-level flour processing
Product quality	High	High	Medium to low	Medium to high
Product range or marketing mix	All products	Pharmaceutical starch Industrial starch Liquid glucose Dextrin Waste to feed market	Native starch Flour Feed Waste to farm animals	Flour Feed Waste to farm animals
Capacity	Unlimited	5–10 t UMS/day 1–5 t glucose/day 1–2 t dextrin/day	1–3 t UMS/week	1 t/day
Production costs	See Table 18	Unknown	Starch - US$270–300/t	US$100–150
Purchase price	US $500–650 c.i.f. Kampala	Unknown	Starch - US$350–400/t	US$190/t
Technical feasibility	Not applicable	Requires importation of all machinery Use of expatriate operators, management	Machinery locally available	Machinery locally available
Investment costs	None	US$5–10 million	$5000/unit	$5,000/unit
Technical plant required to meet starch market demand	None	1 unit operating at 5 tonnes per day would produce 1,500 t in 300 days. Excess to starch demand could be channelled to other products or exported	10 units operating at 3 t/week or 20 at 1.5 t per week would supply 1,500 t	It would require 4–5 units producing 1 t per day to supply 1,000 t
Sustainability	Not applicable	Depends on security and financial management	Subject to market penetration and consumer reliability Can coexist with larger operators	Subject to market penetration and consumer reliability Can coexist with larger operators

For comparison of these options there are a number of assumptions.

1. Market size for UMS = 1,500 t, potential value of this market at $600/t = $900,000.
2. Market size for liquid glucose or HFS unknown but factory target was 4 t/day; at 1,500 t/year market value $750,000.
3. Market size for dextrin unknown but factory target was 1 t/day; at 500 t, value of this market @ $500,000.

Table 16 contd. Comparison of the four identified market options.

Marketing aspects	Importation	Factory starch and subproduct processing	Village-level starch/flour processing	Village-level flour processing
Management requirement	None	Expatriate management /advisors	Local processors need assistance in marketing	Local processors may need assistance in marketing
Availability of raw materials	n.a	Farm supplies subject to production efficiency Require an outgrowers' scheme	Good	Good
Capacity to supply to clients on a regular basis	Generally good but may encounter delays subject to bureaucracy and problems with transit	Good	Questionable—unknown, multiple sources of supply will be required	Questionable—unknown, multiple sources of supply will be required
Possibility of replacing imported goods	n.a	Prospects for offsetting starch imports good if factory can compete with Kenya CPC and other international suppliers	Reasonable prospects for offsetting imported starch if quality is good and price competitive.	High
Benefits revenue	None	Potential revenues Starch revenue US$900,000 Liquid glucose US$750,000 Dextrin US$100,000	Potential revenues Starch market value US$900,000 National flour market value $800–100 million	Potential revenues Dependent upon market size for high quality flour compared with traditional processed products
Benefits employment	n.a	Factory employees from ISI report 31 management 22 technical staff 131 labor 100 farm employees X-outgrowers	30 workers per unit = 300 people	30 workers per unit = 150 people
Internal rate of return	n.a	40% over 10 years = IDU 30% over 5 years = ISI	38% according to preliminary data analysis	23–30% (Ferris et al. 1998)
Potential problems	Capital tied to imported goods, loss of foreign exchange, need to pay at hard currency costs	Insecurity, unable to compete with external market, irregular power, inconsistent supply of raw material at low price and throughout the year, lack of quality water	Technology failure Management failure Lack of marketing skills Inability to sustain supply Uncompetitive price Poor quality	Technology failure Management failure Lack of marketing skills Inability to sustain supply

n.a = Not applicable

Medium-scale industrial starch production

Redeveloping Ugandan industrial starch capacity has been on the Government agenda for more than 15 years, but the project has failed to find strong private-sector support. According to this survey, the plans to develop a factory with a capacity of 5–10 t of starch/day would probably lead to an oversupply of the UMS market in Uganda. Therefore, as suggested by the IDU (1991), such a factory would need to process a range of starch products that are used by the local industries, such as MS, liquid glucose, HFS, and dextrin.

Setting up a factory to produce only starch may be feasible at $2–3 million, but expanding the product range to include MS, glucose, and HFS, will substantially increase investment costs. In order to justify these costs, additional market surveys would be required to provide more detailed information on the current and expected market value for UMS, HFS, and dextrin in Uganda. Studying starch markets in Western Kenya also needs additional review, as this could fall into the catchment area of Ugandan production, but only if prices are competitive with Kenyan suppliers.

According to the ISI report (1995), establishing a medium-scale starch processing factory with a full product range would require an investment of approximately $8–9 million and to operate successfully, a number of technical factors needs to be in place. These include access to constant power via the national grid and back-up generators, access to clean water, and a system to purify waste water. For the process to operate efficiently, the factory would require a supply of 30–50 t of raw materials each day, for 300 days per year. Operations will require skilled staff, security and transportation. Whilst low cost raw materials are available in the Lira–Apac region and Lira was the site of the former starch factory, it is questionable whether it would be prudent to locate the factory in this region. Security in Lira district is not yet assured, supplies of power and water are erratic, distances to potential markets in Tororo, Jinja, Kampala, and Western Kenya are considerable, and transportation is expensive.

Despite these problems with redeveloping factory-level processing, the Government of Uganda has commissioned three studies on the prospects for rebuilding the Lira starch factory. The Government has also made provision for counterpart funds towards investment plans. The return of the Asian community has regenerated interest in several primary business sectors and new investors have rehabilitated three cotton ginneries in Uganda. The recent purchase of the Lira factory site by Ugandan investors further supports the view that there is serious interest in this venture. Given these developments, an update on the local conditions and feasibility studies concerning the factory may provide new insights into the potential for medium-scale starch processing, and may provide a better analysis in terms of locating the factory, investment options, and potential for financial support.

Although there has been some growth in the cotton sector, and an increase in the ginning capacity, most processing is for lint production which does not require starch. The spinning factories, i.e., those that use starch, are mainly in Kenya, Tanzania, or overseas. In addition to the shift in location of the industry, the demand for textiles in the region has suffered due to the widespread importation of cheap, secondhand clothes. There have been some attempts to introduce legislation to increase taxation on imported clothes as a means to make local textiles more competitive. However, as the secondhand clothes sector provides up to 20–30% of transient employment in Uganda, it will be difficult to implement such legislation.

Unlike former times, a factory seeking to supply the domestic market will need to supply more than UMS, as the cotton–textile sector is yet to show strong growth. This survey has shown that there is a small but expanding nonfood market for starch. The Crown Bottling Co. is currently building two soft drinks plants in Kampala and Mbarara, to supply Uganda, Rwanda, and D.R. Congo. The factory currently produces 28,000 crates/day of soft drinks but this capacity will increase to 58,000 in 2 years. Although the growth in soft drinks manufacturing could provide a lucrative market for supplies of high fructose syrup (HFS), the company has indicated that their plant is designed to use refined cane sugar and they would have to make considerable modifications to accommodate the use of HFS. In the circumstances, they considered it unlikely that the shift from sugar to HFS would be made, despite the cost saving they would achieve. Should this situation change, this potential market may prove to be a significant factor in location of a starch factory. Unlike in Kenya, the brewing factories based in Jinja and Kampala do not use brewers' starch, but again they may switch to greater starch utilization if a quality, low-cost starch were available.

The future of industrial starch processing in Uganda, therefore, remains unclear. The market survey does not indicate a large, rapidly expanding domestic market that can be easily captured through local production. Energy costs are relatively high in Uganda and the condition of the roads makes transportation expensive. The location of a starch factory in Uganda is complicated by historical links, and production faces strong competition from Kenya, South Africa, and other overseas markets. Due to the fall in value of the Thai currency against the US dollar, cassava starch is particularly low cost and it is unclear when the Thai currency will return to 1997 levels. The low cassava starch prices may also lead to reductions in the price of maize starch, which would increase the competitive edge of imported products. Given these factors, the evidence suggests that this may not be the most appropriate time to invest in local industrial production of starch.

Small-scale starch processing

Small-scale starch processing is a commercial reality in Latin America and Asia where root crops are processed at the village level into starch and starch products such as noodles, alcohol, maltose, and medicines (Plucknett et al. 1997). Developing the small-scale sector is attractive for a number of reasons, including low costs in investment, labor, and production, and flexibility in location. It is also attractive in developing economies as it provides a means to stimulate the rural sector and employ rural labor.

