Effects of selected process parameters in extrusion of cocoyam (Xanthosoma sagittifolium) flour on functional and physical properties of the extrudates

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Abstract

Raw cocoyam (*Xanthosoma sagittifolium) flour was cooked and extruded in a single screw extruder (*DD85G, 201132, IBG Monforts Gmbhi & Co, D-4050 Monchengladbach, Germany). A second order central composite response surface design was adopted in designing the experiment which generated 20 runs on selected process parameters including feed moisture (22,24,26%), screw speed (60,70,80rpm) and barrel temperature (200,220,240^{0}C) on the functional and physical properties (density, expansion, water absorption index (WAI), water solubility index (WSI) and textural characteristics) of the extrudates. Increase in feed moisture content results in higher extrudate density, lower expansion, higher WAI, lower WSI and higher hardness. Increase in barrel temperature reduced extrudate density, WAI and hardness but increased the expansion and WSI. The extrusion of cocoyam flour led to production of snacks.

Keywords: Cocoyam, single screw extrusion, functional and physical properties

Introduction

Cocoyams (*Xanthosoma sagittifolium*) are edible crops that are widely cultivated in both the tropical and subtropical regions of the world. Cocoyam, a member of the Araceae family is an ancient crop and is one of the minor staple root crops commonly grown in the forest zone of Nigeria and Ghana (Ekanem and Osuji, 2006). Like other tropical crops, cocoyam has very high potential for supplying large quantity of utilizable calories per unit area of land (Lyonge, 1980). Cocoyam contribute significantly portion of the carbohydrate content of the diet in many regions in developing countries and provide edible starchy storage corms or cormels, although, they are less important than other tropical root crops such as yam, cassava and sweet potato, they are still a major staple in some parts of the tropics and subtropics (Ojinnaka *et. al.,* 2009). It was reported that more than three quarter of the world cocoyam production comes from Africa, 65% of about 6 million tonnes of the world production with Nigeria accounting for 32% (FAO, 1989) and recently produced an estimated 2.6 million tonnes of cocoyam as reported by CBN (2006). Cocoyams have nutritional advantages over root crops and other tubers crops (Lyonga and Nzietchueng, 1986). It has more protein than root and other tubers and its starch is highly digestible because of the small size of the starch granules (Ojinnaka *et. al.,* 2009). The main nutrient supplied by cocoyam is dietary energy provided by the carbohydrates. Cocoyam is a good source of Na, K, P, Mg, and Ca and is fairly rich in carotene, ascorbic acid, thiamine, riboflavin and nicotinic acid. The leaves contain beta-carotene, iron and folic acid (Eka, 1998; FAO, 1990). The problem of inherent nutritional hazard such as presence of acridity factors, oxalate and perishability of the tubers call for elaborate processing prior to consumption, thereby improving handling, convenience, palatability, storability and nutritional safety (Iwuoha, *et.al.,* 1995). Most processing methods are known to reduce the level of oxalate in cocoyam. Cocoyam can be processed into several foods, feed products and industrial inputs, similar to that of potatoes in the Western World. The processes include boiling, roasting, frying in oil, pasting, milling and conversion into 'fufu', soup thickeners, flour for baking, chips, beverage powder, porridge and specialty food for gastro-intestinal disorders (Onwueme, 1978; Hussain *et al.,* 1984; Obiechina and Ajala, 1987).

3 Extrusion cooking is one of the most versatile and well established food processes and is used world wide for the production of expanded snack foods, pastes, modified starch, flat breads, meat and cheese analogues, ready to eat cereal foods and porridge (Li and Lee, 2000; Thymi *et. al.,* 2005). The main purpose of extrusion is to increase the variety of foods in the diet, by producing a range of products with different shapes, textures, colours and flavours from basic ingredients (Fellows, 1998). During extrusion cooking, the raw materials undergo many chemical and structural transformations such as starch gelatinization, protein denaturation, degradation reactions of vitamins, pigments, modification of lipid, inactivation of enzymes, microbes and many anti-

nutritional factors (Ding *et al.,* 2005; Yagci and Gogus, 2008). It has been reported that small variations in processing conditions affect process variables as well as product quality, which can vary considerably depending on the extruder type, screw configuration, feed moisture, temperature profile in the barrel session, screw speed and feed rate (Ding *et al.,* 2005). Starch has many contributions to the final product including expansion, flavour, binding, viscosity, development, caloric value, resilience and functionality (e.g hardness, texture etc) (Riaz, 2000). The degree of expansion determines the extrudate structure and consequently its texture.

