Expanded Markets For Locally Produced Cassava Flours And Starches In Ghana

R6504

Final Technical Report

for

Crop Post-Harvest Programme

Department for International Development

CROP POST HARVEST PROGRAMME

Expanded markets for locally produced cassava flours and starches in Ghana

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FINAL TECHNICAL REPORT

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Abbreviations

ATP	- Cassava flour prepared in Atebubu village from peeled roots
ATU	-Cassava flour prepared in Atebubu village from unpeeled roots
A_w	-Water Activity
CIAT	-Centro Internacional de Agricultura Tropical
DFID	-Department for International Development
EU	-European Union
FAO	-Food and Agriculture Organisation
FORIG	-Forestry Research Institute of Ghana
FRI	-Food Research Institute
HYV	-High Yielding Variety
IDRC	-International Development Research Centre
IITA	-International Institute for Tropical Agriculture
MoFA	-Ministry of Food and Agriculture (Ghana)
MOR	-Modulus of Rupture
MTADS	-Medium Term Agricultural Development Strategy
NARP	-National Agricultural Research Programme
NARSP	-Natural Resources Strategic Plan
NBSSI	-National Board for Small-Scale Industries
NRI	-Natural Resources Institute
PHDU	-Post-Harvest Development Unit
PPMED	-Policy Planning Monitoring and Evaluation Division
RNRKS	-Renewable Natural Resources Knowledge Strategy
T&CG	-Transport and Commodity General
UoG	-University of Ghana
WTO	-World Trade Organisation

Executive summary

The project was developed with the purpose of addressing the need for improved levels of income generation and expanded market opportunities for cassava that had been highlighted by farmers in Ghana.

The project activities were divided as follows:

- An assessment of the market for flour and starch in Ghana;
- An assessment of the potential of cassava starch and flour as substitutes for currently used materials;
- Development of cassava flours and starches to meet market demands;
- Dissemination of key findings to target organisations.

The market for starch comprises a number of end users who use maize, cassava and potato starch, in textiles, pharmaceuticals, paper, food and adhesive industries. The market size in 1996 was estimated at around 4,200 tonnes per annum, with the potential to grow to 6,000 tonnes by the year 2000. Most users have very high quality specifications with 60% of the market being for modified starches. The market for flour in Ghana is currently dominated by wheat flour. In 1996, approximately 300,000 tonnes of wheat equivalents (grain and flour) were imported. Most of this flour was used by the food industry in the preparation of bread and snack foods, but some was used as a glue extender by the plywood industry.

Case studies of cassava starch and flour processing in other parts of the world, and mass production of cassava chips in Ghana for livestock feed, provided clear indications as to which processing options would be most likely to succeed in Ghana in the foreseeable future.

Industrial processing of Cassava starch would seem to be attractive because of the high level of value addition associated with starch, and the apparent opportunities for export. However, the level of capital investment is high, and would be processors need to ensure access to sufficient supplies of high quality fresh cassava of the correct level of maturity. Additional requirements include ready access to large amounts of good quality water, a reliable electricity supply and good road infrastructure to enable roots to be transported rapidly from farm to factory. The experience of Transport and Commodity General (T&CG) in the cassava chip market has shown that these conditions do not exist in Ghana at the present time. It is therefore unlikely that high quality cassava starch would succeed as a business opportunity in Ghana in the short to medium-term.

Production of high quality cassava flour is a more attractive option, as processing is less capital intensive, and the final product can be prepared from dry chips, rather than fresh roots. Cassava flour has the potential to substitute for imported alternatives in the areas of paperboard adhesives, plywood glue extenders and bakery products where the quality specifications of the end users are less critical and therefore easier to achieve. High quality cassava flour could also have potential for use as a textile sizing agent in mills that produce lower quality cloth for the cheaper end of the local market. However, to be successful, cassava flour needs to be made to a high standard to meet the quality specifications set by potential users. Producers of cassava flour will need to ensure timely delivery of specified quantities of flour of a consistently high quality at a competitive price on a regular basis to meet the needs of the user.

Chipping (using a modified IITA mini chipper) was found to be the best option for processing cassava roots with low cyanogen content. This option proved to be cheaper, less labour intensive, resulted in lower microbial load, and less loss of starch when compared to grating. High quality chips and flour could be prepared under rural conditions at lower cost (US$65 per tonne) when compared to centralised processing (US$217 per tonne). However, conversion of chips into flour in larger quantities would be a bottleneck for rural processors. A better option would be to transport dry chips from rural areas to a central processor for conversion into flour.

Cassava flour proved effective as a partial substitute for imported starch based-adhesives in paperboard, and wheat flour in biscuits and plywood glues. Flour prepared from chips produced by a farmers group gave good results in trials, as an extender for plywood glues. However, it is important to ensure that processors do not attempt to improve margins at the expense of quality. Research showed that cassava roots must be processed within 1-2 days of harvest to maintain quality, and should also be peeled before chipping. Flour prepared from unpeeled chips was not suitable for use in plywood glue even though this product had the lowest quality specification when compared to paperboard adhesive and food-grade flour. Under commercial conditions (in Ghana) cassava flour can be stored for 2 months without loss of quality which is more than adequate for most users in Ghana.

Cassava flour can substitute for up to 30% of wheat flour in sweet dough biscuits and 40% in hard dough biscuits, without consumers being able to detect any adverse change in colour taste or texture when compared to 100% wheat flour control. Bakers found that cassava flour could be substituted for up to 35% of wheat flour in dough mixes without noticeable changes in handling characteristics. At higher levels (>40%) of substitution the flour texture was found to be too light. This could be overcome with additional margarine, but this caused an unacceptable increase in production cost. Consumers found biscuits containing >40% cassava flour to be less crispy, bland in flavour and susceptible to crumbling. Biscuits containing a maximum of 40% cassava flour had very low microbial counts, and cyanogen levels that were below the limits of detection after baking.

Three types of cassava flour were evaluated for their suitability as extenders for urea-formaldehyde glues used in the plywood industry in Ghana. The flours comprised: flour from peeled mechanically dried cassava chips (FRI), flour from peeled sun-dried chips (ATP) and flour from unpeeled sun-dried cassava chips (ATU). Results indicated that with the exception of the FRI and ATU at 80% substitution level, all the flours produced glue bonds consistent with BS1455:1963 specifications. Cassava flour prepared from unpeeled roots was found to be unsuitable for use as a glue extender for plywood. Substitution at levels of 20-40% gave the best results.

Cassava flour mixed with 0.05% borax decahydrate had pasting characteristics comparable to those found in imported paperboard adhesives.

Preliminary estimates indicate that cassava flour has the potential to reduce production costs of plywood boards by 35%. Cost savings in biscuit manufacture vary according to type of biscuit and specific formulation. In sweet dough biscuits the cost saving would be approximately 30%, for hard dough biscuits cost savings could be as high as 60%.

Background

Cassava (*Manihot esculenta* Crantz) is probably the most important root crop in Ghana. Annual production has been rising consistently over the last decade and currently is estimated to be approximately six million tonnes of fresh roots per annum. Cassava supplies a major source of daily carbohydrate intake to the majority of Ghanaians and also has an important role as a food security crop due to its ability to grow on poor quality land and its tolerance of drought. In Ghana, cassava is eaten in the fresh state (boiled and pounded to make *fufu*, fried or roasted) or processed into a range of traditional products including *agbelima* and *gari*. Cassava is also cut into chips, sun-dried and pounded or milled to prepare a flour known as *kokonte*. *Kokonte* is generally perceived as a low quality product that is consumed by poor groups within the community. In rural areas consumption of *kokonte* reaches its peak during the "hungry season" when maize (and other carbohydrate staples) are either unavailable or too expensive for many families to purchase.

Cassava is also used on a small-scale for industrial purposes and as a source of carbohydrate in livestock feeds. The internal market for livestock feed has potential to expand but may be constrained by technical difficulties (associated with incorporation of cassava into poultry rations) and the reluctance of feed millers to adopt cassava as a feed ingredient. Potential also exists for Ghana to access the European Union (EU) market for dried cassava which stood at 3.4 million tonnes in 1997 (FAO Food Outlook, November 1997), of this a quota of 145,000 tonnes was allocated to World Trade Organisation (WTO) members excluding Thailand, Indonesia and China. In Ghana, three companies (Transport & Commodity General (T&CG), GAFCO and SILTEK Exports) sought to exploit the opportunity offered by the WTO quota. However, by 1998 only T&CG was still involved in this business, GAFCO and SILTEK Exports having withdrawn as a result of unfavourable market conditions. Marketing dry cassava internationally seemed to offer the largest market and maximum opportunity for a good return on initial investment. However, the EU market for dried cassava is unpredictable with large fluctuations in price, and stiff competition from South East Asia. Problems with poor infrastructure and cassava supply made it impossible for Ghanaian companies to compete in this market.

An assessment of the post-harvest needs in non-grain starch staple food crop systems in Ghana (Kleih, *et al*., 1994) highlighted the need to add value to cassava and improve producer prices, and the apparent interest of farmers, processors and traders in expanding the market for cassava. Stakeholders were concerned that demand for cassava was insufficient to make use of existing supplies, and prices too low. In addition farmers, traders and processors experienced financial constraints and lack of access to credit that limit access to new market opportunities. According to Kleih, *et al*., (1994) a diversification of outlets would be likely to lead to increased demand for cassava products, which in turn should result in upward pressure on prices. Increased production coupled to improved market access has potential to reduce cash constraints of farmers and make the environment more favourable for obtaining credit.

One approach for achieving this aim would be to improve the marketing opportunities for locally produced cassava starch and flour. However, the potential market for industrial uses of locally produced cassava starch and flour has not been explored in detail.

Project Purpose

The programme output addressed by this project is stated as “New market opportunities exploited”.

The purpose of this project is to contribute towards improved sustainable livelihoods, and better levels of income for cassava farmers and processors in rural areas by expanding the range of market opportunities available for cassava-based products.

The outputs of this project are intended to contribute towards the purpose through identification of new market opportunities for cassava-based starches and flours, and by delivering validated procedures for production and utilisation of several cassava-based products for use in local Ghanaian industries.

The main socio-economic benefits envisaged from this work are:

- ♦ Expanded market outlets for cassava facilitating stabilisation of prices.
- ♦ Substitution of imported starches and flours with those prepared locally from cassava.
- ♦ New income generating and employment opportunities in the processing sector.

Output 1: Market requirements for starches and flours assessed.

OVIs: Quality and quantity of starch and flour used by Ghanaian industries assessed by 1997.

Summary

As a starting point for the project baseline surveys were made to characterise the existing starches and flours markets, and to assess the market potential for cassava starch and flour in Ghana. In addition assessments were made of cassava production and supply, factors that influence the supply of cassava for processing, issues in marketing arrangements of cassava for processing and wider policy issues having importance for the project.

The market for starch comprises a number of end users who use maize, cassava and potato starch, in textiles, pharmaceuticals, paper, food and adhesive industries. The market size in 1996 was estimated at around 4,200 tonnes per annum, with the potential to grow to 6,000 tonnes by the year 2000. Most users have very high quality specifications with 60% of the market being for modified starches. Most of the starch is imported, and only three local industrial starch manufacturers were identified. Of these only one produces high quality starch (maize starch) that competes effectively with imported materials. The other factories produce poor quality products based on cassava flour, and have a very bad reputation amongst potential users. There appears to be little potential for development of a cassava starch industry in Ghana under current conditions.

The market for flour in Ghana is currently dominated by wheat flour. In 1996, approximately 300,000 tonnes of wheat equivalents (grain and flour) were imported. Most of this flour was used by the food industry in the preparation of bread and snack foods, but some was used as a glue extender by the plywood industry. Cassava flour has potential to substitute for some of the wheat flour in the food sector, and for use in the plywood, paperboard and textile industries. However, to be successful, cassava flour needs to be made to a high standard to meet the quality specifications set by potential users. Producers of cassava flour will need to ensure timely delivery of specified quantities of flour of a consistently high quality at a competitive price on a regular basis to meet the needs of the user.

Rationale

Preliminary investigations indicated that although some information was available (Faure, 1993) the existing market for starches and flours in Ghana had not been well characterised. It was also unclear as to whether surplus cassava would be available to supply additional markets. It was clear that the starting point for this project must be a detailed economic and technical assessment of the national market for starches and flours in Ghana, coupled to a study of the factors affecting cassava production and availability. The shape of the potential future market for starch and flour and its likely linkages to existing cassava production and marketing systems in Ghana were also assessed.

Research activities

A survey of producers and users of starches and flours in Ghana was made in the period February to April 1996 (Day, *et al*., 1996; Graffham, *et al*., 1998) by NRI and the University of Ghana (UoG). For the first phase of the survey, visits were made to as many potential users and producers of starch and flour as possible to obtain a broad view, via a formal questionnaire. In the second phase, more detailed information was obtained by revisiting selected producers and users, and carrying out semi-structured interviews using the methods reported by Kleih, *et al*., (1997).

Method

Activities were initiated in order to assess the market for starches and flours, and identify potential market opportunities for further development. Information was collected through:

- A survey of a representative cross-section of Ghana's commercial starch and flour users to collect information on types of flour and starch used, source of supply (local or imported), reliability of supply, quality required, quantity used, current prices paid, perception of potential for new products and desired properties for specific end users. This activity was focused on the main commercial centres of Accra, Tema and Kumasi. Samples of starch and flour were collected from end users to enable the users requirements to be related to quantitative measures of starch and flour quality.

- A preliminary investigation of domestic starch and flour processors in Ghana paying particular attention to location, scale and capital intensity of operation, cost and price structures, raw materials used and marketing linkages. This activity involved making visits to selected starch and flour processors (where possible). Samples of locally produced starches and flours were collected to enable product characteristics and quality to be determined.

- An assessment of existing technologies for cassava flour and starch processing developed by local institutes and NGOs and to identify the constraints that have prevented dissemination and commercialisation of these technologies, so that future adaptive research may be more clearly focused to meet the requirements of end users.

- A survey to collate available secondary information on broad factors affecting cassava supply and prices.

- An assessment to determine in broad terms the price margins required for the manufacture of cassava-based starch and flour products to be commercially viable.

Outputs

Market potential for cassava starch

The market for starch within Ghana comprises a number of end-users (Table 1) who make use of maize, cassava and potato starch which is mostly imported. The survey carried out by NRI/UoG (Day, *et al*., 1996; Graffham, *et al*., 1998) indicated that the market size in 1996 was approximately 4,200 tonnes per annum, which compared well with figures in a survey commissioned by Glucoset Limited of Ghana (Anon., 1994). The Glucoset survey also predicts that demand will increase to 5,600 tonnes by the year 2000. Both the UoG/NRI and Glucoset surveys found that most users have very high quality specifications with 60% of the market requiring modified starches.

Table 1. Market for starch (maize, cassava and potato) in Ghana 1996.

Sector	Market share (%)	Estimated quantity tonnes/annum	Requirements
Textiles	40	1,680	Medium specification; requires high level of purity and consistent product quality with respect to viscosity.
Pharmaceuticals	20	840	High quality specifications in terms of purity and microbiological quality.
Paper	10	420	Low specification; requires low fibre and particulate contaminants.
Food	3	126	High quality specifications in terms of purity, microbiological quality and specialised pasting characteristics for particular products
Plywood	27	1,134	Low specification; requires low fibre and particulate contaminants.
Total		**4,200 metric tonnes**	

Source: Graffham, *et al.*, (1998).

Although the market for starch is small (equivalent to approximately 50,000 tonnes of fresh roots per annum) compared to the annual production of cassava at about six million tonnes per annum, there is still potential for a large-scale producer of cassava starch within Ghana to meet these high quality specifications and reduce Ghana's dependence on imported products. There is also potential for the export of cassava starch from Ghana to other countries in the sub-Saharan Region, and the Middle East. In 1996, South Africa appeared to be a particularly attractive possibility due to its large industrial base relying mainly on imported starch. However, in 1998 a large-scale starch producer commenced operations in the north east of South Africa. This company is mainly producing maize starch, but has started to produce cassava starch from cassava grown in the eastern region of the country.

The small-scale less sophisticated producers already operating in Ghana have little chance of competing against imported starches on the basis of product specification and scale of production. However, there may be scope for these producers to produce cassava starch (or flour) for conversion into maltose and malto-dextrins for use as sweeteners by Ghana's expanding food industry. Malto-dextrin production has the advantage of producing a higher value product with relatively unsophisticated technology and it eliminates the need for drying which is always a key constraint for small-scale producers of cassava starch.

Market potential for non-*kokonte* cassava flour

In Ghana, most people associate cassava flour with *kokonte* a relatively low-grade traditional product. The product can be of poor quality because drying times are typically long allowing time for microbial growth. In this project all references to cassava flour, can be taken as referring to non-*kokonte* flour, which is a high quality product.

The market for flour in Ghana is currently dominated by imported wheat flour. In 1996, Ghana imported approximately 250,000-300,000 tonnes of wheat equivalents (wheat grain and flour) per annum (Table 2).

Table 2. The Ghanaian wheat market: key statistics.

Year	**Wheat imports (tonnes)**	**Estimate of current wheat milling activity and capacity**	
1980	131,000	**Miller**	**Milling activity (mt/yr)**
1981	150,000	Takoradi mills	80,000
1982	120,000	Golden Spoon	45,000
1983	111,000	Irani Brothers	40,000
1984	93,000	GAFCO	80,000
1985	77,000		
1986	75,000		
1987	140,000	**Miller**	**Milling capacity (mt/day)**
1988	170,000	Takoradi mills	1200
1989	154,000	Golden Spoon	150
1990	225,000	Irani Brothers	750
1991	207,100	GAFCO	200
1992	164,800		
1993	248,200		

Source: Graffham, *et al.*, (1998).

Most of this flour is used by the food industry in the preparation of bread and snack foods such as biscuits, cakes, pies and doughnuts. However, food grade wheat flour is also used as a glue extender by the plywood industry in Ghana. Although the market for glue extenders is relatively small (approximately 1,200 tonnes per annum) the quality specifications are quite low, which makes this market an attractive starting point for developing cassava flours. Previous DFID funded research in Peru has shown that cassava flour can be used to substitute for wheat flour in plywood glues at a level of 46% (Jones, 1994). Cassava flour has been successfully adopted by plywood manufacturers in Peru who appreciate the cost saving derived from using locally-produced cassava flour. There is also potential for formulating water-resistant wood glues by mixing chemically modified cassava starch or flour with urea or phenol formaldehyde resins. Glues of this type (containing cassava starch) have been successfully tested by the timber industry in the Philippines (Fidel, *et al*., 1992).

The food sector is an attractive market for high-grade cassava flour because of its high consumption of imported wheat flour. Previous research carried out in Ghana and many parts of the world has demonstrated that cassava flour can be used to substitute for a percentage of the wheat flour in many products. In the case of bread the maximum substitution level is 15-20%. Above this level, technical problems are encountered due to a reduction in the amount of gluten present in the flour (Ruiter, 1978; Dendy and Trotter, 1988; Satin, 1988). In the case of snack foods such as biscuits and cakes that are non-gluten sensitive products, the theoretical level of substitution is 100%. However, in practice, commercial producers of biscuits in Colombia found that the maximum level of substitution was around 30%. In this case high levels of cassava flour made the products brittle. Cassava flour is also very hygroscopic which can be advantageous in cake formulations but will cause hard biscuits to go soft if too high a level of cassava flour is used.