There are several examples in Africa and other developing economies where small-scale rural agro-enterprises compete effectively and coexist with larger scale industrial developments. These small-scale operators produce up to 1 t of flour or 0.5 t of starch, generally use basic equipment, and are labor intensive. Taking advantage of low labor costs allows for lower investment costs for each processing center and means that capital risks are more widely spread. As shown in Vietnam, the production costs: investment ratio is lower for small-scale operators than for larger manufacturers, and this provides the competitive advantage (Goletti et al. 1998).

In Uganda, there are already traditional methods for processing cassava and this type of activity can be improved relatively easily with the introduction of simple equipment that can increase processing efficiency, output, and product quality. Although small-scale processing technologies for root crops in Africa have tended to focus on flour and *gari* production, the system can be altered to produce starch with minor adaptations in the process. Water requirements can be substantially reduced if the process uses water tanks.

To provide farmers or processors with a range of market options, technologies should provide flexibility in terms of end products, i.e., one system to produce cassava chips, flour, and starch. This would mean that farmers will not be bound to the vagaries of one market and can test market opportunities according to demand and their ability to sell products. In addition to the supply of basic goods such as chips, (in this case, cut chips from improved chippers), flour, and starch, cassava processing can be further diversified at the small scale to process products such as maltose, alcohol, and crude adhesives and dextrins.

As with the larger scale operators, the production of a range of value-added products creates new options for income generation and helps to reduce risk. The information in Table 16 provides a comparison of the four identified market options. Table 17 provides an overview of the advantages and disadvantages of small- versus medium-scale processing. Essentially, dealing in small-scale processing is a low cost/lower risk investment, compared with establishing a factory but has more problems with regard to quality and regular supplies.

Small-scale processing of high quality cassava flour as a substitute for starch. This survey found that in the nonfood sector, industrial processors were substituting cassava flour for starch. In most cases, the processors were initially reluctant to discuss this aspect and it is probable that the level of substitution is underrepresented in the results from this work. According to B. Munaganizi (Pers. comm), almost all textile factories in the former Zaire replace starch with cassava flour.

Prospects to supply the nonfood market with higher quality flour, using improved but small-scale techniques, are therefore high, and this market option has several advantages. First, the market already exists and is likely to increase with industrial expansion and secondly, the nonfood industrialists are interested in a cassava flour that is of higher quality than traditionally processed flours. To supply such markets, small-scale processing is ideally suited as it requires low investment, uses rural labor, and technologies for the production of high quality cassava flour are available in Uganda. All that is required is for farmers to be trained in the use of equipment and then the processing groups to be linked with the industrial processors.

Table 17. Commercial medium- to large-scale versus small-scale starch production in Uganda.

Advantages	Disadvantages
Medium-scale starch processing	
• High and efficient rates of output	• High initial investment for buildings, equipment, and water and power supplies
• Consistent supply of high quality products to markets	• Factory needs a constant high volume supply of good quality, fresh cassava
• Use of modern technologies to produce higher value secondary starch products such as HFS and dextrins	• Product output needs to be competitive with changes in the global market
• Low product output costs due to economies of scale	• May require expatriate management and technical experience
• Potential for supply to end-users in Uganda and to a limited extent, western Kenya	• Factory needs to run an efficient farm to ensure supply of raw material
• Increased local demand for raw materials and generators to ensure constant processing	• Constant supply of power will be needed
• Use of outgrowers to supply cassava	• High quality water supply is required at high volume
• General development of the region	• Effective waste water treatment capacity
• Provides employment opportunities	• Factory will face strong competition from Kenya CPC and with international markets
	• Factory will need access to spare parts and also market information, probably requiring a satellite link?
	• Location of factory, if at Lira, means high transport costs to consumers in Jinja, Mbale, Tororo, Kampala, and Mbarara
Small-scale starch processing	
• Use of local resources, in terms of crops and labor force	• Small-scale village-level producers often supply low quality products
• Low initial investment	• Considerable training is required for developing the new labor force
• Minor adaptations can be made to flour technologies to facilitate starch processing	• Questionable ability to supply on a regular basis
• Ability to produce a range of products	• Credit schemes needed to facilitate purchase of equipment and enterprise development
• Increase in farmers' income	• Poor coordination between the suppliers
• Opportunity to integrate small-scale farmers with larger industry and increase utilization of local crops	• Lack of access to market information

VII

Strategies and technologies for small-scale market intervention

The technical details and prospects for medium-scale market development are clearly outlined in two reports (UNIDO 1991; ISI 1995). Therefore, this section of the report will focus on technologies required for small-scale processing and the possibilities for farmers and entrepreneurs to make the shift towards value-added cassava processing for three products: chips, flour, and starch.

In Uganda, farmers are already processing cassava flour using traditional methods. Results from a national survey revealed that in the major cassava growing areas up to 70% of cassava is processed into chips, flour, local beer, and gin (*waragi*) (Bukenya 1998). In the national baseline survey it was found that the most commonly mentioned constraints to processing were poor drying conditions, lack of processing equipment to increase the volume of processing, and high costs of labor. These constraints suggest there are opportunities for the adoption of techniques that offer increased processing efficiencies, reduce labor costs, and enable farmers to get access to higher value markets.

From traditional to high quality flour processing

Traditional cassava processing. In Uganda, there are two types of cassava, locally referred to as "sweet" and "bitter." Sweet cassava is generally consumed as a raw snack or boiled as a vegetable. Bitter cassava is usually processed, as this type of cassava is potentially toxic. It contains substances capable of producing hydrogen cyanide if the roots are consumed in the unprocessed form. In the drier northeast and northwest parts of the country, there is a greater percentage of bitter cassava that is traditionally fermented before consumption or grated and dried to make flour. Throughout the world, both types of cassava are common; the advantage of cassava toxicity is that people do not steal bitter cassava as a casual snack and the wild animals that eat sweet varieties do not harvest the crop. The bitter aspect, therefore, provides a protective mechanism against random harvesting and fields can be cultivated with confidence at considerable distance from the homestead.

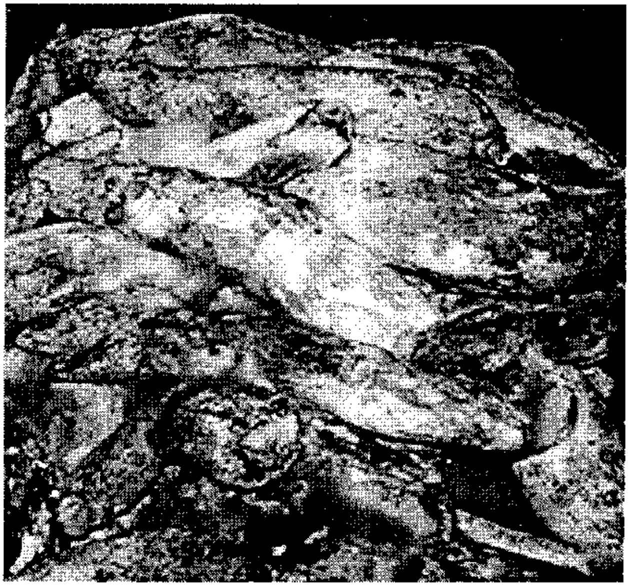

Plate 1. Heap fermentation.
Source: National Resources Institute, UK.

In Uganda, bitter cassava is traditionally processed to a safe, nontoxic product, using two methods: heap fermentation and wet fermentation. Heap fermentation is most common in areas with limited water supply. This process involves peeling and heaping roots into a pile that is covered with dry leaves, grass, or sacks. Over a period of 7–10 days, molds grow on the roots and facilitate the fermentation/detoxification process (Plate 1). After fermentation, roots are uncovered and the surface molds are scraped away with a knife. The cleaned roots are then pounded, using a mortar, into a coarse pulp that is spread on mats to sun dry. The dried product is sold as "local chips," a mixture of small granules and large coarse pieces up to 2–3 cm in diameter. Wet fermentation/detoxification involves soaking peeled cassava roots in water for 3–5 days in a river, pond, or container (Plate 2). When the roots have softened sufficiently, they are removed from the water and similarly pounded into a pulp that is sun dried. Dry cassava chips, the product of both processes, have an average shelf life of one month. However, if stored in good conditions, this period can be extended up to 3 months. For best quality flour, the chips are taken to a local hammer mill for milling into the fine flour that is most desirable.