The recent problem of geometric population growth in many West African countries, especially Nigeria calls for drastic solutions to food problems. The food habits of Nigerians are rapidly changing from traditional foods to lighter food such as snacks (Adebowale *et al.,* 2007). The rate of snack foods consumption in Nigeria is on the increase among the school children and adults due to the adopted popular eating habits outside the home especially among the working class. The new extruded snacks from cocoyam flour will not only exploit the use of cocoyam but also produce a new variety of snack that can be accepted across Nigeria and neighboring countries. It is therefore important to find an appropriate processing condition to manufacture extruded snacks that are preferred by consumers. Thus, there is need to study the effect of extrusion parameters (feed moisture, barrel temperature and screw speed) on cocoyam based snacks.

Materials and Methods

Preparation of flours

Cocoyam tubers (*Xanthosoma sagitifolium)* were purchased in Abeokuta, Ogun State. Cocoyam tubers were selected, cleaned, hand peeled, washed and sliced into chips of 3 mm thickness. The chips were sulphited in 0.1% potassium metabisulphite for 3hrs. The sulphited chips were steeped for 12 hrs, dried (5.38% moisture content) in a cabinet dryer (600C for 24 hrs), milled in attrition mill and sieved (600ìm) into flour. The cocoyam flour was stored in high density polyethylene bag until processed. Before being processed, cocoyam flour (500g) was rehydrated according to each moisture content (Table 1) by calculated amounts of water being sprayed into each sample. After that, the samples were sealed in high density polyethylene bags and kept at ambient temperature for 12h to reach homogeneous moisture distribution.

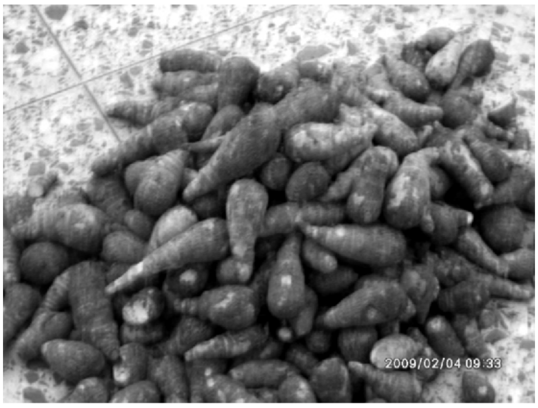

Fig. 1: Xanthosoma sagitifolium

Table 1:Coded Levels for the Response Surface Design

Variables	**Levels**				
	$-\alpha$	**-1**	**0**	**+1**	$+\alpha$
Feed Moisture (%), X_1	20.32	22	24	26	27.68
Screw speed (rpm), X_2	58.32	60	70	80	81.68
Temperature (^oC), X_3	198.32	200	220	240	241.68

Where α =1.682

Extrusion process

The cocoyam flours were extruded using a single screw extruder (model 1993 DD85G, 201132, IBG Monforts Gmbhi & Co, D-4050 Moncheng-ladbach, Germany). The extruder was equipped with 254mm barrel, a screw diameter of 200mm and was fitted with a die nozzle of 4mm diameter. The rehydrated samples were then extruded and the extrudates were cooled to room temperature and sealed in high density polyethylene films until measurements were taken.

Fig. 2: Extrudates from *Xanthosoma sagitifolium*

Experimental design

A centre composite RSM design was used to show interactions of feed moisture, screw speed and temperature on the extrudates. This comprised 20 runs, of which six were centre point, and 14 for non-centre point (Stat-Ease, 2002). Second order polynomial model was fitted to measure dependent variables (Y) such as bulk density (Y_1), expansion rate (Y_2), water absorption index (Y_3), water solubility index (Y_4), texture (Y_5). The following equation was used:

$$Y=\beta_0 + \beta_1 X_1+\beta_2X_2+\beta_3X_3+\beta_{11}X_1^2+\beta_{22}X_2^2+\beta_{33}X_3^2+\beta_{12}X_1X_2+ \beta_{13}X_1X_3 + \beta_{23}X_2X_3$$

Where β_0, β_1- β_3, β_{11}- β_{33} and β_{12}- β_{23} are regression coefficients for interception, linear, quadratic and interaction coefficients, respectively, X_1-X_3 are coded independent variables 3and Y is the response (Myers and Montgomery, 1995). An Anova test was carried out using Design Expert 6.0.8 (Stat-Ease Inc., Minneapolis, USA) to determine the significance at different levels (0.1%, 1% and 5%) (Stat-Ease, 2002).