Manufacturers of starch and flour in Ghana
At the present time industrial production of starch within Ghana has not been well developed. The NRI/UoG survey team identified only three active manufacturers and one potential manufacturer of starch in Ghana. Two of these manufacturers claim to be producing cassava starch. However, examination of their products and discussions of technical procedure demonstrated that they actually produce either cassava flour or a cassava flour-based paperboard adhesive. Several users expressed dissatisfaction with these products on quality grounds, the high level of impurities (and poor pasting properties) found in these low-grade flours made them unusable by most of the potential users.

Tuyee Products Limited of Tema appear to be the only high quality starch maker active in Ghana at the present time. Tuyee manufacture maize starch on a contract basis for several textile and pharmaceutical companies in Ghana. Their product is of good quality but is expensive (in some cases Tuyee's product costs more than equivalent imports) due to the high cost of raw materials and extraction of starch from maize. Tuyee have attempted to produce cassava starch in the past but have since discontinued this line of business for several reasons. The owner of Tuyee Products stated that, although extraction of cassava starch is simple, it is labour intensive, requires large amounts of water, and results in a relatively poor yield of starch when compared with maize (w/w basis).   He also said that the high perishability of cassava had caused problems.

Cassava production and supply
A range of secondary data on cassava production and supply is available, that provides national figures for production of cassava in Ghana (Table 3).

Table 3. Cassava production in Ghana

	MOFA/ PPMED estimates			FAO Production Yearbook		
Year	Area Plant-ed (000 ha)	Production (000 MT)	Yield (MT/ha)	Area Plant-ed (000 ha)	Production (000 MT)	Yield (MT/ha)
1988	354	3300	9.3	354	3300	9.3

1989	455	3320	8.0	415	3327	8.0
1990	323	2717	8.4	323	2717	8.4
1991	535	5701	10.7	535	3600	6.7
1992	552	5662	10.3	552	4000	7.2
1993	-	5973	-	578	4200	7.3
1994	520	6025	11.6	607	4378	7.2

Both sets of figures show a trend of increasing cassava production. However, the FAO estimates of production are significantly lower than the PPMED estimates reflecting lower estimates of yields. The PPMED figures appear rather high. This has been attributed to problems arising from changes in the method of data collection and analysis. Thus, it is wise to treat PPMED production estimates with caution. However, both sets of estimates indicate that there has been a significant expansion in the area planted to cassava in recent years.

There does not appear to be any statistical evidence which supports the proposition that there is a large national unutilised surplus of cassava. Some sources have suggested there may be a surplus of around 3 million tonnes per year, but this is unsupported by strong evidence. Similarly there is no known data on post-harvest losses or quantities of unharvested roots, although Dadson, *et al*., (1994) estimate post-harvest losses at 30%. Nonetheless, anecdotal evidence from informal surveys suggests that there may be significant in ground surpluses of cassava at local or regional levels.

Regional Patterns

Table 4 gives an indication of regional patterns of cassava production based on PPMED data. The four major producing regions are Eastern, Brong-Ahafo, Ashanti and Volta in order of size. Eastern and Ashanti regions are major producers and consumers of cassava in the form of fufu, from fresh roots, reportedly mainly using traditional varieties which are suited for pounding (Dosoo [ESCaPP], pers comm). Brong-Ahafo and Volta regions reportedly have a higher uptake of improved high yielding varieties which are less suited for consumption as fresh pounded roots. These regions therefore appear to be promising areas for the development of cassava processing.

Table 4. Regional Patterns of Cassava Production

Region	**1992**	**1993**	**1994**
Western	444,980	468,330	492,938
Central	377,100	458,350	530,404
Eastern	1,452,000	1,573,000	1,856,530
Gt Accra	134,200	91,680	94,013
Volta	781,500	802,270	729,900

Ashanti	779,520	1,121,960	1,041,140
Brong-Ahafo	1,536,840	1,259,700	1,149,557
Northern	155,890	197,350	130,565
Upper West			
Upper East			
Total	5,662,030	5,972,640	6,025,047

Figures from the Ghana Living Standards Survey (1992) give some further pointers to the national pattern of cassava production and consumption. Table 5 shows the strong preference for consuming cassava as fresh roots in Ashanti, Eastern and Central regions. There is significant home consumption of *gari* in Western and Volta region, with other processed forms of cassava being consumed in Volta, Northern, Brong-Ahafo and Greater Accra regions. While this data only refers to *home consumption*, it does provide an indication of the regional pattern of end use preferences for cassava - which in turn may influence the willingness of farmers to plant cassava for processing.

Table 5: Home Consumption of Cassava by Region

Average annual per capita value of reported home consumption of cassava in Cedis (1992 figures)			
Region	Roots	Gari	Other forms
Western	8465	424	27
Central	12365	205	77
Eastern	12685	61	332
Gt Accra	227	0	488
Volta	5076	326	3705
Ashanti	6563	3	20
Brong-Ahafo	4697	39	510
Northern	150	9	1690
Upper West	11	0	17
Upper East	0	0	0
Ghana	5858	107	675

The uptake of new varieties is not uniform across the country. Traditional varieties yield typically up to 10 tonnes per hectare and are used mainly for boiling and pounding to make *fufu*. Newer high yielding varieties (HYVs) have been developed by IITA and are now being released in Ghana, with yield potentials up to 25 - 30 tonnes per hectare NB. This figure is unlikely to be achieved in practice). However, these varieties are not suitable for pounding after boiling and they have been most enthusiastically adopted in regions where cassava is generally used for processing into either *gari* or *agbelima* - particularly Volta region and parts of Eastern region. In particular, ESCaPP (Dosoo, pers comm.) estimates that HYVs have been most widely adopted in the Volta region, followed by the Eastern and Greater Accra regions. Adoption is lowest in the Central and Western regions where the newer varieties have been released more recently. Furthermore, data from ESCaPP suggests that yield and cooking quality are the most important criteria in determining the choice of variety.

Table 6: Regional Patterns of Cassava Sales

Region	Estimated annual value of sales (thousand million Cedis)	Estimated annual value of harvest (thousand million Cedis)
Western	4.6	16.8
Central	3.1	15.6
Eastern	3.5	19.5
Gt Accra	0.1	0.8
Volta	0.9	17.2
Ashanti	3.1	18.4
Brong-Ahafo	5.9	17.2
Northern	0.1	1.0
Upper West	0	0
Upper East	0	0
Ghana	21.3	106.5

Table 6 provides an indication of the proportion of the cassava crop which is marketed. Those regions where a higher proportion of the crop is marketed may be better placed to produce cassava as a cash crop for a processing operation. Brong-Ahafo and Western regions appear to be best placed in these terms to supply a processing operation.

Production data according to individual districts is also available from PPMED. When combined with information on the land areas of districts this information may be used to indicate those districts with the most concentrated cassava production. These areas are likely to be producing cassava as a cash crop and possibly for processing. Table 7 shows those districts which were estimated to have produced in excess of 100,000 tonnes of cassava in 1994. Those marked with an asterisk had production estimates in excess of 200,000 tonnes.

Table 7: Districts Producing more than 100,000 tonnes of Cassava in 1994

Eastern	Volta	Ashanti	Brong-Ahafo
Birim South* Asuogyman West Akim Manya Krobo Fanteakwa Yilo Krobo Akwapim North Suhum/Kraboa/ Coalta Kwahu North Kwaebibirim/Kade	Nkwanta* Kete-Krachi	Atwima Amansie West	Techiman* Atebubu Wenchi Nkoranza Sunyani Tano

* indicates greater than 200,000 tonnes

Factors affecting supply of cassava for processing

The existence of a reliable supply of raw cassava roots at a competitive cost will be a factor determining the viability of any alternative cassava processing operation. There are a number of factors which are likely to affect the supply of cassava for processing. Some of the factors which will condition the supply of cassava for processing are considered below.

The ability of farmers to gain access to other markets for their production will be a major factor influencing the supply of cassava for processing. Prices for fresh cassava are likely to be more attractive than those which a processing enterprise could afford to pay. Table 8 shows recent wholesale market price data for fresh cassava at some markets in Volta, Eastern, Ashanti and Brong Ahafo regions.

These prices compare to 70 Cedis / kg of dried chips paid by Transport and Commodity General (T&CG). With a conversion rate of 2.7 kg of roots to 1 kg dried chips, this is equivalent to a price of approx. C 2,600 per 91 kg unit of roots (in practice the hatsacks used are often filled to a weight significantly in excess of 91 kg). The T&CG price is almost a farmgate price - paid to farmers for dried chips at collection points close to their farms. However, it is not strictly speaking equivalent to a farmgate price for cassava roots, since farmers will also incur costs in chipping and drying.

Table 8: 1995 Wholesale Market Prices for Cassava (Cedis / 91 kg)

Month	Ho	Koforidua	Kumasi	Techiman
Jan	7,500	11,500	10,500	4,000
Feb	8,000	9,500	10,500	4,500
Mar	9,500	9,500	9,000	5,000
Apr	13,500	11,500	14,000	5,500
May	10,000	12,000	14,000	8,000
Jun	10,000	11,000	14,500	10,500
Jul	8,500	12,500	11,000	10,000
Aug	7,500	12,500	9,500	10,000
Sept	7,000	12,000	7,000	11,500
Oct	7,500	13,000	7,500	7,000
Nov	7,000	12,000	7,000	11,500
Dec	6,500	14,500	4,000	12,000

The wholesale market prices for roots also reflect transport and marketing costs incurred between the field edge and the wholesale market. Secondary literature suggests that transport costs in rural Ghana are extremely high. Sijm (1993) quotes studies which suggest that transport costs account for 70% of the difference between farmgate and retail prices for agricultural commodities. Similarly, Dadson, *et al*., (1994) point out that Ghana has comparative advantage in the production of several crops at the farm gate, but loses this at the wholesale level through the high cost and inefficiency of its transport and marketing systems. Many rural areas of Ghana still resemble a ‘footpath’ economy with head porterage being the principle means of primary transportation of agricultural commodities. Other studies (Kleih, *et al*., 1994) suggest that fresh cassava roots are rarely transported more than 40 kilometres to market, though this may be longer for major distribution markets such as Techiman.

Kreamer (1986) for example, estimates that the following composition of the wholesale price of cassava at Kumasi.

Item	Percent Share of Kumasi Wholesale Price
Transport costs	42
Farm price of cassava	28
Farm labour costs	12
Marketing contractor’s net margin	18
Total	100

If we assume that the farm price of cassava represents about 40% of the wholesale price (i.e. farm price plus farm labour costs), then the price paid by T&CG becomes more comparable with the prices received by farmers for fresh roots - though, taking into account the costs of chipping and drying, it is still at a significant discount to the prices obtainable from the fresh market except in the very lowest price periods. For example, the T&CG price includes the cost of chipping and drying - which may be estimated at approximately C 900 per hatsack (based on 5 mandays / tonne for manual chipping cited by Barton, 1996) - thus the T&CG equivalent price for roots at the farmgate is approximately C 1,700 per hatsack. Assuming the farmgate price is 40% of the wholesale price, a fresh wholesale price of approximately C 4,250 is equivalent to a farmgate price of C 1,700.

T&CG report that they have had an ‘overwhelming’ response from farmers in the regions where they are working - principally in the transitional zone, mostly in Brong Ahafo region and in areas close or adjacent to the Volta Lake. In particular, farmers value the reliable, guaranteed nature of the market, and the fact that the collection and marketing of the crop is handled by T&CG. This, it appears, is of primary importance due to the comparison with the higher but much more risky and uncertain returns on the fresh market.

In summary, the supply of cassava for processing will depend on:

- **Ease of access to fresh marketing channels -** More attractive returns are likely to be possible through marketing cassava on the fresh market. Thus, those areas further away from major distribution points and markets may be more predisposed to supply cassava for processing.
- **Ease of access to other processing outlets** - e.g. *gari*, *agbelima*. Access to other processing outlets will tend to give rise to competition for cassava supplies. Alternatively, those areas which have cassava production systems adapted to supplying cassava for processing may prove to be the best locations for developing other processing outlets. This would depend on the suitability of the varieties for the processing use proposed, e.g. bitter higher cyanide varieties may be more difficult to utilise in food uses.
- **Other competing uses -** e.g. as a food security reserve.
- **Transport links** - Transport links are a key area. T&CG identify field edge transportation as a key constraint to the development of commercial cassava marketing. Field edge transport continues to be undertaken primarily by women using headloading. Sijm (1993) quotes calculations which suggest that it may take over 100 mandays to headload one hectare of cassava over a distance of 5 kms.
- **Varieties** - There are regional variations in the uptake of new varieties, and in farmer and consumer preferences for different varieties. The willingness of farmers to grow varieties suitable for processing may vary. This may especially be a factor in areas where farmers usually grow cassava for subsistence food uses, e.g. in preparation of *fufu* in Ashanti region.
- **Seasonality -** A number of factors affecting the supply of cassava which will be conditioned by seasonal variation e.g. transportation difficulties during the wet season related to impassable roads, harvesting difficulties during the dry season, seasonal effects on drying operations and the overall seasonality of agricultural production processes. Seasonality will also be a dimension affecting the competing uses of cassava. For example, T&CG managers note increased competition for cassava supplies from *kokonte* processors during the 'hungry' season when the demand for *kokonte* reaches its seasonal peak. Other staple foods are also subject to seasonal price variations with knock-on effects in terms of demand for other substitute staples. For example, maize is subject to extreme inter-seasonal price variations in many parts of Ghana.

The organisation of supply of cassava for a processing operation would need to take account of the effect of these factors on the availability of a steady and predictable flow of cassava for processing. In effect, new end uses of cassava will need to be integrated with existing production and marketing systems.

Issues in marketing arrangements of cassava for processing

Farmer Views on Marketing

A farmer representative on the Ministry of Food and Agriculture's Cassava Task Force made a number of observations on marketing. Marketing is the most important constraint facing cassava farmers: the fresh market is difficult to access, is risky and unpredictable. Lack of marketing opportunities prevents farmers from harvesting their cassava in a timely manner and land is left tied up under cassava awaiting marketing. Processing industries are perceived to have a key role to play in developing marketing opportunities for farmers, and in the provision of production credit to farmers. Vertical integration of farmers into processing activities was not perceived as a way forward.

Other key constraints from the farmer point of view include chipping and drying facilities. Year round harvesting and processing would allow farmers to replant at the optimum period.

Gari Processors

Kreamer (1986) provides a detailed account of how *gari* processors operating at Anloga an area of Kumasi organise the supply of raw materials for their processing operations. *Gari* processors are organised in informal groups with a secretary who is responsible for sourcing raw cassava and dividing supplies between individual processors who operate on their own account. Cassava for these *gari* processors is often sourced over comparatively long distances e.g. from the Techiman area, a distance of over 125 kms.

A key role in the sourcing and assembling of supplies is played by the cassava 'contractor'. The contractor identifies sources of cassava, agrees prices with farmers and labourers for harvesting, arranges loading and transport, and bears marketing and transport risks. In order to co-ordinate local arrangements and identify supplies, many contractors maintain village-level agents. At the other end of the chain, contractors often build up ongoing relationships with *gari* processors since they both have an interest in maintaining a high-volume, relatively predictable trade. The role of contractors in linking existing processors to many scattered smallholder producers may merit further investigation in order to clarify the options in organising the supply of raw materials to potential processing operations.

Scale and Organisation of Production

Some initial observations may be made on the pros and cons of different methods for organising processing and scales of production. Small-scale processes using simpler technology suited to village-level enterprises will have the advantage of being located very close to the production sites of cassava. This will minimise the transport costs associated with the movement of volumes of relatively low value raw roots. However, product quality assurance will be more difficult at a smaller scale, and the scope for developing formal marketing arrangements (e.g. packaging, branding) much reduced.

More centralised larger-scale processing methods will require larger investments, and the development of sophisticated marketing systems to ensure a continuous and reliable supply of roots for processing, in order to maximise the utilisation of capital equipment. In addition, the transport costs associated with the supply of roots are likely to be a greater cost component. This will give rise to pressure to develop some form of 'estate' production of cassava - possibly leading to reduced benefits flowing through to smallholder farmers.

Employment Generation Issues

Policy papers on employment generation identify roots and tubers as one area with high potential for future development. There is an increasing recognition of the large raw material base which the root and tuber sector represents, and a realisation that product development is required to expand markets. The promotion of value-adding linkages to the agricultural sector is seen as a key means of generating employment, both in processing activities and in generating livelihood opportunities in commercial agriculture.

Dissemination and Commercialisation of Research Outputs

As mentioned above, the area of cassava processing has been the subject of a considerable body of technical research work. However, in Ghana at least, this has not resulted in a great commercial impact.

Research ideas have not been translated into commercial processes on a significant scale and this is clearly an issue, which must be addressed.

A recent survey of the constraints to the adoption of small-scale food processing technologies has been carried out by the Food Research Institute (1996) and has raised a number of issues. Access to credit, the lack of development of the packaging industry, the 'laboratory-focus' of research and the lack of linkages between researchers and entrepreneurs emerged as major problem areas constraining the dissemination of research outputs. Interestingly, in the case of cassava processing it was found that improved methods of processing traditional products were frequently uncompetitive because inputs such as family labour and firewood in traditional processing methods are not fully costed into the sale price, as would be necessary in a fully commercial operation. This probably reflects both a low opportunity cost of family labour and, to the individual, of communal resources, as well as the existence of non-commercial social objectives.

Many of the factors identified by FRI are echoed by policy documents on promoting employment through small enterprise development. Among the key issues identified by a paper prepared for the National Employment Policy Forum (Appiah-Koranteng, 1994) are the need to provide credit, infrastructure and technology appropriate for small enterprises. In the food processing subsector the need for appropriate technology, improved product quality, product diversification and the filling in of 'missing links' in the value-adding chain, packaging being one example of this in Ghana, is identified. The absence of any form of industrial 'extension' may explain the weakness of links between researchers and industries.

In addition, it appears that weaknesses in the technical and business management skills of entrepreneurs have not been addressed by technical research projects. Similar to the FRI study, Appiah-Koranteng (1994) identifies the lack of understanding of costing principles as a constraint on the ability of small-scale enterprises to grow and develop more complex product selections and patterns of organisation. Another organisational issue identified is the need to promote co-ordination to enhance linkages in the value adding chain, through for example promoting business associations for co-ordinated action and improved market and business information. In particular, there is a need to make these types of initiatives accessible to women. Much food and crop processing in Ghana is traditionally associated primarily with women. Thus, it appears likely that social and legal constraints on female entrepreneurship have some part to play in explaining the limited commercial impact of most of the technical research on food processing.

Research in the area of new product development clearly involves a difficult process of estimating both what kind of product will meet with consumer acceptance and what kind of process will prove to be acceptable to potential entrepreneurs in the context of the wider business environment. In addition, research must focus on those areas where clear commercial potential exists in terms of market demand and competitive costings, and should work closely with the potential users of research outputs to ensure its relevance to their needs. Socio-economic research inputs will be necessary in order to maximise the probability of commercial uptake of any technical research output.

Cassava's Role in the Agricultural Economy

The current Medium Term Agricultural Development Strategy (MTADS) is under review, and a number of key issues are emerging in the formulation of agricultural sector policy. Dr Asenso Okyere, a member of the MTADS review team, identifies the following issues:

- how to promote the commercialisation of agriculture
- providing livelihood opportunities in agriculture which are comparable with other sectors in order to retain agricultural producers

- how to promote investment in the agricultural sector.

Within this context there are a number of key questions which emerge concerning the role of cassava within the agricultural economy:

- can cassava realistically be promoted as an export commodity
- the development of market opportunities / utilisation strategies for cassava
- concern over agronomic and soil fertility effects of promoting increased cassava cultivation
- questions relating to the selection of appropriate varieties for promotion (also connected to utilisation strategies).