Cassava chips or flour are used by the household or sold. Consumers rehydrate the flour in boiling water to produce a stiff porridge, locally known as *posho* or *ugali*. Using these traditional methods, a family requires approximately one week to process 10–30 kg of chips. In addition to the drudgery of traditional processing, the output is low and quality is often poor in terms of color, odor, and contamination with earth. Costs of this method of processing are difficult to establish as labor costs are generally

Plate 2. Soaking cassava, wet fermentation.
Source: National Resources Institute, UK.

not considered in the total, the assumption being that food processing is part of women's daily work. If this task were charged at an average cost of 300 Ush/hour, then the processing costs would be relatively high as the process is labor intensive and time consuming. Drying is also dependent upon prevailing weather and this affects both quality and labor costs.

Traditional sweetpotato processing. Sweetpotato contain no toxic substances and roots are simply sliced and sun dried. Processing of sweetpotato in Uganda is restricted to the drier, more northern parts of the country, particularly Lira, Apac, Katakwi, Kitguma, and Gulu districts. Typically, sweetpotato are not washed or peeled. The tubers are brushed to remove the earth and then sliced longitudinally into 5–10 mm sections before being sun dried on rocks or the ground. The dried sweetpotato chips are rehydrated when added to a stew to bulk the food. The quality of the end product is generally poor, as no attempt is made to prevent or reduce oxidation during drying. Hence sweetpotato chips are often brown and the flour is grey.

Processing is generally a household activity although recent market surveys have found that some sweetpotato is being processed into flour at commercial milling centers. Milling of sweetpotato chips has been observed only during peak production periods when the markets are oversupplied with fresh tubers. Farmers indicated they do not sell the sweetpotato flour but take it to their houses to mix with cassava flour (Ferris et al. 1998). Sweetpotato flour is not yet a commercially traded commodity in Uganda.

Improved methods for processing cassava and sweetpotato flour

Although traditional cassava processing is simple and effective in terms of producing safe and tradable goods, the flour is generally of low quality and there are few alternative market opportunities for this product. Prices of the chips and flour are dependent upon seasonal yields and ceiling prices are generally limited by the price of maize flour, which is considered a product of higher quality. To test the potential for improved processing of root crops IITA, in collaboration with the Postharvest Program of the National Agricultural Organization of Uganda (NARO), has developed simple, small-scale cassava processing equipment (Plates 3–9).

- Chipping equipment can produce up to 1,000 kg of chips/day and during the dry season it takes 2–3 days to sun dry the chips.
- Grating equipment can produce up to 500 kg of fine, white, odorless cassava flour/day.

The processing techniques, therefore, offer farmers the prospects of premium prices at the local marketplace and also access to secondary processing markets. This potential to engage in more vertical integration, from farmer to primary and secondary processors, will lead to increased farm-gate prices, and the ability to diversify the product range is a critical factor in expanding the market sales points for a commodity and therefore in stimulating demand. A sample cost–benefit analysis of the production of processing chips and flour using the motorized processing techniques is given in Annex 4. The internal rates of return for these methods are shown in Table 18, and the cost–benefit is described in more detail later in this chapter.

Stages in processing high quality flour from cassava

1. Roots manually harvested and peeled.
2. Peeled roots are grated, using a power grater (Plate 3).
3. The grated cassava paste is dewatered using a press (Plate 4).
4. The drained mash is removed from the gunny bags and regrated. The regrated cassava flour is then spread out to dry (Plate 5). To avoid contamination by dust, the cassava flour can be dried on plastic sheets, concrete beds, or on raised racks.
5. Manual chipping equipment was also developed for cassava processing (Plate 6). Chipping can be used to accelerate flour processing only for roots with relatively low HCN content.

Table 18. Relation between method of processing and profitability.

Method of processing	Product	Internal rate of return (%)
Grating	Flour	32
Chipping	Flour	68
Vietnamese rasper	Starch	36
Rasper and grater	Starch and flour	33
Low acreage	Flour	27

6. Power chipping equipment was developed for cassava processing (Plate 7).
7. Dried mash or chips are then milled using a hammer mill, bagged, and sold into the markets.

Manual processing

One of the obvious disadvantages of power processing is the cost of the equipment for resource-poor farmers who have great difficulties in getting access to credit. The manual chipper was designed to offer a lower cost processing alternative and this equipment can be used for cassava and sweetpotato processing. The disc slicer/chipper has an output of approximately 100 kg/hour, when used as a chipper and up to 150 kg/hour when used for slicing. The equipment costs $60/unit and $10 for each of the cutting plates. The slices or chips are dried on plastic sheets or raised platforms to avoid contamination with dust, and the slices are either used directly or can be milled into flour. The reason why manual processing has not been analyzed economically is that demand for this technology has been low.

Evaluating small-scale processing technologies

Starch processing technology. The process of wet starch extraction from cassava requires that roots are ground into a fine paste which can be sieved through a muslin cloth. The types of equipment that had previously been introduced into Uganda from Nigeria were to support cassava flour processing, using a *gari* type processor. The rasping head for the *gari* processor is a punched metal sheet which produces a coarse textured paste that cannot be used efficiently for starch extraction. The granule size of the mash is too coarse to separate starch from the fibers through a muslin cloth. See Plate 8 for the *gari* rasping head.

Therefore, a visit was organized to observe and transfer Vietnamese starch processing technology. The Vietnamese technology was obtained through a study tour organized by the Vietnamese Root Crops Program and the National Postharvest Program of the Vietnamese Agricultural Sciences Institute, with the assistance of CIP and IFPRI. Simple, small-scale starch technology is common throughout the Red River Delta region of Vietnam where cassava starch processing is a widespread rural agro-enterprise, particularly for farmers living in the more remote regions (Golletti 1998).

The Vietnamese grater has an output of 200–400 kg/hr producing 1–2 t of starch/week. The technology is similar to that of the Nigerian *gari* machine except for the rasping head. This is made from fine pieces of steel wire which are hammered in rows into a wooden cylinder (Plate 9). These wires provide the fine mash required for starch extraction. The cost of the starch machine was approximately $800 (1998 prices), including the 3.5 Hp engine at $500–550. More recent links with suppliers from Dubai have reduced the engine's cost to $200–250. The equipment used for starch processing includes muslin cloths, sedimentation tanks, and stirrers.

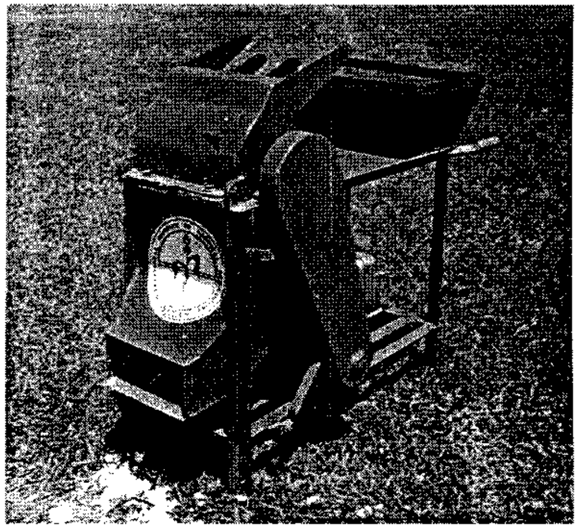

Plate 3. Bitter cassava is peeled and grated into a fine mash using a power grater.

Plate 4. Grated mash is dewatered using a press.

Plate 5. Sun drying dewatered mash or chips. The dried product is then milled.

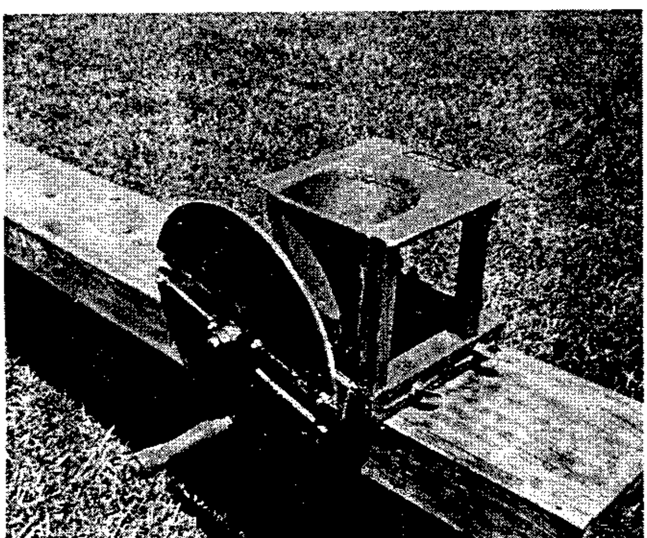

Plate 6. Sweet cassava is chipped using a manual or power chipper.