Analysis

Bulk density

The bulk density was calculated by measuring the actual dimensions of the extrudates according to the method described by Ding *et al*., (2005). The diameter and length of the extrudates were measured using Vernier caliper. The bulk density was then calculated using the following formula,

$$\text{Density (g/cm}^3\text{)} = \frac{4 \text{ x } M}{\eth \text{ x } D^2 \text{ x } L}$$

where: M= Mass (g), D= diameter (cm), L= length (cm). Six replicates of extrudate were randomly selected and an average taken.

Expansion Ratio

The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudate according to Ding *et al.,* (2005). Six replicates of extrudate were randomly selected and an average taken.

Water absorption index (WAI) and Water solubility index (WSI)

The WAI and WSI were measured using the method of Ding *et al.,* (2005).

The extrudate samples were milled and sieved through 600µm sieve. 2.5g samples was dispersed in 25ml distilled water, using glass rod to break up any lumps and then stirred for 30min, centrifuged at 4000rpm for 15 mins. The supernatant was decanted into an evaporating dish of known weight and dried at 105°C until constant weight. The weight of the gel remaining in the centrifuge tube was noted. The results were expressed as the average of the two measurements.

$$\text{WAI (g/g)} = \frac{\text{Weight gain of gel}}{\text{Dry weight of extrudate}}$$

$$\text{WSI (\%)} = \frac{\text{Weight of dry solids in supernatant X 100}}{\text{Dry weight of extrudate}}$$

Determinations were made in triplicate.

Texture

The texture measurement was determined by using Erweka (Gmbh D 63150, TBH200, Heusenstamm /Germany) hardness tester fitted with a 2mm cylinder probe. The samples were punctured by the probe to a distance of 6mm and the hardness recorded.

Results and discussions

The effect of extrusion conditions on extrudate density can be found in the 3-D surface plot (Fig.3). Increase in feed moisture leads to increase of extrudate density at all temperature levels. However, increase in barrel temperature causes a decrease in the density of the extrudates. Bulk density has been linked with the expansion ratio in describing the degree of puffing in extrudates (Asare *et al*., 2004). Feed moisture has been found to be the main factor affecting extrudate density. The high dependence of bulk density on feed moisture would reflect its influence on elasticity characteristics of the starch-based material. Increasing feed moisture content during extrusion may reduce the elasticity of the dough through plasticization of the melt, resulting in reduced specific mechanical energy (SME) and therefore reduced gelatinization causing increase in the density of the extrudates. It was observed that an increase in screw speed resulted in an extrudates with lower density. Higher screw speed was expected to lower melt viscosity and increasing the elasticity of the dough which results in a reduction in the density of the extrudates (Ding *et al.,* 2005. Increase in barrel temperature may have increase the degree of superheating of water in the extruder encouraging bubble formation and also a decrease in melt viscosity (Fletcher *et al*., 1985) leading to reduced density in all the extrudates, which was observed in this work. Ding *et al.* (2005), reported the same trend in the effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks.

The effect of extrusion parameters on the expansion of extrudate are shown in 3-D surface plot (Fig. 4). Increase in feed moisture content decreases the expansion ratio of the extrudates, while increase in barrel temperature increases the expansion ratio of the extrudates. Harmann and Harper (1973), postulated two factors in governing expansion: (a) dough viscosity and, (b) elastic force (die swell) in the extrudate. The elastic forces could have been dominant at low moisture content and temperature. The bubble growth which was driven by the pressure difference between the interior of the growing bubble and atmospheric pressure resisted primarily by the viscosity of the bubble wall, dominate the expansion at high moisture content and high temperature (Panmanabhan and Bhattachyrya, 1989). Feed moisture content has been reported to have a highly significant effect on the radial expansion ratio. The radial expansion decreased with an increase in feed moisture content. Launay and Lisch (1983), suggested that radial expansion was most dependent on the melt elasticity. The stored energy could have been released in expansion process, thereby increasing the radial expansion ratio. Increased feed moisture content during extrusion would have change the amylopectin networks and change the melt rheology characteristics, thus leading to greater elastic effect and changes in product density and expansion. An increase in barrel temperature could have decrease the melt viscosity in the extrudates, which was confirmed by the report of Mercier and Feillet (1975), that extrudate viscosity decreased with increase temperature. The reduced viscosity effect would have favour the bubble growth during extrusion. The degree of superheating of water in the extruder would have increase at higher temperature also leading to greater expansion (Fletcher *et al.,* 1985; Ilo *et al.,* 1999).