Thus, research on the promotion of alternative end uses for cassava appears to be highly relevant to the current policy context. Data suggests that Ghana has comparative advantage at the farm gate for cassava, but that this is quickly lost further down the marketing chain due to the poor transport infrastructure and comparative inefficiency of marketing systems. Thus, marketing systems are likely to be a key determinant of the competitiveness of alternative end uses for cassava.

Cassava retains an important role in safeguarding the food security of many communities in Ghana, and future policy on variety selection and end use promotion will need to take account of this, and the need to develop an adequate protein base to complement the carbohydrate potential of cassava. In the case of the new high yielding varieties there are concerns over cyanide content for some food uses, but they appear to be ideal for industrial/processing uses because of their lack of suitability for pounding implying that there will not be competition between usage for *fufu* preparation and other forms of processing.

Output 2: Potential for cassava starch and flour as substitutes for currently used materials assessed.

OVIs: Technical and economic potential of cassava flours and starches assessed by 1997.

Summary

Case studies of cassava starch and flour processing in other parts of the world, and mass production of cassava chips in Ghana for livestock feed, provided clear indications as to which processing options would be most likely to succeed in Ghana in the foreseeable future. Industrial processing of Cassava starch would seem to be attractive because of the high level of value addition associated with starch, and the apparent opportunities for export. However, the level of capital investment is high, and would be processors need to ensure access to sufficient supplies of high quality fresh cassava of the correct level of maturity. Additional requirements include ready access to large amounts of good quality water, a reliable electricity supply and good road infrastructure to enable roots to be transported rapidly from farm to factory. The experience of T&CG in the cassava chip market has shown that these conditions do not exist in Ghana at the present time. It is therefore unlikely that high quality cassava starch would succeed as a business opportunity in Ghana in the short to medium-term.

Production of high quality cassava flour appears to be far more attractive, as processing is less capital intensive, and the final product can be prepared from dry chips, rather than fresh roots. Cassava flour would appear to have potential to substitute for more imported alternatives in the areas of paperboard adhesives, plywood glue extenders and bakery products where the quality specifications of the end users are much less critical and therefore easier to achieve. High quality cassava flour could also have

potential for use as a textile sizing agent in mills that produce lower quality cloth for the cheaper end of the local market.

Rationale

The results of the market study carried out by NRI/UoG indicated that potential exists for marketing of locally produced cassava starch and flour in Ghana. However, the detailed specifications of potential users were not known. It was also clear that a decision needed to be made as to whether to focus project activities on cassava starch or flour. To make this decision it was necessary to evaluate the technical and economic feasibility of each approach within the context of current conditions pertaining in Ghana.

Research activities

To determine the requirements of potential users of cassava starch and flour, users of existing products were asked to specify their needs, and provide samples of existing products for analysis. A study was made of the technical and economic factors that influence the potential for success of a given processing option. Case studies of cassava flour and starch as business opportunities were prepared using material from Ghana, Nigeria, Benin, Malawi and India. In addition a detailed case study was made on the activities of T&CG. Although T&CG do not produce flour or starch, their activities illustrate many of the practical difficulties associated with exploitation of cassava as a business opportunity, and dry chips can provide a starting point for cassava flour production.

Method

Activities were initiated in order to determine the specifications of potential users of cassava flour and starch in Ghana, and to identify which of the two main processing options would have the most potential as a business opportunity in Ghana in the short to medium-term (5-10 years). Information was collected through:

- Visits to selected factories in Accra, Tema and Kumasi, covered in the market survey to obtain samples of starches and flours in current use for determination of basic physico-chemical properties, and to obtain details of factories quality specifications for starches and flours.

- A series of case studies of the potential of cassava flour and starch as business opportunities, using available literature, and information derived from interviews with representatives of research projects and commercial enterprises in Ghana, Nigeria, Benin, Malawi and India. Each case study should assess the current situation, identify growth trends (physical and economic factors), determine the role of stakeholders and assess the potential for growth of the market.

Outputs

Characteristics of starches and flour and user specifications.
Samples of starch and flour were collected from various users and suppliers of starch in Ghana (Table 9). Samples were tested to provide information on moisture, pH, particle size distribution, colour and pasting properties, as these were the main parameters specified by users of these products (Tables 10-33). In addition all users specified that suppliers must be able to provide regular supplies of starch or flour of consistent quality, and ensure timely delivery. Detailed specifications of product characteristics were obtained from paperboard and plywood manufacturers and one biscuit factory (Tables 34-35).

In general, users were happy with the imported products that met all of the specified criteria. The locally made starches and flours were more variable in quality. Maize starch supplied by Tuyee Limited (sample

15) was of the highest quality and was of similar quality to imported materials. However, the paperboard adhesive supplied by A. T. Cooke was of poor quality and did not meet the users specifications. Most users purchased Mr Cooke’s products on the grounds of price for blending with high quality imported glues.

Table 9. List of samples collected from current users and suppliers of starches and flours in Ghana.

Code	Country of origin	Manufacturer	Source	Sample type and intended use.
01	France	Roquette	Pakrite (4/96)	Maize starch based SBA for paperboard manufacture.
02	Imported	Unknown	A E Soud Plywood	Modified thin boiling maize starch for use as a plywood glue extender.
03	Ghana	Elsa Foods	Direct from manufacturer	Native cassava starch derived from factory based *agbelima* process.
04	France	Roquette	Polykraft (10/97)	Maize starch based SBA for paperboard manufacture.
05	India	Unknown	Akosombo Textiles	Native maize starch for textile sizing.
06	Ghana	Unknown	Kumasi Glue	Native cassava starch derived from village based *agbelima* process. For use in starch based glues.
07	France	Roquette “120”	Freedom Textiles	Modified high viscosity, low temperature maize starch for textile sizing.
08	Ghana	FRI	Direct from manufacturer	High quality cassava flour for use in preparation of snack foods.
11	Ghana	A T Cooke	Polykraft (10/97)	Cassava flour based SBA for paperboard manufacture.
12	Ghana	Unknown	Akosombo Textiles	Native cassava starch derived from village based *agbelima* process. For use in textile sizing.
13	Ghana	A T Cooke	Polykraft (4/96)	Cassava flour based SBA for paperboard manufacture.
14	Ghana	A T Cooke	Pakrite (4/96)	Cassava flour based SBA for paperboard manufacture.
15	Ghana	Tuyee	Juapong Textiles	Native maize starch for textile sizing.
16	Imported	Milled at GAFCO	A E Soud Plywood	Food grade wheat flour for use as a plywood glue extender.
17	India	National Starch, Salem, India	Direct from manufacturer	Sun-dried native cassava starch, many uses including textile sizing, food etc.

Samples 9 and 10 were not available in sufficient quantity to permit analysis.

Starch for textile sizing.

(a). Cassava

Table 10. Moisture and pH

Code	Moisture%	pH
03	9.59	4.23

12	9.76	6.01
17	10.74	4.78

Table 11. Particle size distribution.

Mesh size in mm.	Sample 03		Sample 12		Sample 17	
	Over %	Under %	Over %	Under %	Over %	Under %
1.4mm	3.25	96.75	1.15	98.85	1.45	98.55
1.0mm	0.8	95.95	0.3	98.55	0.3	98.25
0.5mm	3.9	92.05	0.55	98.0	0.9	97.35
0.425mm	13	79.05	4.55	93.45	1.65	95.7
0.250mm	14.65	64.4	11.25	82.2	1.25	94.45
0.180mm	23.05	41.35	23.45	58.75	14	80.45

Table 12. Quantitative determination of colour.

Parameter	Pure white standard	Sample 03	Sample 12	Sample 17
L	+97.87	+85.41	+56.46	+89.64
A	-0.12	+3.35	+12.13	+1.92
B	+2.20	+4.49	+12.44	+3.99

Table 13. Pasting characteristics of 6% suspensions.

Sample code	Pasting temperature °C	Peak viscosity /temperature °C	Viscosity at 95°C	Viscosity after 20 minutes at 95°C	Viscosity at 50°C	Viscosity after 20 minutes at 50°C
03	69.5°C	450 / 79.25°C	380	270	380	370
12	72.5°C	280 / 92°C	260	200	250	240
17	66.5°C	510 / 73.25°C	390	290	430	400

Viscosity in Brabender units (Bu).

(b). Maize

Table 14. Moisture and pH.

Code	Moisture%	pH
05	11.52	5.42
07	10.77	11.33
15	11.50	6.26

Table 15. Particle size distribution.

Mesh size in mm.	Sample 05		Sample 07		Sample 15	
	Over %	Under %	Over %	Under %	Over %	Under %
1.4mm	7.1	92.9	1.05	98.95	1.65	98.35
1.0mm	1.55	91.35	0.15	98.8	0.3	98.05
0.5mm	13.85	77.5	0.9	97.9	2.5	95.55
0.425mm	25.55	51.95	14.85	83.05	2.5	93.05
0.250mm	20.2	31.75	25.4	57.65	11.45	81.6
0.180mm	14.3	17.45	18.4	39.25	22.15	59.45

Table 16. Quantitative determination of colour.

Parameter	Pure white standard	Sample 05	Sample 07	Sample 15
L	+97.87	+55.69	+51.67	+90.37
A	-0.12	+16.02	+18.81	+1.2
B	+2.20	+8.79	+9.49	+3.73

Table 17. Pasting characteristics of 6% suspensions.

Sample code	Pasting temperature °C	Peak viscosity /temperature °C	Viscosity at 95°C	Viscosity after 20 minutes at 95°C	Viscosity at 50°C	Viscosity after 20 minutes at 50°C
05	85.25°C	230 / 93.5°C	230	210	530	530
07	72.5°C	215 / 81.5°C	150	110	1560	1110
15	81.5°C	300 / 95°C	300	300	700	650

Viscosity in Brabender units (Bu).

Starch/flour based adhesives (SBAs) for paperboard.

(a). Cassava

Table 18. Moisture and pH.

Code	Moisture%	PH
11	13.11	11.46
13	10.13	9.04
14	10.63	9.45

Table 19. Particle size distribution.

Mesh size in mm.	Sample 11		Sample 13		Sample 14	
	Over %	Under %	Over %	Under %	Over %	Under %
1.4mm	15.15	84.85	15.55	84.45	24.65	75.35
1.0mm	0.95	83.9	1.35	83.1	2.05	73.3
0.5mm	1.75	82.15	2.5	80.6	17.1	56.2
0.425mm	2.4	79.75	2.4	78.2	4.4	51.8
0.250mm	11.55	68.2	15.7	62.5	13.65	38.15
0.180mm	18.5	49.7	19.6	42.9	12.25	25.9

Table 20. Quantitative determination of colour.

Parameter	Pure white standard	Sample 11	Sample 13	Sample 14
L	+97.87	+48.72	+50.95	+48.78
A	-0.12	+12.10	+13.32	+12.24
B	+2.20	+11.99	+11.66	+12.09

Table 21. Pasting characteristics of 6% suspensions.

Sample code	Pasting temperature °C	Peak viscosity /temperature °C	Viscosity at 95°C	Viscosity after 20 minutes at 95°C	Viscosity at 50°C	Viscosity after 20 minutes at 50°C
11	79.25°C	260 / 91.25°C	260	130	280	260
13	80°C	150 / 89°C	130	100	190 +3 mins = 200 max	170
14	89°C	40 / 95°C	40	30	70	60

Viscosity in Brabender units (Bu).

(b). Maize

Table 22. Moisture and pH.

Code	Moisture%	pH
01	11.23	10.96
04	11.38	12.28

Table 23. Particle size distribution.

Mesh size in mm.	Sample 01	Sample 04

	Over %	Under %	Over %	Under %
1.4mm	1.25	98.75	1.15	98.85
1.0mm	0.35	98.4	0.25	98.6
0.5mm	2.05	96.35	1.0	97.6
0.425mm	1.65	94.7	7.75	89.85
0.250mm	12.15	82.55	24.8	65.05
0.180mm	32.15	50.4	32.3	32.75

Table 24. Quantitative determination of colour.

Parameter	Pure white standard	Sample 01	Sample 04
L	+97.87	+54.23	+53.78
A	-0.12	+16.98	+17.26
B	+2.20	+8.81	+9.06

Table 25. Pasting characteristics of 6% suspensions.

Sample code	Pasting temperature °C	Peak viscosity /temperature °C	Viscosity at 95°C	Viscosity after 20 minutes at 95°C	Viscosity at 50°C	Viscosity after 20 minutes at 50°C
01	74°C	180 / 83°C	140	120	870 +4 mins = 960	810
04	69.5°C	330 / 78.5°C	160	80	330 +5 mins = 400 max	350

Viscosity in Brabender units (Bu).

Starch and flour for adhesive manufacture.

(a). Cassava

Table 26. Moisture and pH.

Code	Moisture%	pH
06	12.75	4.99
08	10.84	5.85

Table 27. Particle size distribution.

Mesh size	Sample 06	Sample 08

in mm.				
	Over %	**Under %**	**Over %**	**Under %**
1.4mm	35.55	64.45	1.05	98.95
1.0mm	12.45	52.0	0.15	98.8
0.5mm	18.9	33.1	0.9	97.9
0.425mm	3.45	29.65	14.85	83.03
0.250mm	5.65	24.0	25.4	57.65
0.180mm	3.55	20.45	13.95	31.2

Table 28. Quantitative determination of colour.

Parameter	**Pure white standard**	**Sample 06**	**Sample 08**
L	+97.87	+38.77	+47.45
A	-0.12	+29.36	+21.40
B	+2.20	+13.17	+11.45

Table 29. Pasting characteristics of 6% suspensions.

Sample code	**Pasting temperature °C**	**Peak viscosity /temperature °C**	**Viscosity at 95°C**	**Viscosity after 20 minutes at 95°C**	**Viscosity at 50°C**	**Viscosity after 20 minutes at 50°C**
06	69.5°C	480 / 77°C	410	290	470 NB 490 +3mins	420
08	71.75°C	310 / 86.75°C	310	190	270	250

Viscosity in Brabender units (Bu).

Starch and flour as extenders for plywood glues.

Table 30. Moisture and pH.

Code	**Moisture%**	**pH**
02	9.27	5.04
16	12.25	6.23

Table 31. Particle size distribution.

Mesh size in mm.	**Sample 02**		**Sample 16**	
	Over %	**Under %**	**Over %**	**Under %**

1.4mm	1.4	98.6	1.0	99.0
1.0mm	0.15	98.45	0.15	98.85
0.5mm	0.5	97.95	33.6	65.25
0.425mm	0.65	97.3	29	36.25
0.250mm	1.0	96.3	17.55	18.7
0.180mm	20.55	75.75	8.95	9.75

Table 32. Quantitative determination of colour.

Parameter	Pure white standard	Sample 02	Sample 16
L	+97.87	+34.27	+59.96
A	-0.12	+32.50	+13.94
B	+2.20	+14.39	+11.47

Table 33. Pasting characteristics of 6% suspensions.

Sample code	Pasting temperature °C	Peak viscosity /temperature °C	Viscosity at 95°C	Viscosity after 20 minutes at 95°C	Viscosity at 50°C	Viscosity after 20 minutes at 50°C
02	Thin boiling modified starch, hence did not paste.	NA	NA	NA	NA	NA
16	84.5°C	30 / 93.5°C	30	10	60	60

Viscosity in Brabender units (Bu).

NA = Not applicable

Table 34. Specification for cassava flour for use in biscuit manufacturer provided by Fairbons Biscuits (GH) Limited.

Parameter	Requirement
Moisture	Dry
PH	Not sour
Colour	White
Odour	None
Taste	Bland
Sand and other extraneous matter	Absent
Cyanide (maximum)	Absent or low level
Dimensions	Finely milled
Shelf life	1-2 months ambient storage.

Table 35. Product specifications for paperboard adhesives and plywood glue extenders.

Parameter	Starch based paper board adhesive	Plywood glue extender
Moisture	10-12%	10-12%
Milling quality	Finely milled	Finely milled
Impurities	Free of insoluble impurities	Free of insoluble impurities
Viscosity of cold mix	33-34 Steinhall* seconds (minimum = 29 Steinhall seconds)	Minimum 35 Steinhall seconds*
Pasting temperature	63-66°C	Not specified

* Measured using a 100cm^3 Steinhall viscometer cup with 6mm aperture.

Case studies on the potential of cassava flour and starch as business opportunities in Africa.

Export of cassava chips from Ghana to the European community: The case of Transport and Commodity General (T&CG).

Current situation

The European Union feed market for dried cassava is well established. European feed millers buy cassava pellets and chips as substitutes for feed grain, basing their purchase decisions on cassava's price competitiveness. The EU market for dried cassava stood at 3.4 million tonnes in 1997 (FAO Food Outlook, November 1997), of this a quota of 145,000 tonnes was allocated to World Trade Organisation members excluding Thailand, Indonesia and China. In Ghana three local companies (Transport & Commodity General (T&CG), GAFCO and SILTEK Exports) sought to exploit the opportunity offered by the WTO quota. However, by 1998 only T&CG were still involved in this business. GAFCO and SILTEK Exports had withdrawn from the market for reasons, which will become apparent later.

T&CG entered the cassava chip market in 1993 in partnership with Tranex a livestock feed brokerage based in Belgium that supplies feed ingredients to a number of feed millers in Belgium and France. Initial exports were of negligible size but in 1996 the company exported 19,725 tonnes to the EU. During this period the company purchased cassava chips for US$30/tonne (farmgate price) and sold cassava for anything upto US$152/tonne. However, in 1997 the average dried cassava price fell to $100/tonne (FAO Food Outlook, November 1997). In the first quarter of 1998 T&CG's input and output prices for cassava chips were US$40 and US$70/tonne respectively.

Processing of cassava chips for export

In the early stages of operations T&CG attempted to establish a centralised processing operation but this proved expensive and inefficient. An improvement on this approach involved creating mobile processing teams to tour the production areas chipping and drying cassava on site. However, ultimately the company settled on farm level processing as the most effective option. Initially the company provided manually operated chipping machines, but as these proved expensive and unreliable the company switched to a policy of encouraging farmers to chip by hand using a knife. Individual farmers harvest and wash roots before chipping and then sun drying at the field edge. Some farmers were equipped with concrete drying floors but as this proved expensive, T&CG have been encouraging farmers to use traditional wooden drying screens made from lengths of bamboo. Under normal conditions chips are reported to take about 2 days to dry.

Product specification
A general specification for cassava chips intended for export to the European Community for use in livestock feeds is given in table 36. Chips should be white or near white in colour, free from extraneous matter, moulds, insect infestation and damage and possess no peculiar odours. In addition shipments of chips must not contain significant amounts of dust as this is considered unacceptable by European importers.

Table 36. Specification of cassava chips for livestock feed.

Parameter	**Percentage**
Moisture (maximum)	10-14%
Starch (minimum)	70-82%
Total Ash (maximum)	1.8-3.0%
Crude Fibre (maximum)	2.1-5.0%
Sand and other extraneous matter (maximum)	3%
Cyanide (maximum)	100mg /kg
Dimensions (maximum in cm)	length 4-5cm, thickness 1.5cm.

Growth trends - Physical factors
This market opportunity has been mainly influenced by changes in national policy and economic factors but it would be true to say that improvements in the network of major roads linking inland areas of Ghana with the coastal cities and major ports have made Brong Ahafo a more attractive production area for this purpose.