Plate 7. Power chipper.

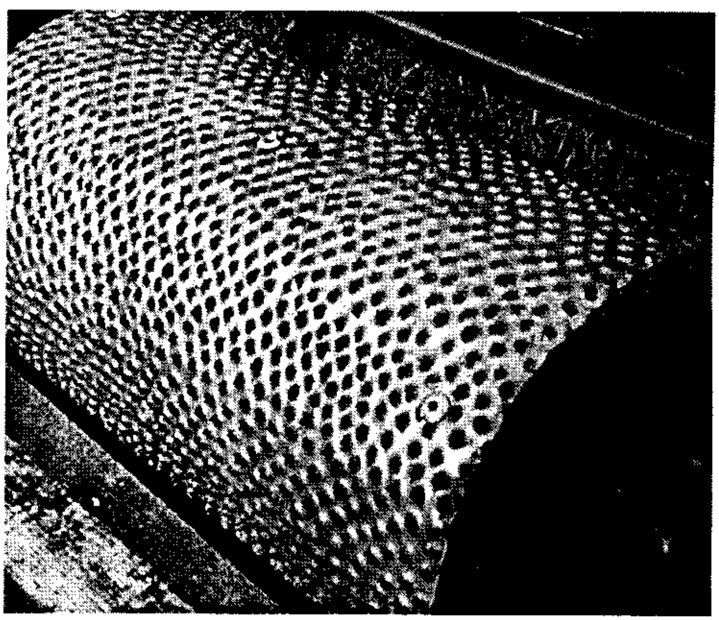

Plate 8. *Gari* coarse granule rasping head.

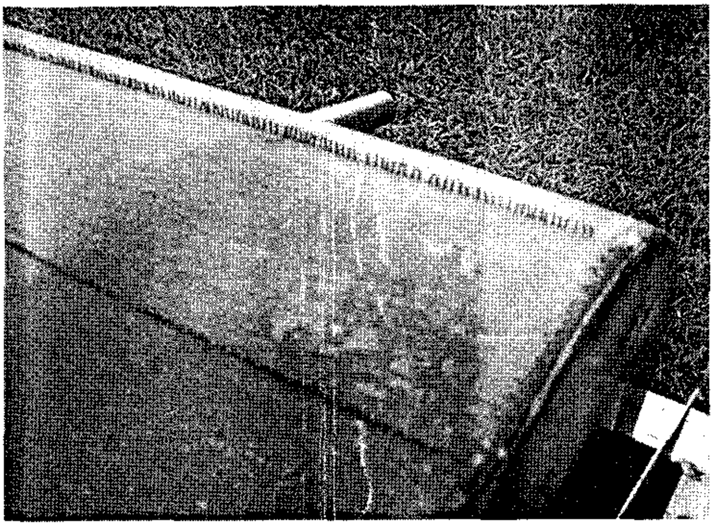

Plate 9. Starch fine wire rasping head.

All of these pieces of equipment, observed in Vietnam, were transferred and fabricated at the IITA starch processing center. This test facility enabled the research team to make starch, learn the process of starch extraction, and find ways to make it more suitable for farmers. It also provided the first place to test the economic viability of the system.

Cost–benefit analysis of the processing technologies

The starch survey revealed there were market opportunities for small-scale processing of cassava into starch and high quality flour. For both processes, technology problems were overcome with the introduction of machinery from Nigeria and Vietnam. However, the question remained whether these packages were economically viable. To test this aspect of the research, a series of ex-ante cost–benefit analyses was conducted to measure the profitability of flour and starch processing enterprises, using data from on-station and on-farm processing units. The method of cost–benefit analysis used to evaluate the performance of the starch processing centers was that developed by Wheatley and Ostertag (1995). A summary of the cost–benefit analysis for flour and starch production at Katakwi processing site with internal rates of return is shown in Table 18.

The economic analysis showed that chipping was the most cost effective method of producing cassava flour. The research team did not expect this result, but the higher profitability of the chipping method was related to lower handling costs and a more rapid turnout than from the grating systems. Chipping, however, has one drawback: it is recommended only with varieties that have a low-to-medium level of cassava toxicity (CNp) as it does not reduce cyanide levels as much as grating. (See later in this chapter.)

For more details of the cost–benefit analyses, see Annex 4. The Internal Rate of Return (IRR) for flour production was 32% and the same analysis provided an IRR of 36% for starch processing. Part of the reason for the higher profitability for starch processing was related to sales of a higher value product, even when the extraction rate was relatively low. The information to date has found that at an extraction rate of only 10–20% starch, the group was able to produce UMS at a cost of approximately $200–250/t, with a sales delivery price of $350–500/t. It is envisaged that a farmers' group would process and sell both starch and flour, which had a slightly lower return.

The reason for combining the two processes was because the level of starch extraction is relatively low, and the waste product from starch could be incorporated into the flour. Therefore, losses would be negligible. These IRR figures of between 32 and 68% are relatively healthy values, given an inflation rate of 5% and a prime bank rate of 25% interest. From these data, it is clearly more profitable to invest in this type of processing over a 5-year period than merely investing the funds in the bank. In addition to the profit, there are also a number of social benefits including provision of employment, use of land, and sales of a high quality processed product.

Sensitivity analysis of cost–benefit

Although the IRR was considered relatively good for flour production, it is conceded that such analyses are highly dependent upon the assumptions made. Therefore, it is useful to review the sensitivity of the assumptions for the IRR value (Annex 5). As the IRR falls below 25%, the model assumes that it may be better to invest the funds in an alternative venture and this therefore raises the option of opportunity costs. The operator should assess the changes in the IRR based on the assumption that analysis of these parameters can allow for better performance by making changes in the main cost variables or factors. For example, if the "capacity utilization" of the operation falls below 25%, what changes can be made to other factors, such as labor costs, to maintain the desired return on investment? The sensitivity analysis of flour production indicates the merit in seeking premium prices for the product and the dangers of producing a lower quality product, as the IRR is only 6% when the sales price falls from 300 to 250 Ush/kg. If an analyst were to apply this type of information on a national view, the best locations could be decided, based on spatial price maps using data from the national market information services. Flour recovery, a measure of the percentage flour from the roots, is another key factor in analyzing the efficiency of the operation. For best results, as much of the roots should be transformed into flour, the sensitivity analysis showed that only a 5% loss in extraction may be the difference between healthy profits and losses.

As with all agro-enterprises, labor costs are a vital factor and should be maintained at a low level to enable long-term profits. According to the latest UNDP reports, the national average Ugandan wage is between 0.8 and $1/day; this is equivalent to

Ush 1,200–1,500. For an 8-hour day, a laborer should therefore expect a range of 100–175 Ush/hour. It is unfortunate that in many cases, agro-enterprise projects are run as "projects" rather than business ventures. Labor is paid often at an unrealistically high level that basically makes feasible projects unviable.

The analysis of production area revealed that as this falls below 20 acres, profitability falls dramatically. This was a surprising result that indicates small groups may be less likely to develop profitable enterprises if they do not plant out relatively large areas of raw material quickly, i.e., within 2 years. This finding runs counter to the approach of supporting the poorest and smallest farming groups. It rather emphasizes the need to select groups that either have the potential for rapid expansion into higher volume processing or have social structures in place, such as collective marketing groups, which can exploit larger areas of cassava.

The cost–benefit exercise was therefore important not only in showing the most profitable means of processing but also in providing a means to ascertain the minimum levels at which agro-enterprises can operate, relative to local opportunity costs. Perhaps it is also realistic to comment on the net present value that was based on an interest rate of 25%. This level is based on prime bank interest rates in Uganda. Although higher rates of return are available at banks, the vast majority of farmers are not in a position to gain from such opportunities for their capital. It may be more realistic to determine real alternatives of opportunity costs which may be lower and these may be from 5 to 15% if such capital opportunities exist and if people have funds to invest. The point is that low rates of return may be acceptable in the rural farming system. In that case, processing centers for a smaller area may be the best financial options for a given locality.