The effect of extrusion parameters on the WAI and WSI of the extrudate are presented in 3-D surface plot (Fig. 5 and 6). Increasing feed moisture content significantly increases the WAI of the extrudates. WAI also increase with increased screw speed. Increase in barrel temperature was observed to cause a significant decrease in WAI. Increasing feed moisture content was observed to result in a significant decrease in WSI of the extrudates. However, increase in barrel temperature was observed to cause a significant increase in WSI of extrudates. The WAI measures the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion (Mason and Hoseney, 1986). WSI is often used as an indicator of degradation of molecular components (Kirby *et al.,* 1988), and measures the degree of starch conversion during extrusion which is the amount of soluble polysaccharide released from starch component after extrusion. Gelatinization, the conversion of raw starch to a cooked and digestible material by the application of water and heat, is one of the important effects that extrusion has on the starch component of foods. Water is absorbed and bound to the starch molecule with a resulting change in the starch granule structure. Barrel temperature and feed moisture are found to exert the greatest effect on gelatinization. The maximum gelatinization occurs at low moisture and high temperature or vice versa (Lawton *et al.,* 1972). Decrease in WAI could have been due to dextrinization or starch melting prevailing over the gelatinization phenomenon. The observed increase in WSI also indicates that dextrinization could have appears to play an important role in these experiments. Mercier and Feillet (1975), also found that soluble starch increased with increasing extrusion temperature and decreasing feed moisture content.

The effects of extrusion parameters on the texture of the extrudate are presented in 3- surface plot (Fig. 7). An Increase in feed moisture content caused an increase in the hardness of the extrudate, while increasing in screw speed and barrel temperature resulted in a decrease in hardness of the extrudates. The hardness is the average force required for a probe to penetrate the extrudate. The hardness of the extrudates increased as the feed moisture content increase which could be due to reduced expansion caused by the increase in moisture content (Lui *et al.,* 2000). An increase in temperature resulted in a decrease in hardness which could be due to reduction in melting viscosity favouring bubble growth, increasing expansion and lowering the density giving a softer extrudate. An increase in screw speed could have lowered the melting viscosity of the mix resulting in a less dense and softer extrudates. The same trend was reported by Ding *et al.,* (2005).