Product flow
A number of Districts in Eastern, Volta, Ashanti and Brong-Ahafo Regions produce more than 100,000 tonnes of cassava per annum (Day *et al* 1996), however, not all these Districts are appropriate as sources of cassava for export as many have good access to fresh markets or competing processed products that command higher prices than cassava chips. In practice T&CG have concentrated on 6 Districts in Brong Ahafo Region where large amounts of cassava are grown, drying conditions are good but farmers access to alternative markets is poor. Production is decentralised with 4-5 production zones per district. Each zone contains a number of farmers organised into groups to supply chips to T&CG, farmers groups are expected to supply a minimum of 25 tonnes of marketable chips per month. Farmers are expected to deliver chips to one of 20 zonal buying agencies which then forward batches of chips to the zonal buying centre, for onward transport by road or lake to the companies warehouses in the port of Tema. When sufficient supplies have accumulated, chips are forwarded by ship to the companies feed broker (Tranex) in Europe who takes responsibility for distribution of chips to the feed millers.

Bottlenecks

The major physical bottlenecks associated with T&CG's activities are:

(i). **Transport infrastructure.** The main production zones have a low level of road infrastructure and lack linkages from field areas to the main roads. In addition there is almost no mechanisation of transport from field to road. Dry chips have to be head loaded through the bush to reach the road. This is another activity that increases labour costs and reduces flow of supplies to the collection points.

(ii). **Equipment.** In an attempt to increase production rates, the company introduced a manual chipping machine. This machine proved costly, inefficient and unreliable under field conditions. Motorised equipment was not considered as an option due to unacceptably high capital costs (Day *et al* 1996).

(iii). **Labour shortages.** This an ongoing problem in rural Ghana. Manual chipping requires a high labour input which is not always readily available.

(iv). **Farmer confidence.** Farmers involved in this project valued the benefits of regular income and guaranteed market access. The success of the company in 1996 lead farmers to have high expectations of market returns and sustainability. However, the collapse of world prices for dry cassava in 1997 resulted in cash flow problems, many farmers lost confidence with the company and switched to other markets for their product.

(v). **Expansion difficulties.** To create a large supply of chips within two years, T&CG operated a policy of rapid expansion into 9 Districts in Brong Ahafo and Northern Regions. In each District the company had to provide an extension service to raise awareness among farmers, provide training and establish field based management systems that could provide the necessary level of quality control. In retrospect the company recognises that this level of expansion was too rapid, and was partly responsible for failings in quality control.

(vi). **Quality.** The policy of decentralised production can lead to problems with establishing and maintaining consistent quality standards. Farmers can be tempted to increase production at the expense of quality. The most common problems were mould spoilage, contamination with sand, and high moisture contents due to inadequate drying. The dimensions of chips may also fail to meet the importers specification.

(vii). **Supply problems.** Increases in the price of fresh roots and dry cassava chips for local human consumption have made it difficult for T&CG to source enough chips to meet their contractual obligations.

(viii). **Handling methods and loading rates.** Low levels of mechanisation at the companies facilities in Tema have resulted in very low loading rates, typically 500 - 1000 tonnes per day. In contrast a similar company in Thailand would expect to load 20,000 tonnes per day. The problem of bulk handling is a key constraint as it increases shipping costs.

(ix). **Power supply.** In 1998, Ghana experienced a national power shortage resulting from a combination of several years of unusually dry weather, increased demand for both water and electricity and problems with the operation of the nations main source of power generation. The power shortage lasted for 9 months, but the underlying problems may take several years to resolve.

Growth Trends - Economic Factors

The initial success of T&CG's operation was influenced by several factors, these were:

(i). **Competitiveness of cassava as a feed ingredient.** In the period from 1993 to 1996 dry cassava with a suitable protein supplement was able to compete on a price basis with alternative feed ingredients such as barley and maize.

(ii). **Access to funds to develop the opportunity.** It is difficult to put a figure on the cost of developing a market opportunity but T&CG have estimated that a minimum of US$600,000 were required for research and development over a 5 year period in order to exploit this opportunity. A substantial amount of this money was supplied by the European backer Tranex.

(iii). **Farmers interest in chip production.** In the production zones identified by T&CG farmers faced problems with access to markets for fresh cassava roots and relatively poor prices for dry cassava for local human consumption (*kokonte*). Although the equivalent fresh root price was three times higher than that offered by T&CG for dry chips (Day *et al* 1996), farmers valued the opportunity offered by T&CG, as it promised ease of market access, regular and guaranteed income stream, payment by weight (which farmers considered to be fairer than volume basis) prompt payments and the possibility of credit from the company.

(iv). **Positive policy environment.** During the early stages of the development of this opportunity a positive policy environment for cassava development existed in Ghana. Cassava was identified as a first priority crop in the National Research Strategic Plan (NARSP) and Medium Term Agricultural Development Plan (MTADS). The MTADS recognised the importance of adding value to cassava through income generating opportunities, expanded markets and interventions by the private sector.

Bottlenecks

Although demand for dry cassava remained steady throughout 1996 and 1997, changes in market prices during 1997 placed a severe stain on T&CG. In 1997 world cassava prices fell from US$150 to US$100/tonne. In the same period reductions in set-aside subsidies within the EU depressed the price for barley. In addition the price of soymeal (protein supplement required for cassava feeds) was very high. It is clear that under these conditions cassava can only maintain its competitiveness by becoming cheaper. Unfortunately this is not a viable option for T&CG which faces very high production and transport costs when compared to major competitors in South East Asia. The problems of the European market affected the companies cash flow and interfered with payments to farmers in the production zones.

In Ghana unusually dry conditions attributed to the *El Nino* weather system lead to increases in prices for both *kokonte* and fresh cassava for local consumption. Many farmers who were already upset by the uncertainty of payment by T&CG switched to alternative markets. In three Districts in Northern Region *kokonte* prices increased to US$0.13/kg. T&CG who could only offer US$0.04/kg were unable to compete and had to withdraw from these areas.

In addition to these problems the company is limited by the very high costs associated with transport and handling of the product in Ghana, and difficulties in sourcing lines of credit to maintain cash flow through a difficult period.

Role of stakeholders

The case of T&CG provides an example of a complete commodity system where all the stakeholders have a vital role to play in ensuring the successful exploitation of the opportunity. Farmers are the primary stakeholders in this system who take responsibility for providing a constant supply of chips of consistent quality. If the farmers lose confidence in the market or fail to pay attention to quality the system must collapse. The T&CG have a key role in providing the farmers with a point of access to the market and technical and financial support to exploit the opportunity, as well as providing a management structure to co-ordinate supplies and maintain quality control. The presence of a large and organised purchasing organisation should also help to build the confidence of the farmers as to the sustainability of the opportunity. If the buying organisation fails then farmers will not be able to access the international market. The European feed broker provides a means of reaching the feed millers in Europe, and this case has also provided a substantial financial commitment. Without the feed broker it seems unlikely that T&CG could have developed the opportunity or accessed the European markets so readily.

Conclusion

The case of T&CG provides a good example of a commercial company attempting to address the problems of a complete commodity system using a mixture of commercial and developmental techniques, and provides many useful pointers for the development of any cassava processing option in the future.

T&CG concentrated solely on the export market as this seemed to offer the largest market and maximum opportunity for a good return on initial investment. In retrospect it is clear that the company would have been wise to consider domestic markets for high quality cassava chips as well, as this would have provided a buffer against fluctuations in the world market price for dry cassava.

The international market for dry cassava in livestock feed appears attractive as a means of adding value, expanding market opportunities and providing a source of foreign exchange. This information coupled with knowledge of the examples provided by Thailand, Indonesia and China could attract many nations growing cassava to try and enter the market. However, prospective entrants need to be aware and unpredictable nature of the EU cassava market, and must prepare themselves for mixed trading fortunes and stiff competition from South East Asia.

Cassava flour as a substitute for wheat flour in Nigeria

Current situation

Preparation of flour is one of the traditional ways of preserving and adding value to cassava roots that is practised widely in Africa (COSCA). However, cassava flour prepared using traditional methods is often fermented and frequently of poor quality, thus making it unsuitable as a substitute for wheat flour in bakery products.

A combination of increased urbanisation, rising incomes, market promotions and specific policy decisions favoured the importation of large amounts of wheat into Nigeria between 1960 and 1987 (Bokanga and Djoussou 1998). In 1985 Nigeria was the largest importer of wheat in Africa with imports totalling US$37 million, that accounted for 2.2% of the nations foreign exchange earnings (Djoussou and Bokanga 1997).

Between 1987 and 1990 the Federal Government of Nigeria banned importation of grain thus drastically reducing consumption of wheat products. According to Djoussou and Bokanga (1997) wheat imports recovered when the ban was lifted but overall the trend for wheat imports into Nigeria is one of decline. Djoussou and Bokanga attribute the decline in wheat imports to a combination of high prices for imported foods including wheat and wheat products, currency devaluation and a continual fall in real per capita incomes. These circumstances have created a favourable environment for the development and adoption of cheaper locally produced alternatives to wheat flour.

Preparation of high quality unfermented cassava flour for human consumption

To minimise requirement for capital investment IITA developed a method for flour production that makes use of equipment already in common use in Nigeria for preparation of *gari* (Onabolu and Bokanga 1998). This technique was shown to be suitable for preparation of cassava flour from both sweet and bitter varieties of cassava. Mini chippers were also tried in place of the mechanical grater but were found to be unsuitable for bitter varieties because of insufficient reduction in the concentration of cyanogenic glucosides during processing (Abass *et al* 1997 & Onabolu and Bokanga 1998).

Product specification

A practical standard for edible cassava flour established by several biscuit manufacturers in Oyo State, Nigeria is given in Table 37. This standard is less sophisticated than the international standard for edible cassava flour defined by the FAO (CODEX 152-1985 Rev. 1-1995) but gives a better indication of the practical requirements of users. Manufacturers of bakery products in Nigeria are mainly concerned with acidity, gross contamination and cyanide rather than microbiology or specific pasting characteristics.

Table 37. Specification for cassava flour used by Nigerian biscuit manufacturers.

Parameter	**Requirement**
Moisture	Dry
PH	5.0 - 8.0
Colour	White
Odour	None
Taste	Bland or sweet
Sand and other extraneous matter	Absent
Cyanide (maximum)	10mg /kg
Dimensions	Finely milled

Source: Abass *et al* 1997.

The dissemination phase of the IITA project commenced in December 1994 with the training of 77 women and 3 men who were involved in processing of cassava or preparation of bakery products in Oyo town. In February 1995 a commercial biscuit manufacturer commissioned the trainees to produce an initial batch of high grade cassava flour for use in product development. By 1997 three biscuit manufacturers, two bread bakeries and several small producers of snack foods had placed regular monthly orders for cassava flour to use as a substitute for wheat flour. A fourth biscuit manufacturer was in the process of product development in 1997. During the same period IITA provided training to 900 primary processors wishing to manufacture cassava flour.

Cassava flour can reduce a food manufacturers bill for flour by as much as 48-50% depending on the degree of substitution. Primary processors normally operate in groups of 14 who share processing equipment. During the dry season a processing group can produce 1000-2000 kg of cassava flour. In the wet season this falls to 100-1000kg per week (Abass *et al* 1997). Using these figures an individual group member could expect to make a maximum of 714 Nira per tonne of cassava flour (US$32.62) and a maximum income of 1428 Nira per week (US$65.24) depending on level of production and cost of raw material.

Although cassava flour can theoretically be used to substitute for 100% of wheat flour, Nigerian food manufacturers have determined practical limits for a range of food products (Table 38).

Table 38. Practical levels of substitution of wheat with cassava flour.

Product	**Maximum level of substitution of wheat with cassava flour.**
Snack foods (chin chin, fish pies, buns and fish rolls)	12.5 - 100% dependent on product and user.
Biscuits	5-25% normal, 60% maximum depending on type of biscuit.
Bread	20% maximum

Noodles	10% maximum

Source: Abass *et al* 1997.

Growth trends-Physical factors
This market opportunity has been mainly influenced by changes in national policy and economic factors but has also been influenced by the existence of food processing industries, ready availability of cassava, ready access to suitable processing equipment and acceptance of cassava as a convenience food (as *gari*) by urban and rural consumers.

Bottlenecks

The major physical bottlenecks for the IITA process are access to processing equipment, power to provide mechanisation and reliance on good weather for drying the product. In the Nigerian case weather appears to be the major factor as it can reduce production rates by 90% and thus interfere with delivery and also lead to reductions in product quality and hence sale price, because prolonged drying will lead to fermentation of the wet mash and consequent reduction in pH value.

Growth Trends - Economic Factors
The success of high quality cassava flour as a partial substitute for wheat flour in Nigeria has been mainly due to economic factors and changes in government policy. As long as wheat was readily available at low cost it remained the favoured raw material for bakery products in Nigeria. The ban on importation of cereals between 1987 and 1990 created an environment where manufacturers were forced to look at alternatives to wheat to remain in business regardless of quality and other technical difficulties. Experience gained during this period has lead food manufacturers to be more ready to accept cassava flour as a cheaper alternative to wheat flour if processors can provide the necessary quality. In the post ban period Nigeria's economic difficulties, currency devaluation and falling per capita incomes have all helped to maintain interest in cassava flour as a means of continuing to produce competitively priced products. Djoussou and Bokanga (1997) have estimated that a reduction in wheat flour imports of 15% through substitution with cassava flour could save Nigeria US$14.8 million per annum in foreign exchange. The net return to processors from this saving would be in the region of US$12.7 million and cassava farmers could expect to receive a gross benefit of US$4.2 million.

Level of investment required
Production of cassava flour is a relatively simple procedure requiring access to small amounts of clean water for root washing, and a number of items of processing equipment (Table 39). A group of 14 processors would require between US$1780 and US$2750 depending on the type of equipment used to produce high quality unfermented cassava flour for human consumption independently. These costs could be reduced if the group could gain access to a central mill facility equipped with hammer mills and possibly mechanical graters as well, or by using a belt drive to power the grater and mill from a single engine.

Table 39. Equipment required for production of high quality cassava flour.

Item	**Capacity**	**Total cost in US$**
Mini chipper – manual	30-60kg roots/hr	150
Mechanised	500-1000kg roots/hr	700
Mechanical grater	300-500kg roots/hr	body 320

		engine 550
Cassava press: - Board type (x1) Metal cage (x1) Double screw (x1)	All 50-100kg mash/hr	50 230 250-300
Wooden drying racks (x15)	Not determined	30
Hammer mill (x1)	250-400 kg flour/hr	body = 750 5-8 hp engine = 800
Total cost:		**US$ 1780 - 2750**

Source: Bokanga (1998) & SIS Engineering Ghana Limited (1996)

Bottlenecks

The primary economic constraints affecting this market opportunity are high raw material costs which can make production of cassava flour uneconomic and lack of capital available to primary processors for investment in additional items of machinery for production of cassava flour.

Conclusion

Cassava has advantages as a raw material for flour production because of the ease of processing and low capital investment required to establish a processing unit. In addition cassava flour has a bland flavour and is thus unlikely to alter the flavour of any product in which it is used. The example from Nigeria appears to have potential for replication elsewhere. The following factors are likely to be important for the success of this opportunity:

- There must be a positive economic and policy environment for adoption of cassava flour as a substitute for wheat flour.
- Users and consumers must be willing to accept cassava flour in food products.
- Primary processors must be able to provide a reliable supply of cassava flour of a consistently high quality at a competitive price.
- Cassava roots must be available at a sufficiently low price to undercut imported wheat.
- Government and NGO support needs to be available to promote the acceptability of cassava flour and provide training, financial and technical support to primary users.

Potential for production of native cassava starch in Benin, Ghana and Malawi

Current situation

Starch is an important raw material for a number of industries including textiles, paper, adhesives, pharmaceuticals and food. As a country becomes more industrialised demand for both native and modified starches increases but this demand is typically met through imports rather than locally made starch. This case study looks at the potential for production of native cassava starch in Benin, Ghana and Malawi as a substitute for imported products.

Benin - In 1993 Benin imported 120 tonnes of starch for use mainly in textiles, adhesives and food. Most of this came in the form of native starch derived from cassava (30 tonnes from Cote d' Ivoire), sweet potato (30 tonnes from China) and corn starch (60 tonnes from European Union). Although small amounts of starch were produced locally as by-products of tapioca and *gari* production none of this starch was used industrially because it was perceived as being of poor quality by potential users. Imported starch cost between US$818 - US$940/tonne. Given that fresh cassava roots could be purchased for US$14-21/tonne it was estimated that native cassava starch could be produced locally for between US$264 - US$343/tonne if suitable processing equipment were available. From these figures it would appear that an attractive margin exists for local cassava production. However, the market size is very small with little opportunity for significant growth and the capital investment required to exploit this opportunity would be very high. A small starch factory producing 10 tonnes dry starch per day would produce a years supply of starch in just 10 days and consume only 480 tonnes of fresh roots (national production of ~1,000,000 tonnes/annum).

In 1993 a proposal was made by a joint Beninian and Canadian Company (Bencan Ltd) to establish a cassava starch factory in Ketou to produce 9,500 tonnes of dry starch/annum from 50,000 tonnes of fresh roots/annum. The projected cost of the venture was US$6.8 million (inclusive of capital investment, running costs and civil works). Bencon proposed to supply all national needs and then sell surplus to Japan and Europe to generate foreign exchange (Faure 1993). It is evident from this information that the national market for starch in Benin was too small to support a cassava starch industry. Exports might solve this problem but it should be kept in mind that the world market for starch is highly competitive.

Ghana - In 1996 the market size for starch in Ghana was some 4,200 tonnes, most of this starch was imported and 60% of the market went to modified starches with high product specifications. At the present time the starch market in Ghana is quite small and dominated by modified starches with high quality specifications and thus offers limited scope for local production of cassava starch. However, there is scope to produce high quality cassava flours from dry cassava chips for use in starch based paperboard adhesives and plywood glue extenders. This area is discussed in more detail in the section dealing with opportunities for cassava flour.

Malawi - In 1997 the market size for starch (excluding food uses) in Malawi was around 780 tonnes this requirement was met by importing maize starch from South Africa and Zimbabwe for US$650/tonne. As part of an IDRC funded project the University of Malawi has been collaborating with two local manufacturers of paperboard and Forintek Canada (supplier of wood glues) to assess the technical potential for local manufacture of cassava starch and cassava starch based adhesives for the paperboard industry. Laboratory and factory trials have shown that locally produced cassava starch can be used replace 50 to 100% of maize starch in starch based adhesives. Cassava starch has the added advantage of reducing the amount of sodium hydroxide (gelatinisation modifier) and borax (viscosity enhancer) required to prepare a suitable adhesive for paper board manufacture, thus further reducing costs. This project has been of an essentially technical and laboratory based nature, however, it is hoped that the project will look at options for starch processing and assess the economic feasibility of cassava starch production with a view to commercialising the findings of the project.

Processing methods

To process cassava roots into native cassava starch there are three factors which are essential for successful processing, these are:

a. **Root maturity** - Roots should be harvested after 10-12 months to ensure optimum starch content and quality. Immature and old roots will give reduced yields of poor quality starch.

b. **Rapid transport** - Roots should reach the factory for processing within 12 hours of harvest so as to avoid physiological deterioration.

c. **Rapid processing** - Roots should be converted into dry starch as quickly as possible to prevent adverse changes to starch quality resulting from fermentation of the starch during processing.

There are two main methods for industrial processing of native cassava starch, these are: (i). the traditional approach favoured in India and some Latin American countries; and (ii). the modern "Alfa Laval type" approach used for large-scale industrial processes in many parts of the world. A brief description of these processes with comparative advantages, costs and inputs is given below.

Traditional process.
In the traditional process fresh roots are washed and de-barked before crushing in a rotary rasper. Starch is separated from the crushed pulp by passing through a series of reciprocating nylon screens of decreasing mesh size (50-250 mesh). The resultant starch milk is settled over a period of 4-8 hours using a shallow settling table or a series of inclined channels laid out in a zig-zag pattern. Settled starch is sun dried on large cement drying floors for approximately 8 hours. During this period the moisture content reduces from 45-50% down to 10-12%. To achieve efficient drying sunny conditions are required with ambient temperatures of >30°C and relative humidities of 20-30%. Dried starch is ground to a fine powder and packaged for sale.