The use of chipping and medium cyanide varieties of cassava

In 1996/7, there was a spate of reported poisonings in Uganda that were attributed to cassava-based cyanide toxicity. This led to a moratorium on the multiplication of the rapidly spreading, newly released variety TMS 30572 that was assumed to have caused the outbreak. To investigate this matter, IITA and NARO set up a series of experiments to evaluate changes with age in the CNp of TMS 30573 and other commonly grown cassava genotypes. According to farmers in the main cassava growing region, TMS 30572 was considered to be bitter and therefore toxic until it was mature at 12 months after planting. At 12 months it was claimed that the roots were then safe to eat even as a boil-and-eat product. To test this theory, an age experiment was established to record changes in CNp of a range of cassava varieties with time after planting (Table 19). The FAO-recommended safety limit for cassava and cassava products is approximately 10 mg CN eq/kg dw. However, this level is considered by many researchers to be too conservative and for the breeding community a value of approximately 100 mg CN eq/kg dw is used to differentiate between low and medium CNp varieties, i.e., those that can be consumed without processing and those that are recommended for processing.

Table 19. The effect of crop age on root cyanogen levels at Serere station (mg CN/kg DM).

	Months after planting							
Variety	3	6	9	12	15	18	21	24
Myghera	869	389	267	91	60	105	51	29
PDB	1,084	463	360	263	144	296	138	186
Tongolo	1,856	400	384	184	115	191	79	89
Nase 1	185	136	158	58	54	54	32	24
Nase 2	734	257	85	71	53	90	24	30
SS4	395	190	165	98	47	100	46	35

cv 44%	MAP	Variety	MAP × Variety
rep	54	63	9
df	311	311	311
sed	22	20	53
lsd	43	40	104

MAP = months after planting
rep = replicate
sed = standard error of difference
CN = cyanide
cv = coefficient of variation
df = degrees of freedom
lsd = least significant difference

The data in Table 19 shows that in the first 6–9 months, all varieties except for Nase 1 and Nase 2 were relatively high in CNp. However, after 12 months, only PDB and Tongolo were in the medium-to-high risk range. These data fully support the farmers' view that TMS 30572 is safe to eat after being grown for 12 months. Implications of this finding are that all the varieties were potentially toxic in the first 3 months after planting, but that levels for all varieties except PDB and Tongolo were in the safe range after 12 months. In terms of processing safety, this finding supports the shift from grating to chipping as the most efficient means of processing cassava flour from varieties such as TMS 30572 (Myghera) in Uganda. It was the toxicity problem which initially led the processing research focusing on the grating method, but the financial and food safety data suggest that chipping is more attractive.

VIII

Conclusions

Major findings from the survey

- Uganda had an industrial starch processing capacity until 1985, but this capacity and much of the associated market were lost during the period of civil unrest. In the past 10 years, there has been stable development and entrepreneurs are now investing in a broad range of industries including food and nonfood processing. As a result, there is a small but growing demand for starch within the pharmaceutical, food, brewing, textile, wood processing, and paper industries.
- At present, all domestic markets are supplied from imported maize starch. In 1998/9, the factory–gate cost was about \$500–650/t c.i.f. Kampala.
- The information from the market survey suggests an approximate annual domestic consumption of starch (1,000–1,500 t), liquid glucose (1,000–1,500 t), and dextrin (300–500 t). These markets have a combined value of \$2–3 million/year.
- Import prices for starch products were in the range of \$400–500 t in 1998, but due to changes in the value of the Asian currencies, starch prices had fallen in 1999 to \$250–350/t f.o.b., making cassava starch more competitive with cornstarch which was selling at \$350–450/t.
- The international starch market is highly competitive. It is unclear whether Uganda has sufficient market volume or comparative advantages in terms of financial investors, infrastructure, security, and marketing advantages to support factory-level production.
- Small-scale starch processing is technically feasible and an economic analysis of processing flour and starch indicates rates of return from 32 to 68%. Further work is required to determine whether small-scale industries can be made into a profitable long-term agro-enterprise activity.
- Due to the high cost of imported starch, many processors are replacing starch with low-cost flours, and this offers a market opportunity for processors to supply industries with higher quality flour to improve on their products and still retain low-costs. On a volume basis, the size of the starch replacement market is probably larger than the starch market and this suggests that the cassava flour market is an attractive option for research and small-scale agro-enterprise investment.

Short- to medium-term options for market intervention

For the short term, the most practical means of supplying the "starch-using factories in Uganda" appears to be as follows in priority order.

1. Continued importation of starch and starch products. Due to the devaluation of Asian currencies, this option is becoming more financially attractive.
2. Development of small-scale processors to supply high quality flour to the nonfood starch replacement market.
3. Expanded supplies of high quality cassava flour as a substitute for wheat/maize flour in the food sector.

Longer term options for market intervention

Continued starch importation is possible, but with assistance to processors in the form of improved market information so that processors can take advantage of lower cost products and perhaps lower quality starch lots.

1. Test marketing to industrialists of starch from pilot site processing units.
2. Support in terms of feasibility studies to entrepreneurs interested in developing processing plants for both medium- and small-scale processing.

Options for market intervention

Starch importation. This is an attractive option because of low prices, high quality, and the availability of a range of products from low-grade starch to modified and derived products. Supply is year-round, and if problems with transportation systems can be overcome, problems with delivery time and high cost of transportation will diminish. It is estimated that current transportation costs are $100/t of starch delivered to Kampala from Mombasa by road, and $60–70 by rail. No capital investment is required for importation and manufacturers can meet their needs as required. There is increasing competition within the Kenya market which will drive down prices and the development of the new South African starch factory may stimulate more competitive local prices.

Developing a medium-scale starch factory. Developing a factory-scale processing plant similar to that of the Lira starch plant to supply 5–10 t/day of UMS is one of the projects under investigation by the Government of Uganda. At 5 t/day, production would probably meet the needs of a large percentage of UMS usage in Uganda, approximately 1,500 t/yr. The capacity to produce in excess of 5 t/day of UMS would require a venture into sales of other starch products such as liquid glucose, HFS, and dextrins. The product mix would be dependent on demand and this would require detailed marketing analysis of specific products. The factory option has the advantage of economies of scale in terms of production, but requires a high initial investment, constant power, a regular supply of raw material, highly skilled manpower for management and maintenance, and a good supply of clean water. The Government of Uganda has commissioned three feasibility studies for the rehabilitation of the industrial starch capacity and has offered incentive loans, but as yet no entrepreneur has commissioned work. Although the benefits to an area such as Lira would be appreciable in terms of employment, revenue, and a significant increase in demand for cassava, the starch market in Uganda is relatively small. There is strong regional competition and the critical question concerns future growth of the manufacturing sector.

Two large soft drinks factories will soon be opened in Uganda to supply the Great Lakes region. It is estimated that production will increase from 28,000 to 60,000 crates by 2001. Currently, the industry is using purified sugar as the sweetener, but the imminent growth in the sector offers the opportunity for considerable demand for HFS.

Growth in the cotton sector, the traditional market for Ugandan starch, has been relatively slow in the past 5 years. Although there are more processors and buyers working in Uganda, due to problems with weather, roads, and insecurity, the cotton sector has had a number of poor years, producing only 20,000 bales in 1998. Uganda currently has only two textile weaving industries, both of which are using maize or cassava flour, and therefore prospects for starch are limited. Other growth areas may be in the food and nonfood sector, and as planned in the UNIDO report (1991) a broad market mix may offer greater security in processing.

Development of small-scale processing. There are several examples in other developing countries of the growth of a viable and vibrant small-scale starch processing industry. Developing rural agro-processing in Uganda would improve the skills and incomes of rural farmers and by targeting specific markets long-term economic sustainability could be achieved. Developing this sector will require the adoption by farmers of new but relatively simple technologies. From rapid assessments conducted with farming groups in Uganda, it would appear that the prospects for small-scale processing are feasible. The economic evaluation is promising, particularly when farmers are able to process a range of products, such as cassava chips, flour, and starch. The most attractive option for the farmers in terms of producing these products is that although the small-scale process is inefficient, i.e., only 10–15% of the harvested roots are converted into starch, the waste is of relatively high quality and can be incorporated into the flour process. The problem with developing a small-scale industry is the capacity of the farming groups to produce a product of sufficiently high quality and provide a sustained supply. This sector will need to develop sufficient management and marketing skills to be able to meet the market requirements.