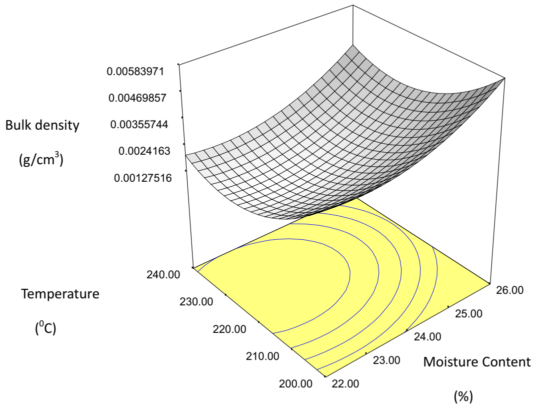

Fig. 3: Effect of moisture content and temperature on extrudate density

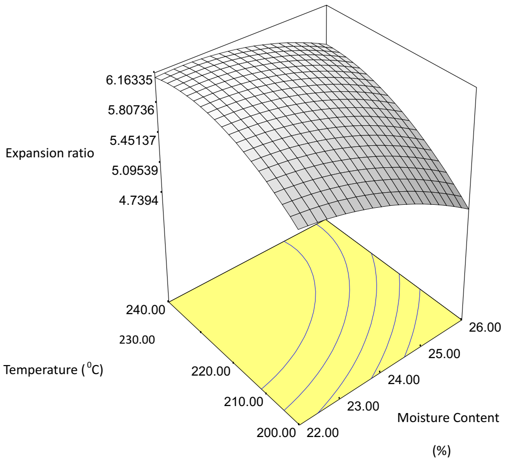

Fig. 4: Effect of moisture content and temperature on extrudate expansion ratio

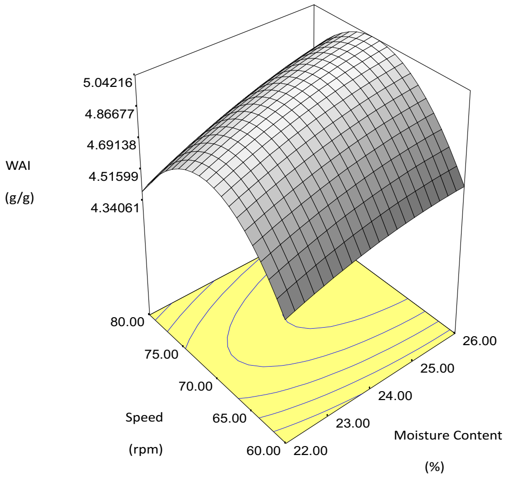

Fig. 5: Effect of moisture content and screw speed on the WAI of the extrudate

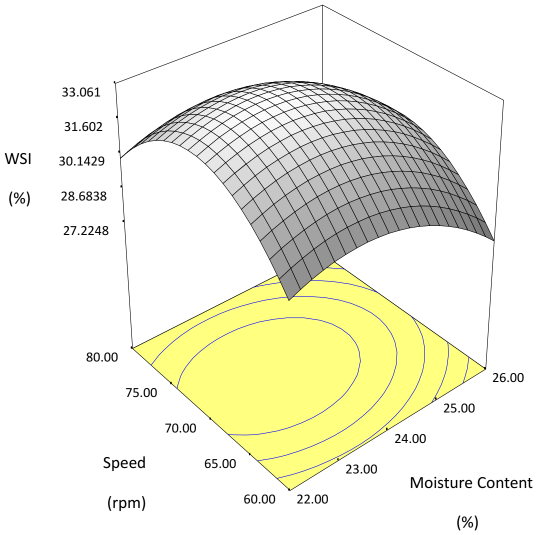

Fig. 6: Effects of moisture content and screw speed on the WSI of the extrudate

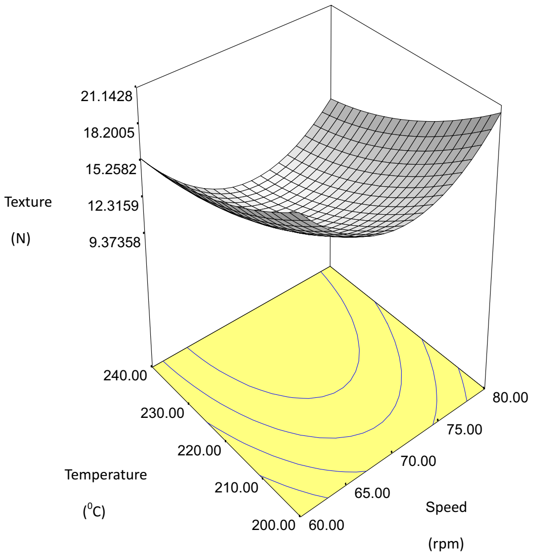

Fig. 7: Effects of screw speed and temperature on the texture of the extrudates

Table 2: Significant coefficients of regression equation for the responses

Coefficient	Bulk Density (g/cm^3)	Expansion Rate	WAI (g/g)	WSI (%)	Texture (N)
β_0	0.307**	-48.609*	-45.840**	-853.758***	851.298*
β_1	-0.009**	1.105*	0.236*	20.952**	-34.042**
β_2	-0.000	0.515	0.545	3.895	-6.812
β_3	-0.001**	0.207*	0.265**	4.441***	-1.771*
β_{11}	0.000*	-0.036	-0.010	0.392***	0648*
β_{22}	0.000	-0.003	-0.003**	-0.027***	0.049*
β_{33}	0.000*	-0.000	-0.000*	-0.009***	0.003
β_{12}	-0.000	-0.001	0.002	0.000	0.015
β_{13}	-0.000	0.002	0.000	-0.012	0.016
β_{23}	-0.000	0.000	-0.000	-0.000	-0.002
R^2	0.883	0.767	0.859	0.975	0.828

X_1: feed moisture , X_2: screw speed, X_3: temperature
*** Significant at the 0.1%%
** Significant at the 1%
* Significant at the 5%

Conclusion

The functional and physical properties of cocoyam based extrudates on single screw extrusion process were dependent on the process variables. The feed moisture and barrel temperature had significant effect on the extrudates properties, with feed moisture having the greatest influence.