Modern "Alfa Laval type" process.
In the modern process roots are washed and de-barked, sliced and then crushed in a rotary rasper. Starch pulp is passed through conical rotary extractors to separate starch granules from fibrous materials, and then fed via a protective safety screen and hydrocyclone unit to a continuous centrifuge for washing and concentration. The concentrated starch milk is passed through a rotary vacuum filter to reduce water content to 40-45% and then flash dried. The flash drier reduces moisture content to 10-12% in a few seconds without allowing time for the starch granules to heat up and suffer thermal degradation.

Comparison of traditional and modern processes.
A comparison of the traditional and modern processes for cassava starch processing is given in table 40. The modern process has the advantage of a very short processing time and excellent product quality. However, modern factories require a high level of capital investment, are costly to operate and require highly skilled labour to maintain the equipment. In addition a reliable electricity supply must be available throughout the process.

In contrast the traditional factory offers greatly reduced capital and operating costs at the expense of a longer processing time and some loss of quality. In practice this quality is sufficient to meet the specifications of food, pharmaceutical and textile industries in India and Latin America and thus unlikely to prevent access to either national or export markets. In the traditional factory electricity is only required for rasping and filtration, settling relies on gravity and drying using solar energy. This can be useful in areas where electricity is in short supply, and also helps to greatly reduce operating costs. The downside of the traditional factory is the large area of land required and the need for more regular maintenance to replace mild steel, plastic and nylon parts which are much less durable than stainless steel.

Overall it can be seen that the choice of method will depend on local conditions, availability of capital, scale of production and quality of starch required.

Product specification

The precise specification for cassava starch will vary according to its intended application. However, cassava starch should always be white in colour, free from contaminates and off odours, moisture should be between 10-12%, pH 4.5 - 5.5, ash content 0.2% (max) and the granule size should be such that 99% of starch granules pass through a 100 mesh screen. Viscosity is a key parameter for determining starch quality, specifications vary according to use, but in general it would be fair to say that a high viscosity indicates good quality whereas low paste viscosity will indicate that the starch undergone some degradation during processing.

Table 40. Comparison of traditional and modern methods for production of native cassava starch.

Factor	Traditional factory processing 4000 tonnes roots/annum	Modern factory processing 42000 tonnes roots/annum
Quantity of roots processed in tonnes	4000 tonnes per annum	42000 tonnes per annum
Quantity of dry starch produced in tonnes	1000 tonnes per annum	10500
Processing capacity (tonnes of roots per hour)	4.5 tonnes roots/hour	6.0 tonnes roots/hour
Total process time from fresh roots to dry starch	2 days	1 hour
Capital cost for basic equipment[1]	US$25,000	US$2.5million
Pay off period[2]	1-2 years	2-5 years
Minimum operating season for economic return[3]	4-6 months/year	10 months/year
Materials used for construction[4]	Mild steel to reduce costs at expense of slight discoloration of product.	Stainless steel to avoid colour problems.
Water consumption without water conservation	7.5m^3 per tonne of roots	5.5m^3 per tonne of roots
Water consumption with water conservation	3.0m^3 per tonne of roots	1.5m^3 per tonne of roots
Power consumption	20kW per tonne of roots	75kW per tonne of roots
Fuel oil for flash dryer	Not applicable	18kg per tonne of roots
Sulphur for sulphur dioxide generator	Not applicable	1.1kg per tonne of roots
Land requirement	Large - space is required for settling tanks and drying yards.	Small - factory is compact and can be contained in one building.
Labour requirement	Semi skilled labour to operate and maintain factory.	Skilled labour to operate and maintain factory.
Quality of starch	High quality but not as good as product from modern factory. Starch loses some quality because of long process time.	Highest quality possible but depends on quality of roots used.

1. These figures are for basic equipment costs and exclude transportation and customs duties, civil works, purchase of land, labour and ancillary structures.

2. The pay off period will be determined by the profitability of the factory which is mainly determined by costs of raw materials, utilities and electrical power.

3. This is the minimum operating season required for the factory to provide an economic return.

4. When cassava is crushed hydrocyanic acid is released which can react with iron components in the factory to form ferricyanide complexes that give the starch a bluish shade when wet. This can be avoided by using stainless steel fittings or peeling roots, and can be reduced by using flexible plastic pipes where possible and operating a regular maintenance schedule.

Source: Trim & Curran (1993), Alfa Laval (1992) and Nivoba Engineering (1995).

Growth Trends - Physical Factors

The market opportunity for native cassava starch will exist to some extent in any country that is becoming more industrialised and therefore consuming more starch in various industrial processes. The main physical factors that are likely to determine success in exploiting this market opportunity are as follows:

(i). **Road infrastructure.** A good road infrastructure is required to ensure that cassava roots can reach the factory for processing within 12 hours of harvest.

(ii). **Cassava supply.** To produce high quality cassava starch a reliable supply of roots at optimal maturity of 10-12 months is critical. Immature roots will have high water content and soluble sugars and less starch. Over mature roots will contain reduced amounts of starch of lower quality and higher fibre.

(iii). **Water supply.** Starch factories require large amounts of water of good quality for processing. Process water should be free of solid particles, low in iron (<0.3mg ferrous ions/litre) and as soft as possible.

(iv). **Power supply.** Starch production is a mechanised process so a reliable source of power needs to provided. This may have to be self contained as starch factories are likely to be situated in rural areas close to the cassava farms.

(v). **Access to land.** This is most important for traditional factories that require a large area for settling tanks and drying yards.

(vi). **Availability of skilled labour.** Modern and traditional starch factories have a relatively low labour requirement, but both require efficient management and the modern factories need highly skilled personnel both to operate and maintain the facility.

(vii). **Choice of drying method.** Sun drying will reduce costs but increase processing time and can only be used if the factory is situated in an area of low rainfall, high air temperatures and low humidity. Artificial drying may seem the obvious solution, but flash drying is the major cost burden of any modern factory both in terms of capital investment and running costs. To be economic a flash dryer must have a high loading for most of the year.

Product flow

Starch processing has to be carried out in a factory environment because of the sophisticated equipment required. Dry starch can be sold by the factory direct to the end user or further processed at the starch factory. Processing may include conversion into modified starches, dextrins or formulation into starch based adhesives for the paper board industry.

Bottlenecks

Once established a cassava starch factory could face a number of physical bottlenecks that interfere with production, these include:

(i). **Cassava supply and seasonality of supply.** Starch factories require at least 20-40 tonnes of high quality fresh roots a day for a period of at least 100 days a year to be effective. To supply these demands cassava has to be treated as a high value cash drop and grown on a large-scale. Reliability of supply could be a serious issue in an area where cassava had always been perceived as a low value, food security or marginal crop. To be effective starch factories need a long processing season with continuous supplies of roots of consistent quality. In many cases climatic problems reduce the season to between 4-6 months.

Factories relying on sun drying face the additional difficulty of finding that the peak season for root availability often coincides with periods of wet and cloudy weather which are unsuitable for sun drying.

(ii). **Root maturity.** Starch factories have highly critical requirements in terms of root maturity. However, farmers will be tempted to harvest roots early to maximise use of available land and may occasionally leave roots in the ground for too long in the hope of getting a better price.

(iii). **Water and power supplies.** These two factors are most likely to cause problems during the dry season, and limited supplies of either could disrupt processing.

(iv). **Cassava.** Although popular as a source of starch, cassava roots can be seen as a liability due to their high degree of perishability and high water content (70% of fresh weight). As a result there is no margin for error in handling cassava and the high water content introduces the added expense of transporting a large amount of water from field to factory for no useful purpose. This problem might be overcome by producing dry chips but starch recovery and quality from dry chips is poor.

Growth Trends - Economic Factors

Local processing of native cassava starch is often seen as an attractive option, because it offers a means of converting a relatively low cost raw material into a high value product which can readily substitute for imported starch. In Ghana a local producer of maize starch found that he could price his product at similar levels to the imported products because users valued the guaranteed nature of the local supply and freedom from the problems of importation such as holding of safety stocks and fluctuations in international markets. Starch is also seen a potential high value foreign exchange earner.
However, to access this market opportunity a high level of investment is required. A traditional factory would require a minimum of US$150,000 to establish. A proposal for a modern starch factory would typically budget for US$8-10million for initial capital investment and significant amounts of additional funding to cover running costs in the first few years of production.

Bottlenecks

The potential economic bottlenecks for native cassava starch production are as follows:

(i). **Capital and running costs.** Production of native starch from cassava on an industrial scale requires a high level of capital investment, followed by high running costs. Modern factories may require 5 years to pay off the initial investment (Table 40) and start providing an economic return. The risk involved in investing in starch production is high because of the number of variables involved.

(ii). **Market size, access and price competitiveness.** In Ghana, Malawi and Benin the national markets for starch remain small and may not grow significantly in the short to medium-term due to a combination of macro-economic factors that limit the rate of industrialisation. Given this situation it would be difficult to imagine a modern starch factory providing an economic return by supplying to a purely national market of this size. The alternative may be to aim primarily at the export markets. Cassava starch is versatile material that competes well with maize, wheat and sweet potato starches. However, it should be realised that many markets are not completely open in nature (eg European Community) and also that price competition is fierce. Much of the market will be for modified and speciality starches prepared from the cheapest raw material available. To enter any of the markets be it national or international the product price and quality must be competitive. Potential users will always aim for the lowest price from reliable sources.

(iii). **Users perceptions of quality and reliability.** In all of the countries dealt with in this case study industrial users of starch had attempted to reduce costs by purchasing locally prepared products. These products sold as "cassava starch" generally turn out to be either very poor quality cassava starch produced as a by product of traditional food processes such as *gari* and *agbelima* production, or low-grade cassava flours that vary widely in quality from batch to batch. These products do not meet the users specifications and lead users to consider locally produced starches as being of poor quality. New entrants to the market may find it difficult to persuade users that they can deliver a high quality product of consistent quality on a regular basis.

Potential to grow market

The international market for starch seems likely to continue to grow, particularly in the area of speciality starches for novel applications in a wide range of manufacturing industries (Jeffcoat 1998). Within this context cassava is likely to continue to have a role as a source of raw material for starch production. However, a would be entrant to the native starch market in Africa would be well advised not to rely on predictions for the international market but to give serious consideration to the potential for growth of national and regional markets. The size and growth potential of the national market for starch will depend on the level of industrialisation and the macroeconomic climate of the nation. For example Ghana has a relatively high level of industrialisation and a good market for starch which should expand on a long-term basis. However, in the short-term problems such as the power crisis and general economic conditions may limit willingness to invest in the expansion of the manufacturing sector and thus limit the potential for growth of the starch market.

Advantages of cassava for starch production.

Cassava offers a relatively cheap source of raw material containing a high concentration of starch (dry matter basis) that can match or better the properties offered by other starches (maize, wheat, sweet potato and rice). Cassava starch is easy to extract using a simple process (when compared to other starches) that can be carried out on a small-scale with limited capital. In addition cassava starch has a high level of purity due to the low levels of proteins and lipids found in cassava roots.

Cassava starch production could have potential with sufficient supplies of raw material and a degree of industrialisation to support a national market for cassava starch. However, potential entrants to this market will only succeed if they have sufficient capital to back the venture, and can deliver reliable supplies of starch that meet the users specifications at a competitive price. If the market is mainly for paperboard and plywood adhesives which have low specifications it should be possible to establish a market for products based on high quality cassava flour in place of starch. This option would have the advantage of lower capital investment, simpler technology and less critical processing, whilst still creating a competitive product that can replace imported starch and starch-based adhesives.

Output 3: Cassava flours and starches developed to meet market demand.

OVIs: Most appropriate technology identified to meet market demands by 1999.

Summary

The findings derived from outputs 1 and 2 indicated that cassava flour for food and non-food applications would offer the greatest potential for development as market opportunities in the short to medium-term. Research activities under output 3 concentrated on factors that influence the production of high quality cassava flour, and use of cassava flour in manufacture of biscuits, plywood and paperboard. Chipping (using a modified IITA mini chipper) was found to be the best option for processing cassava roots with low cyanogen content. This option proved to be cheaper, less labour intensive, resulted in lower microbial load, and less loss of starch when compared to grating. High quality chips and flour could be prepared under rural conditions at lower cost (US$65 per tonne) when compared to centralised processing (US$217 per tonne). However, conversion of chips into flour in larger quantities would be a bottleneck for rural processors. A better option would be to transport dry chips from rural areas to a central processor for conversion into flour.

Cassava flour proved effective as a partial substitute for imported starch based-adhesives in paperboard and wheat flour in biscuits and plywood glues. Flour prepared from chips produced by a farmers group gave good results in trials as an extender for plywood glues. However, it is important to ensure that processors do not attempt to improve margins at the expense of quality. Research showed that cassava roots must be processed within 1-2 days of harvest to maintain quality, and should also be peeled before chipping. Flour prepared from unpeeled chips was not suitable for use in plywood glue even though this product had the lowest quality specification when compared to paperboard adhesive and food-grade flour. Under commercial conditions (in Ghana) cassava flour can be stored for 2 months without loss of quality which is more than adequate for most users in Ghana.

Preliminary estimates indicate that cassava flour has the potential to reduce production costs of plywood boards by 35%. Cost savings in biscuit manufacture vary according to type of biscuit and specific formulation. In sweet dough biscuits the cost saving would be approximately 30%, for hard dough biscuits cost savings could be as high as 60%.

Rationale

The results of market survey and techno-economic assessments indicated that high quality cassava flour had the greatest potential for success in Ghana in the short to medium-term. The most promising applications for the flour were identified as being in snack foods, paperboard adhesives, and plywood glue extenders. The non-bread snack food sector was chosen for its large market size, price competitiveness of cassava flour when compared to wheat, and the absence of technical problems associated with the absence of gluten in cassava. The non-food applications in plywood glue and paperboard were selected as good entry markets on the grounds of price competitiveness, and the relatively low quality specifications required by users.

During the initial surveys many potential users highlighted concerns over a range of issues relating to the use of cassava in their products. All of the potential users were concerned with reliability of supplies (in terms of quantity, price and timeliness of delivery), shelf life and overall quality. Potential users in the snack food sector were concerned that cassava flour might prove to be a source of cyanide, and sour or off-flavours. Only one biscuit manufacturer expressed interest in microbiological quality of cassava flour, but all bakers interviewed required the flour to be safe for human consumption. The overall perception of cassava flour was one of poor quality. The term "cassava flour" was associated with *kokonte*, and *kokonte* was linked to poor processing techniques, and low quality raw materials. Some potential users had experienced quality problems with locally produced products based on cassava flour in the past. Discussions with users and some suppliers of cassava chips, flour and paperboard adhesive indicated that those involved in processing and production of cassava-based products might be tempted to abuse defined processing procedures in an attempt to improve profit margins.

Research activities were therefore focussed to address the concerns of potential users, by developing high quality cassava flour and cassava-based products with the ability to compete against existing imported alternatives. In addition work was carried out on potential abuses in processing of cassava that could impact on end product quality.

Research activities

Research activities for the product development phase of the project were divided between the Department of Nutrition and Food Science at the University of Ghana (UoG) and the Food Research Institute (FRI). In the latter stages of the project the Forestry Research Institute of Ghana (FORIG) made inputs in the area of plywood glue extenders. Work at UoG concentrated on aspects of processing, prediction of shelf-life under different storage conditions, and work with bakers in Accra on consumer acceptability of cassava flour in sweet-dough biscuits. Mr James Ababio carried out the work at UoG as part of his M.Phil in Food Science.

FRI carried out detailed studies on processing of cassava to produce high quality cassava flour, incorporation of cassava flour in hard-dough biscuits, production of cassava-based paperboard adhesives and use of cassava flour as an extender for plywood glue. Several commercial organisations were actively involved in the research activities. The Atebubu Farmers Group in Brong Ahafo provided high quality cassava chips for the work on non-food uses for cassava. Linabel Catering Services and Roses Bakery of Accra participated in commercial trials of cassava flour in sweet-dough biscuits, cassava flour storage trials and consumer acceptability studies. Polykraft (GH) Limited of Accra provided support for development of high quality cassava-based paperboard adhesives. Lumber Processing Limited and Logs and Lumber Limited of Kumasi provided facilities for commercial trials of cassava flour as an extender for plywood glue.

Method

Activities were initiated with a view to developing methods for economically viable production of high quality cassava flour, and to investigate the potential for use of cassava flour in biscuits, paperboard adhesives and as an extender for plywood glues. Research activities covered the following areas:

- A study of the available processing options to identify the best methods for production of cassava flour to meet the specifications of potential users in both food and non-food sectors.

- An investigation of the potential for use of cassava flour as an alternative to wheat flour in sweet and hard dough biscuits. Activities included trials with commercial bakers in Accra, and consumer acceptability studies using trained panellists (FRI), and ordinary consumers drawn from several socio-economic groups in Accra.

- A study of the storability of cassava flour including practical trials in commercial stores, and the use of mathematical modelling techniques to predict shelf-life and determine the optimum conditions for storage of cassava flour.

- A laboratory investigation of the potential of cassava flour as a raw material for production of cassava-based paperboard adhesives. This study was carried out in close collaboration with a manufacturer of paperboard in Accra, who proposed to carry out commercial trials of the most promising formulation.

- An investigation of the potential of cassava flour as a glue extender for the plywood industry. These studies included commercial trials at two plywood factories in Ghana. Cassava flour was prepared from both peeled and unpeeled cassava using both centralised and rural processing options with either electric or sun drying.

- A series of case studies to identify the economic determinants that will ultimately decide whether cassava flour can succeed in the sectors studied in this project.

Detailed description of methods used are not given here, but can be found in Ababio, (1999) and Dziedzoave, *et al*., (1999).

Outputs

The main findings of the research activities were:

- Chipping (using a modified IITA mini chipper) was found to be the best option for processing cassava roots with low cyanogen content. This option was cheaper, less labour intensive, resulted in lower microbial loads, and less loss of starch when compared to grating. With appropriate quality controls sun or oven drying can be used to prepare flour that meets the specifications of bakers and those involved in manufacture of paperboard and plywood. Water quality is a critical factor for processing of flour intended for human consumption. Flour processed with rain water had high microbial counts including faecal coliforms. Peeling was found to be essential for high quality flour production. Flour made from unpeeled cassava formed dark pastes, and had poor pasting characteristics.

- Delays in processing of cassava roots after harvest, result in significant reductions in the concentration of starch and increased levels of soluble sugars. Browning of the roots also occurred leading to production of poor quality flour. Cassava roots should be processed within 24 hours of harvest to avoid reductions in flour quality.

- The shelf-life of cassava and wheat flour was estimated at three relative humidities (60, 70 and 75%). Cassava flour can be stored for up to 7 months at an initial moisture content of 10% under optimal conditions without loss of quality. Under commercial storage conditions cassava could be stored for 2 months without any reduction in quality. In commercial stores cassava flour should be stored at an initial moisture content of 10-11% in polyethylene bags.

- Cassava flour can substitute for up to 30% of wheat flour in sweet dough biscuits and 40% in hard dough biscuits, without consumers being able to detect any adverse change in colour taste or texture when compared to a 100% wheat flour control. Bakers found that cassava flour could be substituted for up to 35% of wheat flour in dough mixes without noticeable changes in handling characteristics. At higher levels (>40%) of substitution the flour texture was found to be too light. This could be overcome with additional margarine, but this caused an unacceptable increase in production cost. Consumers found biscuits containing >40% cassava flour to be less crispy, bland in flavour and susceptible to crumbling. Biscuits containing a maximum of 40% cassava flour had very low microbial counts, and cyanogen levels that were below the limits of detection after baking.