IITA has already established 20 processing sites across the country as part of a USAID-supported initiative to increase income from local crops. This type of initiative could be expanded with the support of NGOs and the Government whose policy does not generally focus on the needs of the small-scale agricultural producers, although most of the GDP comes from the agricultural sector. The current situation with cassava offers a good opportunity for Government agencies to work in close collaboration with the technical and financial NGOs to stimulate this potential rural industry.

Substitution of cassava flour for starch. The substitution of cassava flour for starch is already being exploited by the textile industry. Development of this sector is mainly attributed to the availability and low price of the root crop flour that serves the same purpose as starch. Cassava flour can also be used in other nonfood areas, particularly for dextrin production, and there are options for using high quality flour as a substitute for wheat and maize in the brewing and confectionery industries. According to Gensi et al. (2001), up to 70% of the confectionery manufacturers in Kampala have at some time used cassava flour in their processing, but all have ceased this practice because of the poor quality of cassava flour. Tests are currently underway to supply processors with high quality cassava flour for biscuit making. Initial results show that biscuit quality is good using cassava flour. Providing technical support to this sector may be the most rational first stage in developing the supply of higher value products from the small-scale sector.

Recommendations and areas for future research

Production

- Test with farmers new varieties of cassava, which are not only disease resistant and high yielding but have a higher dry-matter content (DM) than local varieties. Current information from EARRNET indicates that some newly developed clones have a DM of 45%, whereas local varieties have a DM of 25–30%.
- Collect more information on types of sweetpotato used for starch extraction and the methods used in order to avoid enzymatic browning.
- Analyze production efficiency of cassava in terms of production per unit area with and without the use of agricultural inputs, such as fertilizer and best management practices, to determine competitiveness of production compared to other crops based on local market prices.

Marketing

- Make linkages with Ugandan starch producers to investigate their future needs in terms of market analysis and technical support.
- Test consignments of locally made starch from small-scale processors with industrial partners in Uganda.
- Test consignments of high quality flour with those industrial partners in Uganda using either flour as a substitute for starch or mixtures of starch and flour.
- Test use of flour in dextrin production for plywood, cardboard box, and label fixing.
- Determine the level of starch demand in Kenya and Tanzania, prices, and suppliers, to provide a regional perspective.
- Evaluate opportunities for improved quality flours in industrial processing.
- Assess the market for subproducts, particularly HFS, in view of the new soft drinks factories in Uganda.

Technology development

- Modify the existing cassava processor to enable simple shifts between flour and starch processing.
- Evaluate prototype root peeling/cleaning machines to reduce the constraint of cassava peeling.
- Improve or reexamine technologies for drying flour and starch.
- Gather information on traditional and improved sweetpotato starch processing.

Product development

- Assess the quality of the starch required for various markets.
- Assess the type of starch or flour, fresh or fermented, required by the textile industry.
- Evaluate the differences between flour and starch.
- Assess the potential for animal feeds from cassava in Uganda.
- Assess the quality of sweetpotato starch.
- Evaluate simple methods and modifications to reduce browning of sweetpotato starch during drying.
- Assess the possibility of producing and selling other products which are processed in Latin America or southeast Asia, such as tapioca, noodles, and animal feed pellets.

Linkages and training

- *National.* Increase the flow of products and skills from Latin America and Asia to farmers' groups in Uganda and the East African region. Study groups from Uganda or East Africa should link with national programs in Brazil and Vietnam to gain firsthand experience of product range and technologies required. This study should seek to identify and prioritize products, then training sessions need to be devised to enable the national program staff to exchange ideas and products.
- *Intercenter.* Stronger collaboration between the centers offers the advantage of transferring skills among scientists and thereby to the national partners at lower cost. A good example of this is the need for training in marketing for researchers and also for the target community. This could be achieved in East Africa by linking the IITA/CIP group with the agro-enterprise project from CIAT. Similarly, policy analysis to advise Governments and policy-makers at the donor level could be achieved by strengthened collaboration between IITA/CIP and the Marketing Division of IFPRI.
- *Centers with other bilateral agencies.* Currently there are limited opportunities for collaboration between IITA/CIP and the bilateral agencies including GTZ, NRI, CIRAD, ACIAR, and FAO and the leading NGOs in terms of postproduction research and development in East Africa. Greater coordination or awareness among these agencies could have a major influence on the market analysis, delivery of technologies, and therefore the impact of postproduction activities in the region which should be done within a well-defined, market-led approach.

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Annex 1. Glossary of commonly used starch-related terms

Acid conversion	Starch hydrolysis with acid as the catalyst.
Amylopectin	For most starches amylopectin is the major component—a branched glucose polymer with typically 1–6 glucosidic bonds for every 12 glucose units. Amylopectin consists of several 100,000 glucose units.
Amylose	The minor constituent of starch is amylose—a linear glucose polymer with alpha 1–4 glucosidic bonds only.
Carbohydrate	Monosaccharide or natural organic substance giving monosaccharides by hydrolysis, e.g., starch, sugar, cellulose, glucose, fructose, maltose
Conversion	Synonym of conversion hydrolysis or hydrolysis.
Crystallization	In concentrated high DE syrups, glucose crystals are formed and precipitate.
Dextrin	Industrial dextrin is granular starch with molecules reorganized by roasting causing the granules to be cold water soluble. Depending on the degree of roasting, dextrins are grouped as White Dextrin, Yellow Dextrin, and British gum.
Dextrose	Synonym for glucose. Within the industry, dextrose is used to describe 100% pure glucose.
Disaccharide	Carbohydrate with two monosaccharides per molecule, e.g., sucrose, maltose. Sucrose is a disaccharide with one glucose and one fructose per molecule.
Enzyme	Three groups of enzyme catalysts are used in the glucose industry: (1) alpha-amylase for liquefaction, (2) amyloglucosidase for saccharification, and (3) isomerase for conversion of glucose to fructose.
Fructose	Alpha-D-fructose is an isomer of alpha-D-glucose. Standard fructose syrup contains as much as 42% fructose and enriched syrup as much as 55%. High concentration of fructose is achieved by chromatography.
Gari	Processed fermented cassava food, roasted granules, staple food in Nigeria.
Gelatinization	The process of cooking starch.
Glucose	Monosaccharide, $C_6H_{12}0_6$ existing as α– and ß– glucose with an optical rotation of +105.2° respectively +20, 3°. The synonym dextrose refers to the positive direction of rotation (dextra = right).
Glucose syrup	A liquid starch hydrolysate of mono- di- and higher saccharides.
High fructose syrup	A liquid starch hydrolysate with a high content of fructose—typically 42, 55 or 90% fructose.
Hydrolysis	Breakdown of starch to glucose and smaller polymers by cutting glucosidic bonds with simultaneous uptake of water. Industrial hydrolysis is a two-step operation: liquefaction and saccharification.

Isomerase	Enzyme rearranging glucose into fructose. The process reaches a feasible equilibrium with 42% fructose, 53% glucose, and 5% higher sugars.
Liquefaction	Partial hydrolysis of cooked starch followed by a viscosity reduction. Depending on the catalyst, the DE of the liquefied starch is 15–25.
Maltose	A disaccharide of glucose ß–amylase is used for maltose-rich syrups.
Modification	Modification is a process in which native starch is modified by physical and chemical means to suit various industrial applications, e.g., esterification.
Monosaccharide	The smallest unit obtained by hydrolysis of carbohydrates, e.g., glucose, fructose. Glucose is the monosaccharide obtained by hydrolysis of starch.
MS	Modified starch.
UMS	Unmodified starch—native starch.
Native starch	Native starch designates starch in its natural unmodified form, no modification, e.g., native starch from potato, cassava, maize, rice, wheat.
Polysaccharide	Carbohydrate giving more than 6 monosaccharides by hydrolysis, e.g., amylopectin, amylose, cellulose.
Retrogradation	Starch crystallization. Linear chains of starch are able to form crystalline structures – crystallites – causing staling in bread and milky appearance or syneresis in starch gels.
Saccharification	Hydrolysis of starch into higher DE syrups after liquefaction.
Sorbitol	Hexitol – a sugar alcohol – obtained by hydrogenation of glucose.
Sucrose	Ordinary sugar from cane or beet is a disaccharide of glucose and fructose. Synonyms: saccharose, sugar.
Starch	A polymer of glucose found as a reserve in most plants. Another glucose polymer found in plants is cellulose. Compared to cellulose, starch is made up of alpha glucosidic bonds, which cause helix-shaped molecules while cellulose builds with beta glucosidic bonds giving straight molecules and a fibrous structure. In plants, starch is organized in 1–140 μm granules.