- Three types of cassava flour were evaluated for their suitability as extenders for urea-formaldehyde glues used in the plywood industry in Ghana. The flours comprised: flour from peeled mechanically dried cassava chips (FRI), flour from peeled sun-dried chips (ATP) and flour from unpeeled sun-dried cassava chips (ATU). Results indicated that with the exception of the FRI and ATU at 80% substitution level, all the flours produced glue bonds consistent with BS1455:1963 specifications. Cassava flour prepared from unpeeled roots was found to be unsuitable for use as a glue extender for plywood. Substitution at levels of 20-40% gave the best results.

- Cassava flour mixed with 0.05% borax decahydrate had pasting characteristics comparable to those found in imported paperboard adhesives.

Cassava flour production and utilisation in composite flours for biscuit manufacture.

Flour production

A summary of raw material inputs, product outputs, milling efficiency, product recoveries and average work rates at different stages of processing are presented in Tables 41-43; whilst the overall average moisture content of the raw materials and other intermediate products are shown in Table 44. Details of some of the cost elements and the specifications of some of the equipment used could not be immediately assessed either due to the non-availability of the manuals on the equipment or a suitable basis for assessment.

A total of 5 batches of oven-dried Afisiafi, 8 batches of oven-dried Bosomensia and 4 batches each of sun-dried Afisiafi and Bosomensia were produced. However 3 batches of the sun-dried products were spoilt as a result of bad weather, whilst 3 batches of the oven-dried products were ruined as a result of power cuts and malfunctioning of drying equipment. The data provided apply only to the 4 batches of oven-dried Afisiafi, 6 batches of oven-dried Bosomensia, 2 batches of sun-dried Bosomensia and 3 batches of sun-dried Afisisafi.

Table 41. Overall raw material input, product outputs, flour recovery, and milling efficiencies.

FLOUR SAMPLE CODE	FRESH CASSAVA INPUT (KG.)	DRIED INTERMEDIATE PRODUCT (KG.)	CASSAVA FLOUR OUTPUT (KG.)	FLOUR RECOVERY (%)	MILLING EFFICIENCY * (%)
MT	2892.0	548.8	389.6	13.5	71.0
ML	4089.0	873.0	660.0	16.2	75.6
ST	648.0	114.9	94.2	14.5	82.0
SL	600.0	138.6	114.0	19.0	82.3
TOTAL	8229.0	1675.3	1257.8	15.8	77.7

MT - Oven-dried Afisiafi

ST - Sun-dried Afisiafi

ML - Oven-dried Bosomensia

SL - Sun-dried Bosomensia

Table 42. Overall average product recoveries at different stages of processing.

INTERMEDIATE PRODUCTS	% RECOVERY FOR SPECIFIED SAMPLE				OVERALL % RECOVERY	OVERALL C.V.*
	HYV (AFISIAFI)		LOCAL (BOSOMENSIA)			
	OVEN-DRIED	SUN-DRIED	OVEN-DRIED	SUN-DRIED		
Peeled Cassava	68.1	71.0	63.6	61.3	66.0	0.006
Cassava Peels	30.1	29.0	36.0	38.3	33.4	0.135
Grated Cassava	66.2	66.9	62.7	58.7	63.6	0.059
Pressed Cassava Dough	45.5	32.1	46.6	40.9	41.3	0.160
Dried Cassava Dough	19.0	17.7	21.3	23.1	20.3	0.118
Milled Product	18.4	16.9	17.3	22.6	18.8	0.139
Screened Flour	13.5	14.5	16.2	19.0	15.8	0.152

* Coefficient of variation

Table 43. Summary of overall work rates.

PARAMETER	STATISTICAL SUMMARIES FOR SPECIFIED PRODUCTS			
	OVEN-DRIED PRODUCTS		SUN-DRIED PRODUCTS	
	MEAN	C.V.	MEAN	C.V.
Peeling Rate (kg. /person/hr.)	40.62	0.220	32.71	0.323
Washing Rate (kg. /person/hr.)	181.51	0.190	135.01	0.153
Grating Rate (kg. /person/hr.)	112.61	0.508	66.37	0.259
Loading Rate (kg. /person/hr.)	51.46	0.217	11.44	0.213
Loading Density (kg./m^2)	5.77	0.217	1.08	0.315
Milling rate (kg. /person/hr.)	33.19	0.102	40.8	0.097

Table 44. Moisture content of different intermediate products.

INTERMEDIATE PRODUCT	HYV (AFISIAFI)				LOCAL (BOSOMENSIA)			
	OVEN-DRIED		SUN-DRIED		OVEN-DRIED		SUN-DRIED	
	MEAN	C.V.	MEAN	C.V.	MEAN	C.V.	MEAN	C.V.
Grated Cassava	70.57	0.039	70.64	0.008	64.65	0.070	59.43	0.049
Pressed Cassava Dough	57.26	0.053	48.75	0.060	53.28	0.121	44.94	0.011
Dried Cassava Dough	9.31	0.090	9.11	0.260	7.47	0.066	11.17	0.137
% Moisture Reduction After Drying	86.81	-	87.10	-	88.45	-	81.20	-

Discussion

Table 41 shows the total output of products. The total quantity of oven-dried products is about three times the quantity of sun-dried products. This indicates that within the same time frame it was easier to produce flour by mechanical drying than by sun drying. Table 41 also shows the milling efficiency of the Disc Attrition Mill. The figure is lower for the oven-dried products than for the sun-dried products. This may be because the sun-dried products were in granulated form prior to milling whilst the oven-dried products were in lumps and therefore milled less finely. The average milling efficiency was about 77.7% which compares favourably with the efficiency of the hammer mill which was quoted as 80% by Fernandez, (1986).

The overall average flour recovery rate was 15.8% with a coefficient of variation of 0.124. This recovery rate lies between the rates indicted by Orias and Calub (1986) for flour from chips and flour from grates. Compared with the recovery rates of cassava flour (kokonte) from chips (25.3%) at the Cassava Processing Demonstration Unit in Pokoase (Dziedzoave, 1992), the assertion that flour production from chips is a more favourable technique, in terms of flour recovery, than from grates can be said to be true to a large extent. From Table 42 it can be observed that flour recovery is higher for the local cassava variety than for the high yielding variety (HYV). Even though at the stage of peeling the recovery of peeled cassava was higher for the HYV (68.1 -71.0%) than for the local variety (61.3-63.6%); after the drying stage, the recovery, with respect to the original input, was higher for the local variety (21.3-23.1%) than for the HYV (17.7-19.0%). This implies that even though the HYV had a lower peel weight because of its bigger root size and consequently smaller surface area to volume ratio; its higher moisture content as shown in Table 44 was a great disadvantage which outweighed the low peel weight advantage. It may therefore be considered preferable to produce cassava flour from the local variety rather the HYV if the cost per unit weight of cassava is the same for both. Thus if cassava is sold on weight basis then it would be preferable to go in for the local variety, but if sold on 'area' basis then it would be more advantageous to go for the HYV for the production of cassava flour.

With respect to the work rates (Table 43), it may be observed that variations between the measurements are quite high, with the exception of the milling and washing rates. These wide variations in the work rates may be due to several factors which could not have been taken into account during processing, considering the constraints encountered at the time of production, and the urgency of getting flour on time for baking trials to begin. Attention to the regulation of the number of persons working on a particular job, and the control of idle time were therefore overshadowed by the drive to get flour produced on time.

Variations in moisture content of intermediate products during production are quite low, indicating the reliability of the data. Effective moisture reduction did not appear to be very different between the sun-dried products and the oven-dried products.

Flour properties

The results of the analysis are as presented in Table 45 below. The results indicate that the final moisture content of the blended flours was slightly higher for the sun-dried products than for the mechanically dried samples, but these differences are not significant. A slight difference was observed in the average moisture content of the dried dough (Table 44) and that of the blended flours but again these were not significant. Contrary to expectation however, the acidity of the mechanically dried samples were consistently higher than those of the sun-dried samples. This may be attributed to the fact that products intended for sun-drying were pressed to a lower moisture content than those intended for oven-drying, as a result of which there may have been more moisture in the latter to support microbial activity during the first few hours of drying. The relatively high temperature in the drying oven may have further aided this during the early hours of drying. On the other hand, since the sun-dried products had a lower moisture content and larger surface area, due to a lower loading density (Table 43), moisture reduction was faster and therefore microbial activity was more limited.

Table 45. Physico-chemical and microbiological properties of cassava flour.

PARAMETER	MEASUREMENTS AS FOR SPECIFIED SAMPLES				
	OVEN-DRIED SAMPLES			SUN-DRIED SAMPLES	
	MT	MLA	MLB	ST	SL
Moisture (%)	8.25	8.35	8.62	9.59	10.25
Acidity (%)	0.50	0.42	0.40	0.14	0.26
pH	5.64	6.29	6.17	6.59	6.31
Extraneous matter (No. of specks/100cm^2)	9.5	5.5	5	6.5	5
Particle Size (mm)	0.114	0.113	0.114	0.112	0.115
Total Plate Count (CFU)	1.8×10^6	2.5×10^7	4.1×10^5	9.9×10^6	4.7×10^6
Mould Count (CFU)	3.0 x 10	2.0 x 10	1.8×10^2	1.4×10^5	2.7×10^3
Coliforms	Present.	Prsnt.	Prsnt	Prsnt.	Prsnt.
E. Coli	Absnt	Absnt.	Absnt	Prsnt	Prsnt.
Pasting Temperature (^{o}C)	72.5	72.5	71.8	72.5	74
Peak Viscosity (Bu)	810	750	920	800	740
Viscosity at 95 ^{o}C	670	600	500	640	690
Viscosity after Holding 30 min. at 95 ^{o}C	310	260	70	330	320
Viscosity after cooling to 50^{o}C	490	410	220	540	480
Cyanide (mg. CN equiv./kg dry wt.)	29.09	-	14.55	12.86	12.14
Total Sugars (mg./g)	35.71	-	48.42	35.74	41.45
Reducing Sugars (mg./g.)	26.93	-	19.91	17.8	21.23
Starch (mg./g.)	706.48	-	945.74	789.55	960.37
Colour					
L*	99.98	99.25	100.21	99.77	99.22
A*	-0.47	-0.39	-0.83	-0.60	-0.57
B*	+7.21	+7.77	+6.59	+6.29	+8.07
C	7.22	7.77	6.64	6.33	8.09
H	93.7	92.8	97.0	95.4	94.1

MT - Oven-dried Afisiafi ST - Sun-dried Afisiafi SL - Sun-dried Bosomensia

MLA - Oven-dried Bosomensia produced with rainwater. MLB - Oven-dried Bosomensia produced with treated water.

With respect to the pasting characteristics, there is some similarity between the results for all the samples except for the oven-dried Bosomensia produced with treated water (MLB) which showed some deviation from the trend of the others. The oven-dried HYV had an exceptionally high cyanide level compared to the other three samples. The total starch and sugars content was slightly higher for the Bosomensia variety than for HYV. This may be due to varietal differences. Variations in colour between the samples are only very slight. However the sample produced with treated water had a slightly higher colour hue (h) but lower colour purity (C*) than the others.

Sensory Quality
Replacement of wheat flour with up to 100% cassava flour affected the sensory quality of the biscuits. Using paired comparison test to assess differences between biscuits with cassava flour and control biscuits the biscuits with cassava flour level of 5 - 40% did not differ significantly from the control. Biscuits with cassava flour replacement level above 40% showed significant difference ($p<0.05$) from the control biscuits. Table 46 shows results of ranking tests of biscuits containing 0 -100% cassava flour.

Table 46. Ranked Positions Of Biscuits Prepared From Cassava Flour.

% CASSAVA SUBSTITUTION	RANK SUM	ORDER OF PREFERENCE (RANK POSITION)
5	27	1 (most preferred)
20	28	2
10	31	3
0	34	4
40	60	5
30	67	6
60	76	7
50	79	8
100	99	9
80	104	10 (least preferred)

Using a ranking test to assign the order of preference the most preferred biscuit samples were in the range from 0 - 40% substitution level. The least preferred samples were biscuits containing cassava flour substitution levels of 80 and 100%.

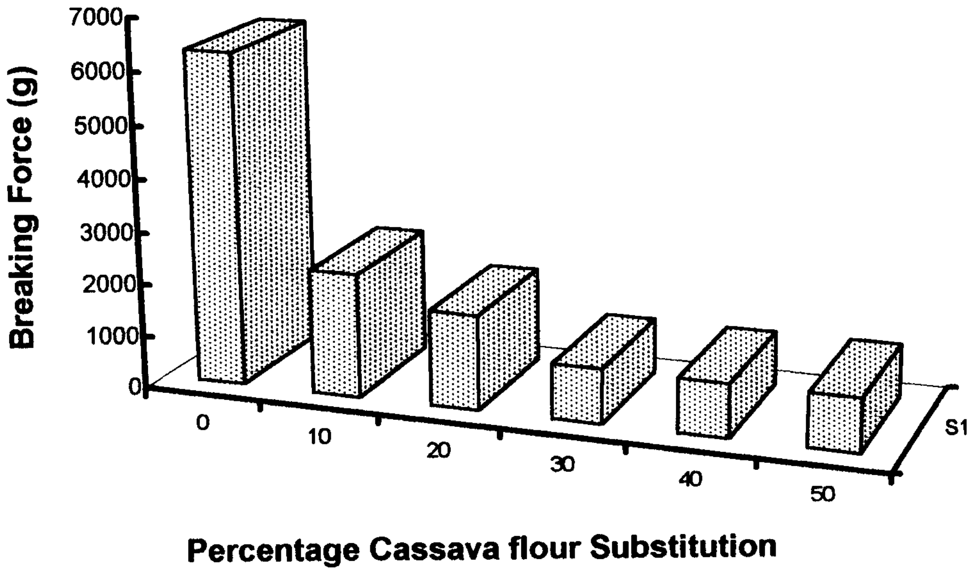
Profiling tests indicated that replacement of biscuit wheat flour with up to 100% cassava flour has effect on sensory properties of the sugar biscuits (Table 47). The changes in the sensory attributes were more pronounced at 60%,

Table 47. Mean Sensory Scores Of cassava Biscuits

LEVEL OF CASSAVA FLOUR SUBSTITU-TION (%)	SENSORY SCORES FOR SPECIFIED ATTRIBUTES													
	APPEARANCE						TEXTURE						SWEETNESS	
	COLOUR		HARDNESS		TEXTURE		CHEWINESS		MOISTURE		FIBROUSNESS		SWEETNESS	
	MT	ML	MT	ML	MT	ML	MT	ML	MT	ML	MT	ML	MT	ML
0 (CTRL)	3.96	3.96	4.58	4.58	4.18	4.18	4.43	4.43	1.53	1.53	3.18	3.18	4.04	4.04
5	3.23	3.61	3.94	3.37	3.04	2.64	4.38	4.00	1.64	2.17	2.17	3.31	5.00	4.21
10	3.33	3.75	3.69	3.03	2.96	2.56	4.82	3.53	2.06	2.10	3.78	2.51	4.97	3.43
20	4.97	3.80	3.97	2.66	2.89	3.08	4.33	2.71	1.67	1.59	2.78	3.26	4.90	4.76
30	3.79	3.43	3.34	2.78	2.06	2.78	4.19	4.30	2.03	2.23	2.77	3.18	4.47	4.03
40	4.40	3.93	2.87	2.09	1.76	2.32	4.05	3.54	2.27	2.22	2.19	2.88	4.60	3.27
50	2.65	5.51	2.72	3.06	2.30	3.74	2.28	2.73	3.01	2.11	2.32	3.03	3.91	4.02
60	2.09	4.13	2.35	2.03	1.52	1.77	2.62	3.86	3.24	1.48	2.15	1.73	3.19	4.01
80	2.28	4.62	2.07	1.86	1.96	2.04	2.34	4.56	1.59	1.85	2.45	2.88	2.48	3.58
100	2.59	2.36	1.19	0.98	1.10	1.31	3.08	4.50	3.15	1.99	1.84	2.28	2.85	4.53

80% and 100% substitution level. Biscuits formulated with 100% cassava flour had the lowest sensory scores. As the level of cassava flour replacement increased wheat flour protein level decreased and this affected baking quality resulting in lighter coloured biscuits. Substitution of wheat flour with up to 50% cassava flour did not affect the sweetness of the biscuits. Flour from both cultivars of cassava showed similar results. Biscuits showed increasing hardness with increasing cassava flour level in the formulation. The crispiness of the biscuits was affected by the level of cassava flour substitution in the biscuit formulation. The breaking force of the biscuits decreased with increasing level of cassava flour as shown in Figure 1. Starch is the major component of cassava flour and affects the visco-elastic properties of the biscuit dough. There may be interaction of cassava starch and gluten of the wheat flour to produce the effect observed in the textural characteristics.

Figure 1. Effect of cassava flour on the crispiness of biscuits.



Objective Colour Evaluation of Biscuits

In general food product colour is an important attribute affecting consumer acceptability. Replacing wheat flour with 0%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 80%, and 100% cassava flour affected colour of biscuits measured by means of a colour meter. The colour values are presented in Table 48.

Table 48. Colour Values Of Cassava Biscuits.**

% CASSAVA SUBSTITUTION	COLOUR VALUES				
	L*	a*	b*	C*	h
0	70.94	5.48	36.92	37.52	81.56
5	77.31	1.15	33.21	33.23	88.03
10	76.49	1.52	35.15	35.19	87.53
20	79.04	1.30	34.35	34.38	87.83
30	76.33	3.46	33.34	33.52	84.06
40	75.04	4.45	33.75	34.05	82.50
50	75.58	5.28	33.14	33.58	80.00
60	82.81	0.94	30.36	30.37	88.23
80	74.03	0.53	31.04	31.46	80.90
100	83.49	-0.22	26.19	26.20	90.50

** Mean values of triplicate readings.

The L values of the biscuits increased with increasing level of substitution. The L values were significantly higher (i.e. of lighter colour) for 100% cassava flour biscuits than the control biscuits. Biscuits with lower level of cassava flour substitution (5 - 40 % tend to have high '+a' values (slightly more red) than those with substitution higher than 40% cassava flour. Higher substitution levels resulted in slight decrease in the '+b' value (i.e. the degree of yellowness) of the biscuits.

Prediction of shelf-life of cassava flour.

Cassava flour has potential to provide a partial substitute for wheat flour in snack foods and plywood glue extenders. However, research has shown that potential users in Ghana are wary of cassava flour on the grounds of quality. Bakers and plywood manufacturers were concerned that cassava flour would have a poor shelf-life when compared to wheat flour. An assessment of currently used materials showed that commercial wheat flour had a moisture content of 11.5-12.5%. Samples of high quality cassava flour had a moisture content of 11-13%. An examination of three commercial flour stores in Accra showed that flour is normally stored under conditions of 75% RH at 27-30°C for periods of 1-2 months.

In order to develop and market the concept of high quality cassava flour to potential users it was clear that a mathematical model would be required to enable the shelf-life of cassava and wheat flours to be predicted. A predictive model for cassava and wheat flour was constructed using modified equations derived from the Heiss and Eichner model. The adsorption and desorption isotherms of the two flours were studied over a range of water activities (a_w) from 0.1 to 0.95 using saturated salt solutions of known a_w. These studies showed that increases in the equilibrium moisture content of cassava and wheat flour correlate well with increasing a_w. Under practical conditions cassava flour absorbed water more readily than wheat flour demonstrating the greater hygroscopicity of cassava flour. The data for equilibrium moisture content was fitted in the modified Heiss Eichner equation to derive information on the theoretical maximum periods for safe storage of cassava and wheat flour (see table 49). Under commercial conditions cassava flour will have a theoretical shelf-life of between 1 and 4 months dependent on the initial moisture content of the flour. The theoretical shelf-life of wheat flour is twice as long. However, this should not be a cause for concern as the predicted shelf-life of cassava flour meets the specifications of potential users.

When the monolayer moisture content was determined for the two flours using the Guggenhein-Anderson-der Boer equation, wheat flour (15.5%) was found to have a higher monolayer moisture content than cassava flour (13.5%). These values are comparable to those given in the Codex Alimentarius specifications for wheat and cassava flour, and can be taken as an indication of the maximum safe moisture content before spoilage occurs.

In practical trials cassava flour (initial moisture content = 10.84%) was successfully stored in commercial stores (RH = 75%, temp = 27-32°C) in Accra for 2 months without any reduction in quality. In sensory trials using sweet dough biscuits containing blends of cassava and wheat flour, consumers were unable to distinguish between biscuits made with freshly prepared flour and those made using flour that had been stored for 2 months. These results demonstrate the validity of the mathematical model, and indicate that the shelf-life of cassava flour is adequate for commercial purposes.

Table 49. Maximum period (months) for safe storage of cassava and wheat flour at 27°C, predicted using a modified Heiss and Eichner model.

Initial moisture content of flour	**Relative humidity of storage area**					
	65%		**70%**		**75%**	
	Cassava flour	Wheat flour	Cassava flour	Wheat flour	Cassava flour	Wheat flour
10	**8**	10	**7**	9	**6**	8
11	**6**	8	**5**	10	**4**	6
12	**3**	4	**3**	3	**2**	3
12.5	**2**	2	**1**	2	**1**	2

Paperboard adhesive formulations

Liquid Bauer-type adhesives

The results as shown in Dziedzoave, *et al.* (1999) indicate that for the liquid Bauer-type adhesive formulations from both flour and starch the Steinhall viscosities correlated perfectly with the quantity of NaOH in the adhesive formulation. However the analysis of variance did not show any significant differences in the Steinhall viscosities at different levels of NaOH except for the trials involving 0.05g/ml concentrations of NaOH where highly significant differences were observed.

The amount of borax added did not seem to have any direct relationship with the Steinhall viscosity even though the differences in Steinhall viscosities in relation to the levels of borax added was found to be highly significant ($p<0.01$). This shows that even though the quantity of borax does affect the viscosity of the adhesive the Steinhall viscosity does not seem to be an adequate objective measure of the effects of borax on the viscosity. The formulations from the cassava flour however showed higher Steinhall viscosities than those from cassava starch. It is also to be observed that using a higher concentration (0.1g/ml) of NaOH gave significantly higher Steinhall viscosities than the lower concentration of 0.05g/ml NaOH. The cassava flour however showed a higher level of significance ($p<0.01$) than the pure cassava starch.

Solid powder-type adhesive

With respect to formulations involving cassava starch, solid NaOH, and borax, the results as indicated in Table 50 show that there was a positive correlation ($p=0.86$) between the NaOH and Steinhall viscosity. However, the borax exhibited a negative correlation ($r=-0.95$) with the Steinhall viscosities; and the differences in the Steinhall viscosities with respect to the difference levels of both borax and NaOH were not significant.

Results of formulations involving cassava flour and solid borax alone are as shown in Tables 51 – 53. For the two flour types, the peak viscosity was the only parameter that consistently correlated perfectly ($r>0.09$) with the quantity of borax in the adhesive formulation. The addition of borax caused an increase in both the peak viscosity and the pasting temperature, but the increases are more pronounced for the peak viscosity than for the pasting temperature which recorded only very slight increases that are not likely to affect the performance of the adhesive very much. The two flour types were not significantly different from each other with respect to the effects of borax on their pasting characteristics. For both flours, at 20% level of borax the peak viscosity of the cassava flour based adhesives compared favourably with the imported adhesive, and was superior to the locally manufactured cassava flour-based adhesive currently on the market.

Blending the cassava flour-based adhesives with the imported adhesive produced mixes with much higher peak viscosities than expected (Table 52). Blends containing cassava flour based adhesives with higher levels of borax gave higher peak viscosities (Table 53). There was also a clear indication that blends involving cassava flour based adhesives with lower levels of borax compared more favourably with the peak viscosity of the imported adhesive. The difference between using 0.05% or 0.1% borax for the cassava flour based adhesive was not significant. The lower level would therefore be more preferable in terms of the economics of the production.

Table 50. Steinhall viscosities of paperboard adhesive formulations from cassava starch and solid NaOH and borax.

Sample Code	**Steinhall Viscosity (secs)**
N1B1(SS)	**18**
N2B1(SS)	**16**
N3B1(SS)	**18**
N4B1(SS)	**19**
N1B2(SS)	**17**
N2B2(SS)	**17**
N3B2(SS)	**18**
N4B2(SS)	**18**
N1B3(SS)	**17**
N2B3(SS)	**16**
N3B3(SS)	**17**
N4B3(SS)	**19**
N1B4(SS)	**16**
N2B4(SS)	**18**
N3B4(SS)	**16**
N4B4(SS)	**16**

Table 51. Pasting characteristics of adhesive formulations from two flour types (8% suspensions).

Sample Code	Gelatinisation Temp. (^{o}C)	Peak Viscosity (BU)	Peak Temperature (^{o}C)	Viscosity at 95^{o}C
PBF0	62.9	464	69.5	325
PBF10	65.0	695	77.0	455
PBF12	65.6	706	77.0	455
PBF14	63.8	762	71.9	430
PBF16	64.4	795	73.4	443
PBF18	68.9	800	77.6	485
PBF20	66.5	852	75.5	460
PBF22	64.4	922	74	464
L(AP)0	65.0	558	70.7	380
L(AP)10	66.6	700	75.3	460
L(AP)12	67.0	750	74.8	440
L(AP)14	68.6	770	75.5	492
L(AP)16	65.9	774	74.0	442
L(AP)18	67.4	760	74.9	435
L(AP)20	66.5	860	74.6	484
L(AP)22	68.0	854	75.5	486

Table 52. Pasting characteristics of blends of modified flours and imported adhesives (8% suspensions).

Sample Code	Gelatinisation Temp. (°C)	Peak Viscosity (BU)	Peak Temperature (°C)	Viscosity at 95°C
ISI	62.0	820	71.9	385
LMA	62.0	240	81.8	228
ISI-LMA	63.2	430	76.1	290
22PBF75	69.5	1110	80.0	488
22PBF50	66.5	1120	77.0	408
22PBF25	63.5	1190	74.0	230
14PBF50	65.0	1160	74.0	270
10PBF75	63.5	865	75.5	435

Table 53. Pasting characteristics of blends of modified flours and imported adhesives (6% suspensions).

Sample Code	Gelatinisation Temp. (°C)	Peak Viscosity (BU)	Peak Temperature (°C)	Viscosity at 95°C
ISI	70.7	210	81.5	164
01PBF25	74.0	250	84.5	210
01PBF50	72.8	266	82.4	210
01PBF75	73.1	270	83.0	220
01PBF100	69.5	205	92.0	200
05PBF25	72.2	228	84.2	218
O5PBF50	69.5	270	80.0	200
05PBF75	72.5	225	83.0	220
05PBF100	71.0	200	82.7	200

Cassava flour as an extender for plywood glues

Industrial trials at Mill "A"
The results for the Mill"A' trial runs are shown in Tables 54 , 55 and 58. On average the Steinhall viscosities of the glue mixes correlated perfectly ($r>0.9$) with the peak viscosity, the temperature at the peak viscosity and the viscosity at 95°C of the flour samples used in the formulation of the glue mixes. Highly significant differences ($p<0.01$) were also observed in the Steinhall viscosities of the glue mixes from the different flour types. The unpeeled sun-dried cassava flour (AU) gave the highest Steinhall viscosity whilst the peeled mechanically dried cassava flour (FR) gave the lowest values. Highly significant differences were also observed in the effects of the different levels of flour substitution on the Steinhall viscosities of the glue mixes. The higher the level of flour substitution the lower the Steinhall viscosity.

An objective assessment of the glue performance as measured by the glue line value of the test plywood pieces is shown in Table 58. The bond quality of the individual glue-lines and the mean numerical values evaluated in accordance with BS 1455:1972 by the knife test method after 24-hour cold water soak pre-treatment are presented in the same table. The BS 1455: 1963 standard specifies that no glue line shall have a bond quality of less than two and the average value for all the specimens shall not be less than five (Fruhwald, 1977). With the exception of flour samples FR(A) and AU(A) at 80% substitution levels, the quality of adhesion in the plywood samples from Mill 'A' met glue-bond quality requirements after the 24-hour cold soak as specified in the standard. The bond quality of the FR(A)-bonded plywood samples (excluding FR(A)60 and FR(A)80, all AP(A)-bonded samples and the AU(A)100 sample compared favourably with the plywood samples bonded with the control adhesive (100% Wheat flour-urea adhesive); and far exceeded the minimum requirements laid down in the standard. The low correlation between the Steinhall viscosities and the glue line values shows that the Steinhall viscosity of the glue mix is not an adequate parameter for predicting the performance of the glue mix. From the analysis of variance, ATU was significantly different ($p<0.01$) from FRI and ATP with respect to its performance in the glue mixes, thereby exposing the adverse effects of peel fragments on the performance of the flour. The five levels of substitution also showed significant differences ($p<0.01$) in their effects on the glue performance. Higher levels of substitution tended to reduce the glue performance. This is apparently due to the relative reduction in the gluten of the wheat flour, which according to Adams *et al* (1969) contributes significantly to the adhesive properties of the glue formulation. The interaction between flour quality and level of substitution was also highly significant ($p<0.01$), thus pointing to the fact that there is a certain combination of flour quality and level of substitution that gives an optimum performance of the glue.

Relating the flour quality (Table 54) to the glue bond quality it is observed that the glue line values correlate highly ($r^2>0.64$) with different physico-chemical characteristics of the flour at different substitution levels. At 20% and 40% levels of substitution there is a perfect negative correlation between the glue line value and the peak viscosity ($r^2>0.76$), the temperature at the peak viscosity ($r^2>0.96$) and the viscosity at 95°C ($r^2>0.85$) of the flours. Again a perfectly negative correlation is observed between glue line value and gelatinisation temperature at 60% ($r^2>0.81$) and 80% ($r^2>0.98$) levels of substitution; whilst at 100% substitution level peak viscosity correlates ($r^2=0.72$) with the glue line value.

It is clear from these correlations that:

- A flour sample with a low peak viscosity and a correspondingly low temperature at the peak viscosity would perform best at lower substitution levels (20% or 40%) whereas a flour with a high peak viscosity or high peak temperature would perform best at higher substitution levels (90% - 100%).
- Similarly flour samples with low viscosities at 95^{o}C would perform best at low substitution levels (20% or 40%) whereas flours with high peak viscosities would perform best at higher substitution levels (90% - 100%).
- A flour with low gelatinisation temperature would perform best at about 60-80% levels of substitution. The converse however does not seem to hold; thereby bringing into question the suitability of the gelatinisation temperature as an indicator of the performance of the flour in the glue mix.

From the above it is now important therefore to determine the cut-off points for the peak viscosity, the temperature at the peak viscosity and the viscosity at 95^{o}C at which the decision is made as to whether to carry out a low or high level substitution .

Industrial trials at Mill "B"

The results for trial runs in Mill 'B' are shown in Tables 54, 56, 57 and 58. Detailed statistical analysis could not be carried out for these results because of the smaller number of samples and lower level of variations in the samples used for the trials. A comparison of Tables 56 and 57 however gives a subjective assessment of the effects of varying percentages of flour on the glue bond quality as measured by the percentage plywood rejects. Comparing AP(B)40 with AP(B)50 suggests that a higher level of cassava flour substitution gives a better glue bond. However the comparison between FR(B)30 and FR(B)40 suggests the converse. These observations expose the flaws in the subjective assessment method. The positive correlation (r=0.87) between the Steinhall viscosities and the percentage plywood rejects confirm that the Steinhall viscosity is an objective measure of the performance of the glue mix.

An inspection of the glue line values in Table 58 shows that substitution levels above 50% produced bonds, which give way easily resulting in the delamination of the plies. Out of the five test glue formulations only FR(B)40 produced glue bonds consistent with BS 1455:1963 specifications. Even though FR(B)30 had a lower flour substitution than FR(B)40, it failed to meet the specifications. Similarly AP(B)40, which had the same flour substitution level as FR(B)40 also failed to meet the specifications. Considering that the flour sample AP(B)had a higher peak viscosity and viscosity at 95^{o}C than sample FR(B); if the conclusions drawn for the trials in Mill 'A' are anything to go by then the explanation for the poor performance of AP(B) may be it's high peak viscosity or viscosity at 95^{o}C. This is however purely speculative since a larger sample variation and more extensive trials are needed to draw valid conclusions from the trials at Mill 'B'.

Generally the boards produced at Mill 'B' with the cassava flour-urea formulations, were inferior to boards produced at Mill 'A' and bonded with similar cassava flour-urea formulations. Differences in mill operating conditions and the species used in the study might account for the variations in bond quality of the plywoods produced at the two mills. Properties of commercial composite board materials are known to vary substantially between mills and even within mills due to raw material source, adhesive manufacturing techniques, quality control programmes etc. Cassens *et al*, 1994 reported on variations in selected properties of industrial grade particleboard from seven manufacturers. Palka (1977) and Smith (1974) noted that species of plywood cross bands clearly influence the magnitude of mechanical properties of plywood and so does the mill sampled. Yartey (unpublished) investigating properties of 7-ply commercial plywood made in Ghana at two plants observed large variations in some selected properties between the two mills. Modulus of rupture (MOR) and the fastener holding properties were the properties that exhibited much variation.

Table 54. Characteristics of flour samples used in two plywood mills.

Mill	Flour Sample	Moisture (%)	Gelatinisation Temp. (^oC)	Peak Viscosity (BU)	Peak Temp. (^oC)	Viscosity at 95 ^oC (BU)
Mill A	FR (A)	9.18	68.0	425	75.5	240
	AU (A)	11.45	67.7	597	87.2	525
	AP (A)	11.46	65.6	509	77.6	350
Mill B	FR (B)	9.32	75.8	490	82.4	247
	AU (B)	8.72	68.0	590	89.6	518
	AP (B)	12.54	65.0	558	70.7	380

Table 55. Steinhall viscosities of laboratory prepared glue formulations.

Formulations Based On Mill 'A' Formula.	
Glue Sample	Steinhall Viscosity
FR (A)0	49
FR (A)20	38
FR (A)40	31
FR (A)60	24
FR (A)80	16
FR (A)100	13
AU (A)0	49
AU (A)20	48
AU (A)40	40
AU (A)60	28
AU (A)80	25
AU (A)100	20
AP (A)0	49
AP (A)20	48
AP (A)40	37
AP (A)60	25
AP (A)80	21
AP (A)100	16

Table 56. Steinhall viscosities of glue formulations prepared and used at mill "B"

Glue Sample	Steinhall Viscosity
AU (B) 0*	35
AU (B) 60	32
FR (B) 30	36
FR (B) 40	37
AP (B) 40	35
AP (B) 50	35

* This represents the control and it refers to the formulation normally used in the mill, i.e. 0% cassava flour.

Table 57. Glue performance at mill "B" as indicated by the number of plywood rejects.

Glue Sample	No. of Plywood Produced	No. of Rejects	% of Rejects
AU (B) 0*	21	1	4.8
AU (B) 60	10	6	60.0
FR (B) 30	18	1	5.5
FR (B) 40	13	1	7.7
AP (B) 40	18	3	16.7
AP (B) 50	21	1	4.8

* This represents the control and it refers to the formulation normally used in the mill, i.e. 0% cassava flour.

Table 58. Bond quality of plywood bonded with cassava-flour based adhesives: 24 hour cold water soak (knife test method).

Adhesive Type	Wood Species	No. of Glue Lines	Test Results*																		Mean Value
			Glue Line Values ***																		
			GL 1	GL 2	GL 3	GL 4	GL 5	GL 6	GL 7	GL 8	GL 9	GL 10	GL 11	GL 12	GL 13	GL 14	GL 25	GL 16	GL 17	GL 18	
Control 1	*Ceiba*	18	10	8	8	9	10	9	10	10	6	9	10	9	8	10	10	10	8	7	9
FR (A)20	*petandra*	18	10	10	9	10	8	9	9	7	9	9	9	10	9	9	9	10	9	10	9
FR (A)40		18	10	9	10	9	9	7	9	10	9	10	10	8	10	9	6	9	9	10	9
FR (A)60		18	7	5	6	6	4	7	7	9	10	8	4	7	6	8	8	6	5	6	6
FR (A)80		12	+	+	+	+	+	+	5	7	5	5	4	6	6	5	0	0	0	0	4
FR (A)100		18	10	10	9	10	8	10	10	8	10	10	9	9	5	7	6	6	2	7	8
AU (A)20		0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
AU (A)40		18	9	9	9	7	8	4	7	6	9	9	9	6	4	4	7	2	9	4	6
AU (A)60		18	9	9	9	6	5	4	2	5	7	6	8	4	2	2	4	5	6	7	5
AU (A)80		17	5	4	4	9	9	0	4	0	2	4	4	+	2	4	2	2	9	9	4
AU (A)100		18	9	9	10	10	9	9	4	10	10	8	9	9	8	9	9	10	10	9	9
AP (A)20		18	9	10	10	10	9	9	9	8	10	9	9	8	8	9	10	10	9	8	9
AP (A)40		18	9	8	8	8	6	7	8	8	9	9	6	9	8	9	9	7	9	8	9
AP (A)60		6	9	9	5	8	6	9	+	+	+	+	+	+	+	+	+	+	+	+	8
AP (A)80		18	7	10	10	9	8	9	9	9	8	9	10	7	8	10	9	10	10	9	9
AP (A)100		18	6	9	9	9	7	9	9	10	8	10	10	9	10	9	9	10	10	10	9
Control 2	*Pterygota macrocarp*	18	6	6	4	8	8	6	6	7	5	8	7	6	6	6	8	6	8	4	6
FR (B)30	*a*	18	5	0	4	0	4	0	2	0	0	0	2	0	0	0	0	0	3	0	1
FR (B)40	*Pcynanthus*	16	9	4	9	7	5	7	0	0	7	5	6	7	8	9	9	4	2	4	5
AU(B)60	*angolese*	0	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@
AP (B)40	+	18	5	2	2	2	0	2	0	0	0	0	4	2	6	5	5	0	7	0	2
AP (B)50	Mahogany	0	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@	@

* Figure attached indicates cassava flour percentage substituted for wheat flour.
** Figures in bold failed to meet the specifications.
*** BS 1455:1963 Specifications: Individual Glue Line value (GL) not less than 2.
Mean Value of specimen should not be less than 5.
\+ Not tested after soaking for lack of time.
@ Delaminated.
Control: 100% Commercial wheat flour.

Economic potential of cassava flour as a substitute for wheat flour in snack foods produced in Ghana

CURRENT SITUATION

Increasing urbanisation has lead to a rapid increase in the market for convenience foods such as bread, biscuits, pies and cakes in Ghana. All of these products contain a significant amount of imported wheat in the form of flour. Since 1980 there has been an upward trend in the amount of imports of wheat equivalents. In 1996 between 250,000 and 300,000 tonnes of wheat were imported by Ghana. The vast majority of this is milled locally by one of Ghana's four main wheat millers. Formerly the wheat market in Ghana was closely controlled by the Government but following liberalisation, the millers have been able to source wheat independently on the world market.