Source: Based on International Starch Institute website. See website for a more complete list.

Annex 2. Questionnaire form used in market survey

Market survey on starch/flour utilization in Uganda

District: ______________________________

Type of institution: ______________________________

Ownership (private/parastatal): ______________________________

Starting date of institution: ______________________________

Firm size (small, medium, or large): ______________________________

Name of respondent: ______________________________

Position of respondent: ______________________________

Telephone number: ______________________________

Survey date:

1.0 Operations of the company/institution

1.1 Describe the products you produce:

1.
2.
3.
4.

1.2 *What has been your trend of production over the past three years?*

Year	Product(s) produced	Quantity produced per day/wk/mth/yr (kg/t)	Consumers of the product /country of export	Trends in production (+/–)	Reason for trend
1997					
1996					
1995					

1.3 Briefly describe your plans for the next two years
(e.g., scale of production, products, markets)

____

____

2.0 Starch utilization

2.1 Do you use starch in the production of any of your products? Y / N ___

2.2 If Y, could you please fill in the table below:

Product	Type and grade of starch used (Refer to the lists given below)		Starch quality, characteristics (e.g., color, texture, taste, odor)	Purpose of the starch in the production of the product	Amount of starch used in the production process (kg)
	Type	Grade			
1					
2					
3					

Types of starch

01 Maize (corn)
02 Cassava
03 Wheat
04 Sweetpotato
05 Other (specify)

Grades of starch

06 Food grade
07 Pharmaceutical grade
09 Industrial grade
10 Other (specify)

2.3 What is the source of your starch? (Can tick more than one option).

1 Local __ 2 Imported __

2.4 If local, please fill:

Name of company	Type of starch	Grade of starch	Quality characteristics	Amount used per wk/mth/yr (kg/t)	Cost per kg/t

2.5 If imported starch is used, please fill:

Country of origin	Type of starch	Volume of consignment (kg/t)	Value of consignment (Ush)	Other costs incurred (Ush)
Last one month or last month imported				
Last 6 months				
Last year (1997)				

2.6 What is the minimum amount of starch you require on a weekly/mthly/annual basis?

____

2.7 If you prefer a specific type of starch, please explain reasons why
(e.g., cost, quality, availability etc.)

____

____

____

2.8 Do you think that there are any advantages or disadvantages in using local starch instead of imported starch in the manufacture of your products?

Local starch		Imported starch	
Advantage	Disadvantage	Advantage	Disadvantage

2.9 Would you be interested to use cassava starch in your product if it were available and of high quality?

____

____

2.10 Do you face any problems in the procurement of starch? Y / N __

2.11 If yes, what are they? (rank in order of importance; 1. most important, etc.)

Problem	Rank
1 ____________	____
2 ____________	____
3 ____________	____
4 ____________	____

2.12 Could you suggest possible solutions to the above-named problems:

____

____

2.13 What would be your major concern with supplies of starch from a local manufacturer?

____

____

2.14 What percentage of your total product(s) costs do the starch costs cover?

Product	Overall product costs	Starch costs in this product	Starch costs/overall product costs
1			
2			
3			

2.15 Would using local supplies reduce your costs of production?

____

____

2.16 Have starch prices over the past 5 years affected your company in any way? If so, please, explain

____

____

3.0 Utilization of starch subproducts

3.1 Do you use any of the starch subproducts listed below? (Can tick more than one option)

a. Dextrin ___
b. Glucose ___
c. Fructose ___
d. Glues ___
e. Other (Please specify) ______________________

3.2 If yes, please fill in:

Starch sub-product (SSP)	Source of SSP [Co./City]	Used in which product?	Purpose of the SSP	Amount of SSP used kg/ d/wk/mth/yr	Cost of SSP/ kg/tonne (Ush)	Cost of SSP/overall product costs

3.3 Please list any problems you face in the procurement of the above-named starch subproducts

Problem	Possible solution
1	
2	
3	

3.4 What would be your major concern if all the starch derivatives you require are locally available? Would you be willing to use them in your products?

____

____

____

4.0 Flour utilization

4.1 Do you use any of the following flours in your institution? (Can tick more than one *option).*

a. Cassava ___
b. Maize ___
c. Sweetpotato ___
d. Wheat ___
e. Other (specify) ___________

4.2 If Yes, fill table below:

Type of flour	Source (City/Co.)	Quality of the flour	Purpose of the flour	Amount used per day/wk/ month/year	Cost/ kg (Ush)

4.3 Please give the price trend of the flours you have used over the past 2 years

____

____

____

4.4 Has this had any effect on your company/institution?

____

____

____

4.5 What do you think of using cassava flour instead of the usual type you use in the manufacture of your product(s)?

____

____

____

4.6 Do you have any questions/comments?

____

____

____

Annex 3. Factories/Institutions visited that do not use starch or any subproducts in the manufacture of their products

Institution

1. Africa Basic Foods[a]
2. Banada Poultry Feeds[b]
3. Berger Paints[a]
4. BMK industries[a]
5. Boflo Bakery[a]
6. BPC chemicals Ltd[a]
7. Bulemezi Farm Enterprises Ltd[b]
8. Bulangiti Dairy Farm[b]
9. City Bread[a]
10. Corpus[a]
11. Country taste[c]
12. Daily Bread Lt[a]
13. Dairy Corporation[a]
14. Desbro (U) Ltd – Importer of starch[a]
15. East African Foods[a]
15. Elgon Feeds
16. Everfresh[c]
17. Family Loaf[a]
18. Fidodido icecream[a]
19. Gator's café[a]
20. G.B.K[c]
21. Hwan Sung Ltd[a]
22. House of Foods[a]
23. International Paints[a]
24. Kasanga Bakery[a]
25. King Loaf Bakery[a]
26. Maganjo Grain Millers[a]
27. Magric (U) Ltd[a]
28. Masters' Bakery[a]
29. Mengo Hospital[a]
30. New Bakecraft and Dairy Ltd[a]
31. Ntake Bakery[a]
32. Nyange Bakery Ltd[a]
33. Oscar industries[a]
34. Peacock Paints[a]
35. Professional Paints[a]
36. Sadolin Paints[a]
37. Tuwereza Bakery[a]

Nontrading companies that were visited

1. Africa General Foods Ltd[a]
2. Anifarm Commodities Ltd[a]
3. Bame Agro Investments Ltd[a]
4. Butambala Enterprises[a]
5. Leather Tanning in Kawempe[a]
6. Makindu Growers[a]
7. Ministry of Defence—textiles in Kawempe[a]
8. Mukono Growers[a]
9. Quick-bite Industries Red Hot Chillies Co. (U) Ltd[a]
10. Suntrade and Consulting (U) Ltd[a]

Note: [a]Kampala [b]Mukono [c]Mbarara

Annex 4. Cost–benefit analysis of flour processing

Evaluation of small-scale cassava flour processing in Katakwi district using power grater
Project life: The economic life of the processing plant is assumed to be 5 years
Production capacity: The plant will operate throughout the year
Capacity utilization: Constant rate of 80% capacity utilization has been assumed
Inflation rate: This has been put at 5% per anum and same for all the life span of the project
Residual value of assets: At close of the project, the plant will be worthless

Financial profitability analysis

A. Parameters of the cassava flour production process used in the model

Annual acreage of cassava garden	150
Yield of tubers per acre (t)	5
Flour recovery rate per ton of fresh tubers	23%
Shillings per man-hour	167
Price per kg of flour	275
Capacity utilization rate	80%
Weight of bag of flour (kg)	100
Annual plant capacity (t) (assuming 100% utilization capacity of the plant)	166
Annual plant production (t)	132

B. Estimated investment

1. Equipment		Cost	Maintenance coefficient	Cost of maintenance
Power graters (2)	2	1,800,000	0.05	90,000
Press incl. 4 grids and jack	6	1,284,000	0.05	64,200
Black drying sheet	187	178,000	0.05	8,900
Wheelbarrows	4	220,000	0.05	11,000
Drums	4	50,000	0.05	2,500
Spanners	8	16,000	0.05	800
Bags	15	7,500	0.05	375
Oil and fuel	10	10,000	0.05	500
	Subtotal	**3,565,500**		**178,275**
2. Infrastructure				
Bricks for wall repair		100,000	0.05	5,000
Cement for fence and drying area repair		178,100	0.05	8,905
Timber		30,000	0.05	1,500
Labor for repairs (unskilled)		24,000	0.05	1,200
Labor for 3 masons for 2 days		73,500	0.05	3,675
Store painting		15,000	0.05	750
Borehole repair		15,000	0.05	750
	Subtotal	**435,600**		**21,780**
Total investment		**4,001,100**		**200,055**

Fixed costs

		Cost/acre	Cost/t of flour
Plant maintenance		1,667	1,510
Subtotal		**1,667**	**1,510**

Variable costs

Item		Cost/acre	Cost/t of flour
a. Cost of growing of cassava		75,000	67,935
Land clearing and plowing		25,000	22,645
Planting labor and material		15,000	13,587
1st weeding		20,000	18,116
2nd weeding		15,000	13,587
	Man-hours/acre	**Cost/acre**	**Cost/t of flour**
b. Uprooting and transporting	**200**	**30,000**	**27,174**
	Man-hours/acre	**Cost/acre**	**Cost/t of flour**
c. Processing costs		**93,167**	**84,390**
Transport (water, tubers, equipment)	60	10,000	9,058
Peeling tubers	200	33,333	30,193
Washing tubers	53	8,833	8,001
Grating tubers	35	5,833	5,284
Difibering/screening	80	13,333	12,077
Drying starch	55	9,167	8,303
Bagging and storage (starch)	30	5,000	4,529
Management and miscel.	25	4,167	3,774
Fuel cost		3,500	3,170
	Cost/bag	**Cost/acre**	**Cost/t of flour**
d. Transport, milling, and marketing	**5,550**	**61,272**	**55,500**
Transport Katakwi–Kampala	3,000	33,120	30,000
Loading cost	600	6,624	6,000
Milling cost Soroti (1000/per bag)	1,000	11,040	10,000
Rebaging cost and cost of bags	700	7,728	7,000
Marketing and storage cost	250	2,760	2,500
Total variable costs		**259,439**	**234,999**
Total production costs		**261,106**	**236,509**

C. Sales price and margins

Price/t at Kampala	275,000
Net margin (%)	0.14
Net margin/t (Ush)	38,491
Gross margin (%)	0.15
Gross margin (Ush)	40,001

D. Cash flow matrix

	1998	1999	2000	2001	2002
Inflation	0.05	0.05	0.05	0.05	0.05
Investment					
Equipment	3,565,500				
Construction	435,600				
Working capital[a]		3,113,264	155,663.20	163,446	171,619
Income:					
Sales		36,432,000	38,253,600	40,166,280	42,174,594
Less:					
Variable costs	9,000,000	31,132,640	32,689,272	34,323,736	36,039,923
Cost of growing cassava	9,000,000	9,000,000	9,450,000	9,922,500	10,418,625
Uprooting and transporting		3,600,000	3,780,000	3,969,000	4,167,450
Processing		11,180,000	11,739,000	12,325,950	12,942,248
Transport, milling, and marketing		7,352,640	7,720,272	8,106,286	8,511,600
Fixed costs		200,055	210,058	220,561	231,589
Total production cost		31,332,695	32,899,330	34,544,296	36,271,511
Net cash flow	(13,001,100)	1,986,041	5,198,607	5,458,537	5,731,464

[a]Working capital increased annually according to inflation

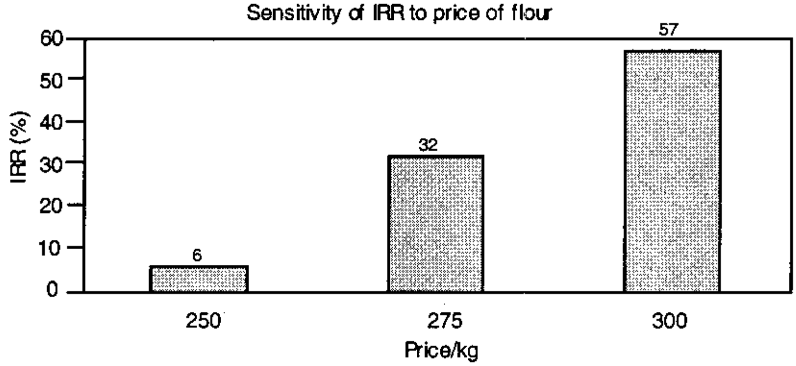
E. Profitability parameters

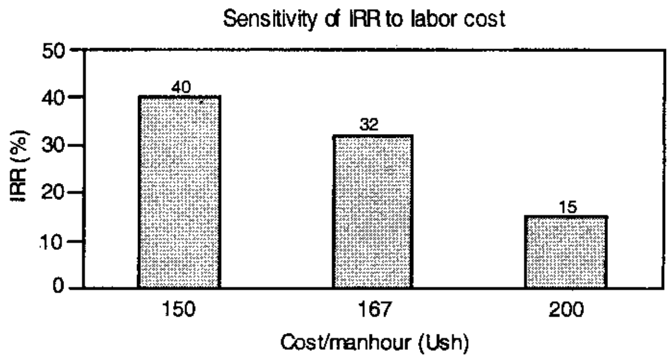
Internal Rate of Return	32%
Minimum acceptable IRR or opportunity cost of capital	25%
Net Present Value using 25% discount rate	2,091,107

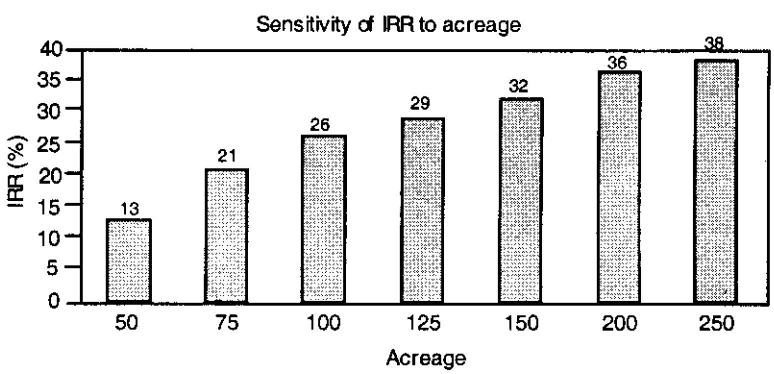
Reference

Gittinger (1982).

Annex 5. Sensitivity analysis of flour processing







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Layout: G.C. Bright

About IITA

The International Institute of Tropical Agriculture (IITA) was founded in 1967 as an international agricultural research institute with a mandate for improving food production in the humid tropics and to develop sustainable production systems. It became the first African link in the worldwide network of agricultural research centers known as the Consultative Group on International Agricultural Research (CGIAR), formed in 1971.

IITA is governed by an international board of trustees and is staffed by approximately 80 scientists and other professionals from over 30 countries, and approximately 1,300 support staff. Staff are located at the Ibadan campus, and also at stations in other parts of Nigeria, and in Benin, Cameroon, Côte d'Ivoire, and Uganda. Others are located at work sites in several countries throughout sub-Saharan Africa. Funding for IITA comes from the CGIAR and bilaterally from national and private donor agencies.

IITA's mission is to enhance the food security, income, and well-being of resource-poor people primarily in the humid and sub-humid zones of sub-Saharan Africa by conducting research and related activities to increase agricultural production, improve food systems, and sustainably manage natural resources, in partnership with national and international stakeholders.

To this end, IITA conducts research, germplasm conservation, training, and information exchange activities in partnership with regional bodies and national programs including universities, NGOs, and the private sector. The research agenda addresses crop improvement, plant health, and resource and crop management within a food systems framework and targeted at the identified needs of four major agroecological zones: the dry savanna, the moist savanna, the humid forests, and the mid-altitude savanna. Research focuses on smallholder cropping and postharvest systems and on the following food crops: cassava, cowpea, maize, plantain and banana, soybean, and yam.

Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP), the CGIAR is an informal association of over 40 governments and about 15 international organizations and private foundations. The CGIAR provides the main financial support for IITA and 15 other international centers around the world, whose collective goal is to improve food security, eradicate poverty, and protect the environment in developing countries.