The continued depreciation of the Ghanaian Cedi against the US Dollar coupled with increases in US Dollar prices for wheat on the world market has lead to sharp increases in the price of wheat flour in Ghana. In March 1995 the wholesale price for 50kg of wheat flour was 21,000 Cedis; by mid March 1996 this had increased to 38,725 Cedis per bag. A further increase to 42,000 Cedis for white bread flour was reported in April 1996. In October 1997 the wholesale price for 50kg of wheat flour was 58,000 Cedis. These increases reflect unavoidable economic problems as it is recognised that the wheat flour market is not truly competitive and is likely to be influenced by the political wish to keep prices of food staples low. Increasing prices and currency devaluation have encouraged food manufacturers in both the formal and informal sectors to look for local alternatives to wheat flour.

Given the ready availability of cassava in Ghana, and the existence of suitable processing technologies cassava flour would appear to be an obvious choice as a partial substitute for wheat flour. However, manufactures of food items in Ghana expressed concern over the quality of cassava flour and consumer acceptability. From past experience manufacturers associated the name "cassava flour" with poor quality fermented products having a low pH, unpleasant taste, odour and colour. Some manufacturers were concerned that cassava flour would lead to toxicity problems due to the presence of cyanogenic glucosides. Market acceptability studies in Greater Accra showed that consumers would accept substitution levels of 35% cassava flour in sweet dough biscuits and 60% cassava flour in hard dough biscuits. However, bakers would never go above 50% in hard dough biscuits because of problems of brittleness associated with products containing high levels of cassava flour.

Growth Trends - Physical Factors

Determinants

This opportunity has been mainly influenced by the economic factors, although it would be true to say that improved road infrastructure has increased the potential for development of a processing industry to supply locally produced cassava flour to potential users in urban areas.

Bottlenecks

The likely physical bottlenecks include access to consistent supplies of high quality cassava, transport problems and problems with lack of power for processing equipment.

Growth Trends - Economic Factors

Determinants
The major economic determinant influencing this opportunity is the rising cost of wheat flour set against the potential to produce cassava flour at a lower price. In production trials cassava flour was produced for between US$0.13/kg and US$0.22/kg depending on whether sun or oven drying was used. This compared favourably with the wheat flour price if US$1.30/kg. Small bakers producing sweet dough biscuits use 0.5kg of wheat flour per kilo of biscuits produced, thus giving a wheat flour cost of US$0.65. When cassava flour was used to substitute for 35% of the wheat flour, a cost saving of 32% was achieved.

Investment requirement
The level of investment required will vary between US$2,000 and US$20,000 depending on what type of drying method is employed and whether chips are produced in the field or at a centralised processing site.

Bottlenecks
This opportunity is likely to be affected by the same economic factors as other opportunities already discussed. These include macroeconomic and infrastructural problems affecting end users, raw material price and access to credit to support farmers and primary processors wishing to exploit this opportunity.

Role of stakeholders
To be successful this opportunity requires active support from the potential users of cassava flour who need to demonstrate that a market exists for the product, and to set standards for production. At the present time many prospective processors of cassava flour are reticent about taking up production because it is believed with some justification that the food sector will be unwilling to use cassava flour in its products.

Economic potential of high quality unfermented cassava flour for industrial purposes in Ghana

Current situation
Within Ghana the paperboard and plywood industries are significant users of starch, flour and starch based products. The paperboard industry used 420 tonnes of starch based adhesives for manufacture of corrugated board in 1996, and the plywood industry used 1,134 tonnes of starch and 1,200 tonnes of food grade wheat flour as extenders for synthetic wood glues in the same period. The paperboard and plywood industries account for 37% (excluding wheat flour) of the market for starch and starch based products in Ghana.

There are currently six manufacturers of starch based adhesives for paperboard in Ghana, half of which prepare some or all of their products using locally produced cassava starch or flour (Day *et al* 1996). The paperboard sector comprises four companies who use starch-based adhesives (SBA) in the manufacture of corrugated board. Imported adhesives based on maize starch account for 55% of the market and cost between US$900 and US$1,260/tonne depending on country of origin. The remaining 45% is taken by a local manufacture of cassava based adhesives who sells at the equivalent of US$430/tonne. The imported materials are prepared from pure maize starch, and the local product is prepared from a rather poor quality cassava flour derived from unpeeled cassava roots, sun dried, coarsely milled, screened, and blended with other adhesive components. Both local and imported products are supplied as ready mixed dry powders in 50kg bags.

Three out of the four paperboard factories use local as well as imported adhesives. The local product is favoured because of its low price and ready availability. However, all users commented unfavourably on the quality of the local product. Locally produced SBA's form weaker bonds, have a short shelf life contain too many contaminants and are not finely milled. Users overcome bonding problems by blending local and imported products together.

The plywood industry in Ghana comprises at least eight large-scale factories, who use imported synthetic resin based glues in the manufacture of plywood sheets. These glues cost US$2220/tonne. To reduce costs synthetic glues are mixed with an extender which can either be imported maize starch (US$650/tonne) or food grade wheat flour (US$500/tonne). Typically 50kg of synthetic glue will make 55-60 1/8" plywood sheets, with an extender this increases to 80-85 sheets of 1/8" plywood sheet. For each 50 kg batch either 10kg of maize starch or 25kg of wheat flour is required. Several factories have tried locally produced cassava flour and starch as extenders but found these to be of poor quality and discontinued use. Locally produced flour was not milled properly, insufficiently dried and contained many insoluble impurities that caused blistering in the plywood sheets. One manufacturer that local flour caused his percentage of rejects to rise from 1-7%.

Preparation of high quality unfermented cassava flour for industrial use.
The Natural Resources Institute (United Kingdom) and Food Research Institute (Ghana) have followed two approaches for production of cassava chips (Fig 2) that can ultimately be milled into flour for industrial use at a centralised processing facility. The first approach focuses on field based production of cassava chips by farmers, the second makes use of a centralised processing facility with higher levels of mechanisation and mechanical drying. The NRI/FRI process uses modified IITA mini chippers as these provide chips that dry in the shortest possible time. The farm based option has the advantage of low cost (US$65/tonne)* and produces chips of sufficient quality if some measure of quality control is in place. The centralised option for chip production is more suited for large scale production of chips of consistent quality albeit at much higher cost (US$217). In many cases field based production of chips would be appropriate followed by milling and formulation (for SBA's) in a centralised facility such as a flour mill or glue factory.

* Chips are purchased at this price from farmers co-operatives who normally produce chips for livestock feed purposes, the nominal price for chips is US$40/tonne but higher prices ensure quality and reliability.

Figure 2. Options for production of unfermented cassava flour for industrial use.

FIELD BASED	**CENTRALLY BASED**

CASSAVA ROOTS
(WASHED AND PEELED)

↙ ↘

FIELD BASED	CENTRALLY BASED
CHIP MANUALLY	**MECHANISED CHIPPING**
↓	↓
SUN DRY ON RAISED TRAY FOR ONE DAY, AND PLASTIC SHEET FOR ONE DAY	**ARTIFICIAL DRYING FOR 8 HOURS AT 55°C OR SUN DRYING**
↘	↙

MILL FINELY
(USING HAMMER MILL)

↓

SCREEN THROUGH STAINLESS STEEL MESH
(250µM)

↓

PACKAGE

Preparation of starch based adhesives (SBA) for use in the manufacture of paperboard.
Starch based adhesives consist mainly of starch or flour blended with certain chemicals. The essential ingredients for an SBA are starch/flour, gelatinisation modifier (sodium hydroxide), viscosity enhancer/stabiliser (borax) and preservative (sodium formaldehyde). A basic formulation for 1 tonne of SBA in dry form could be as follows:

(i).	Starch/flour (96.4%)	=	964kg
(ii).	Sodium hydroxide (1%)	=	10kg
(iii).	Borax (2.5%)	=	25kg
(iv).	Sodium formaldehyde (0.1%)	=	1kg

Using the prices given (Table 59) this product would cost between US$204 and US$350 per tonne depending on the cost of cassava flour. The amount of borax and sodium hydroxide must be determined experimentally so as to provide an SBA with the correct viscosity and pasting temperature to meet the users specification. As the range for these ingredients is quite wide costs could vary considerably in practice.

In addition to the basic ingredients fillers such as clay or coconut shell are often added, and in some cases plasticisers, lubricants, bleaching agents and antifoams may be included. All of these will greatly increase the cost of the product and should only be used if essential to meet the user requirements.

The chemical costs quoted in Table 59 only apply to relatively small quantities purchased for trial purposes by NRI/FRI. In commercial practice prices would be much lower because chemicals are normally sold in 16-20 tonne containers at negotiable rates. Price is normally determined by quantity, customer reliability, prevailing exchange rate and shipping cost.

Table 59. Materials used in the preparation of starch based adhesives (SBA) for paperboard.

Ingredient	Importance	Cost US$ per kg	Percentage/quantity per tonne of SBA	Cost per tonne of SBA	Comment
Cassava flour	Essential	$0.065-0.217	61.1-96.4% / 611-964kg	$39.72/62.66 - $132.59/209.19	Price is dependent on production cost of flour.
Borax	"	$3.33	0.05-18% / 2.5-180kg	$8.33 - 599.40	Creates high viscosity stable paste, normally use around 2.5%.
Sodium hydroxide	Use when necessary	$2.66	0.1 -5% / 1-50kg	$2.66 - 133.00	Partially degrades starch to reduce pasting temperature.
Sodium formaldehyde	"	$31.93	0.1% / 1kg	$31.93	Improves shelf life of wet paste.
China clay or other filler	"	$8.32	0-10% / 0-100kg	$0.00 - 832.00	Reduces penetration of paste into paper. Costs can be reduced by using locally available materials.
Aqueous antifoam	"	$33.26	0.1% / 1kg maximum	$33.26 maximum	Can often reduce foam by reducing mixer speed.
Sodium bisulphite	"	$7.32	0.5% / 5kg maximum	$36.60 maximum	Used to bleach adhesive if colour is a problem.
Calcium stearate	"	$8.98	0.2% / 2kg maximum	$17.96 maximum	Used to improve flow of wet adhesive.
Magnesium sulphate	"	$5.32	5.0% / 50kg max	$266.0 maximum	Used to make paste more flexible in use.

Growth Trends - Physical Factors

Determinants

Physical factors
This market opportunity has been mainly influenced by changes in national policy and economic factors but it would be true to say that improvements in the network of major roads linking inland areas of Ghana with the coastal cities and major ports has made cassava more attractive as a raw material for locally produced starch-based adhesives and glue extenders.

Product flow
Current production of cassava-based adhesives centres around Central and Ashanti Regions which have large supplies of cassava, good road infrastructure and easy access to users of these products in Accra, Kumasi and Tema. Cassava chips are sourced directly from the farm and milled and formulated at the adhesive factory. Adhesive suppliers produce and supply adhesives to paperboard factories on a contract basis.

Bottlenecks
The likely physical bottlenecks affecting this opportunity are access to cassava of sufficient quality for use in SBA production, infrastructural problems and access to technical information required for development of locally produced SBA's that can compete with imported products by providing equivalent quality at a lower price. At the present time Ghanaian manufacturers of SBA's compete well on a cost basis but their products are of inferior quality which reduces their competitiveness.

Growth Trends - Economic Factors

Determinants
Increasing prices for imported materials and continuing fall in value of the Ghanaian Cedi against the US Dollar have provided an impetus for Ghana's paperboard and plywood industries to look for cheaper locally produced alternatives to imported adhesives and extenders. Commercial adhesive manufacturers have shown that a reasonable product can be prepared from cassava and sold at 1/3rd of the price of the imported material.

The level of investment required to exploit this opportunity will depend on the approach adopted for production of the basic cassava chips. If a field based approach is taken each farmer will require a capital investment of approximately US$120 to cover the cost of a manual chipper, plastic sheet and 15 bamboo drying trays. Farmers would normally operate in groups of six so the capital investment per group would be US$720. If a factory based approach is adopted US$700 will be required for each mechanical chipper. Artificial drying will increase costs by around US$10,000 depending on the design and origin of the drying unit. To prepare cassava flour for industrial use approximately US$3,000 is required to purchase a suitable hammer mill and screening equipment with stainless steel screens covering the range from 1mm to 250µm. To prepare premixed glue powders an industrial mixer is required at a cost of US$8,000, alternatively costs could be reduced by using a cement mixer fitted with plastic shields to reduce dust. However, this is not a very satisfactory alternative and will increase hazards from chemical dusts in the factory environment.

Bottlenecks

The most likely economic bottlenecks affecting this opportunity are access to capital for processing equipment, and potential fluctuations in raw material prices and availability. Although cassava flour will be locally sourced, most of the chemicals required for SBA production are likely to be imported and thus subject to supply problems, changes in market price and currency devaluation.

Role of stakeholders

The production of cassava flour for industrial uses offers another attractive opportunity for cassava farmers who are willing to process cassava into high quality cassava chips. However, to realise this opportunity farmers will require financial and technical support to prepare chips and access to the market. This is likely to be provided by the manufacturer of the SBA's and glue extenders who needs to be willing to provide the necessary financial and technical support as well as providing some form of infrastructure to maintain quality and provide a mechanism for transfer of chips from the field to the factory. The experiences of T&CG (Ghana) in the area of chips for livestock feed could prove invaluable in this case. It is evident from experience in Ghana that quality is an important issue for users of adhesives and glue extenders. It is therefore vitally important that the adhesive manufacturer meets the user specifications at a competitive price. If these specifications are met users will favour the local product because of the large cost savings made (typically 65-75%).

Potential to grow market

Locally produced SBA's based on cassava flour accounted for 45% of the market for paperboard adhesives in 1996. However, by 1999, this had reduced almost to zero. If manufacturers took more care over milling and screening of their products, and improved their understanding of the formulation of these products they could easily take over the entire market. The SBA's are essentially quite simple products and the necessary improvements are straightforward and could be achieved at low cost. However, many operators lack the technical knowledge to improve the quality of their products and have no access to external support.

In a conventional plywood process, synthetic adhesive contributes US$1.85-US$2.0 per sheet. Conventional glue extenders (maize starch & wheat flour) reduce this cost to US$1.38-US$1.54 (inclusive of cost of extender) depending on the cost and amount of extender used. If high quality cassava flour at a cost of US$65/tonne is used in place of wheat flour at a level of 25kg of flour per 50kg of adhesive the cost of adhesive and extender would fall to US$1.32-US$1.40 per sheet. However, experience in the Philippines (Fidel *et al* 1992) showed that an extender consisting of cassava starch mixed with sodium hydroxide, calcium hypochlorite and filler allowed the percentage of resin solids to be reduced from 45% down to 22% without loss of bond strength. This formulation was able to reduce adhesive costs by more than 50%. Plywood glue extenders offer an excellent opportunity for cassava flour with a relatively large market of more than 2,300 tonnes per annum in Ghana. However, plywood manufacturers have been upset by the poor quality of locally produced products produced in the past. To exploit this opportunity manufacturers of cassava flour need to provide high quality on a consistent basis to build up the confidence of potential users of the product.

Output 4: **Information disseminated to target organisations.**

OVIs: **Key information disseminated by 1999.**

Summary

In planning the project, the original intention of the research team was to complete research activities at least 6 months before the end of the project so as to allow time for dissemination of research findings to key stakeholders via a series of workshops. However, the research activities were delayed by almost 10 months as a result of the national electricity crisis in 1997-1998. In view of this unavoidable setback the Programme Manager of the CPHP agreed to re-allocate funds from output 4 to output 3 so as to provide sufficient funding for completion of the research activities. Although dissemination activities could not be included in the present project, they have been included as a major component of a follow-on proposal to CPHP entitled "Development of new market opportunities, to increase the contribution that cassava makes to sustainable rural livelihoods".

Contribution of Outputs and Follow Up

The importance of the contribution that cassava makes to the livelihoods of the rural poor, and the desire of stakeholders for new market opportunities was confirmed in the early stages of the project. A relatively small domestic market for cassava starch, and much larger potential market for high quality cassava flour were identified during the first phase of the research. In the latter stages of the project new opportunities for cassava were identified in the area of sugar syrups and industrial alcohol.

Industrial production of cassava starch is unlikely to succeed in Ghana in the short to medium-term. This is due in part to the limited size of the domestic market for starch, but is also influenced by a number of other factors. The experience of T&CG has shown that the major problems will include cassava supply, quality of available roots, availability of water and power, transport (cost of transport, and low level of road infrastructure in rural areas). In addition a potential starch manufacturer would require a high capital investment to obtain the necessary equipment for drying of starch. It is very unlikely that an industrial starch producer in Ghana will be able to overcome these factors and access the world market by competing effectively against rival manufacturers of starch in other countries.

Potential markets for high quality cassava flour were identified in the food (biscuits and snack foods), plywood and paperboard sectors. These options have lower quality requirements that could be met by processors in rural areas. Cassava flour is easier to produce with a much lower capital investment than cassava starch, and is better suited for production by rural processors who can use the sun to dry cassava chips for conversion into flour. In many cases chipping, drying and milling equipment is already available in the village thus further reducing the initial costs.

Research activities demonstrated that rural processors can produce flour of sufficient quality to meet the needs of potential users in Ghana. It is clear that cassava flour has the technical and economic potential to provide a partial substitute for imported materials in biscuits, plywood and paperboard.

However, potential problems were identified that could adversely affect uptake of the research findings. Potential users in the target sectors were extremely wary of locally produced cassava-based products on the basis of past experience. Plywood manufacturers had found suppliers of cassava flour to be unreliable. Problems were encountered involving adulteration, short measures, poor time keeping on deliveries and generally poor product quality (heavy contamination with fibre, bark/peel fragments and poor pasting characteristics). In 1996 locally prepared cassava-based paperboard adhesives accounted for 45% of the market for these materials. In 1999 this market share had reduced almost to zero because of problems with product quality. These problems could easily be overcome with a little care and attention on the part of the supplier. The key weakness appears to be a lack of business sense and understanding by those seeking to exploit new market opportunities for cassava.

In Brong Ahafo Region many farmers expressed concern over the shortcomings of companies involved in exploitation of the opportunity to export cassava chips to Europe. These companies failed to appreciate the volatile nature of the market and operated on the assumption that prices would remain consistently high. Farmers planted cassava in 1996 with the intention of benefiting from the market opportunity in 1998. The drastic fall in chip prices on the European market in 1997 left farmers with no market for their cassava and no opportunity to recover the cost of their investment. The market recovered slightly in 1999 but farmers were still waiting for five months to get paid for chips supplied to the exporter. Under these conditions farmers are understandably cautious about new market opportunities for cassava. Farmers need opportunities that are sustainable, and provide prompt returns for their investment.

At the conclusion of the present project it was clear that more work was required to extend activities in the area of plywood and paperboard and to develop opportunities for cassava in the area of sugar syrups and industrial alcohol. A new project was developed by a team of collaborators from NRI, FRI, FORIG, University of Ghana, Ministry of Food and Agriculture and National Board for Small-Scale Industries, for submission to the CPHP. Dissemination activities were integrated into the new project so as to start dissemination of findings from the previous project (R6504) and new findings during the life of the new project.

In addition to the research reported here, the project has also been used as a resource and focus for other projects, namely:

- Expanded markets for cassava in Uganda (CPHP)
- Global cassava market study (IFAD/CFC)
- 2nd Phase of the Regional Africa Project On NGSS (DFID)
- Ghana case study for the Global Cassava Development Strategy (MoFA)

Publications reports and other dissemination outputs

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