Acknowledgements

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Adaptation of *gari* processing technology from Nigeria to improve traditional *rale* processing and marketing in Mozambique

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Abstract

Rale is one of the major traditional cassava products in rural Mozambique. The traditional processing technique is rudimentary and leads to poor and unsafe products. The processing technique requires improvements as part of the Mozambique industrial policy which aims to promote the cassava sector in relation to increased food production, agri-business, income generation and poverty reduction. In order to increase rural income and reduce poverty, a pilot processing project for high quality rale production was initiated with the participation of smallholder farmers in Inharrime district of Inhambane Province. This paper describes the implementation steps for the development of a profitable rale value chain through the adaptation of the gari technology of West Africa to improve the traditional rale technology and establish sustained links between farmers and city-based supermarkets. The technical feasibility and potential profitability of the adapted technology and marketing innovations were compared against the traditional approaches.

Introduction

As the economy is growing in Mozambique, consumer tastes and food preferences are changing. The demand for fast foods in the urban centers is growing. Such demands are often met with imported foods such as wheat, rice, etc, and their products. Nevertheless, changing consumer tastes provide opportunities to modify the traditional processing methods to improve the quality of foods eaten by the majority of the population and meet the new acquired tastes. Therefore, improving traditional processing methods for locally grown crops creates the opportunity for smallholder farmers and processors to access new market channels.

Cassava (*Manihot esculenta* Crantz) is one of the starchy staple foods in Sub-Saharan African countries, supplying at least 200 calories per day to near 200 million people in the region and up to 400 calories per day to many poor households in Mozambique (Dorosh, 1989). Cassava is the most important staple food in Mozambique followed by maize; it represents 35% per capita calorie intake of the people followed by maize which accounts for 26% (Wulff and Torp, 2005). Cabo Delgado and Nampula provinces in the north, Zambezia province in the central area, and Inhambane province in the south are the four largest producers of cassava in the country. Inharrime district in Inhambane province is the highest producer and supplier of cassava roots, leaves and processed cassava products. However, the traditional cassava processing techniques in Mozambique are not developed with little or no mechanization. The risk of mycotoxin contamination and high residual cyanide in cassava through improper processing practices is real. Due to lack of knowledge, cassava is deliberately processed in ways which promote fungi growth to make products such as 'blue cassava' considered to be delicacies in some localities (Wulff and Torp, 2005). The fungi produce high levels of mycotoxins in the products. Other processes, sometimes short-cut processing practices, leave high levels of residual cyanide in the cassava products. Both mycotoxins and cyanide have reportedly caused major health hazards among the local the populations (Trivana et al, 2009). While several cases of a paralytic disease, known as konzo, caused by acute cyanide toxicity from consumption of improperly processed cassava have been reported, stunted growth in children have been linked to Aflatoxin ingestion (Coulibaly *et al*, 2008).

Rale, an important traditional cassava product in Mozambique is similar to gari which is popular in West Africa or farinha de mandioca in Brazil. Gari is obtained by peeling cassava roots, washing, grating, fermenting, dewatering to a semi-dry cake, breaking of the cake to granules, sifting and roasting or frying of the granules to a partially gelatinized and dried granular form which is then sifted to obtain market grade gari (Oguntimein *et al* 1994). In Nigeria, over 70% of cassava produced is processed to gari and used as urban food (Nweke, 2003). Inhambane Province is the only location in the east coast of Africa where r*ale is* produced, but inadequate knowledge and poor traditional processing method affect the quality and the marketability. Consequently, an alternative product, "*Farinha de Mandioca*", is imported from Brazil and sold in the middle-class supermarkets. Due to superior quality and packaging, the imported product is more than ten times the price of locally made *rale*. Improving the quality and quantity of rale to meet the requirements of the changing food patterns in the increasingly urbanized Mozambique should therefore increase market opportunities for the smallholder farmers.

In the early 1990s, the International Institute of Tropical Agriculture (IITA) developed novel cassava products and processes and tested them in some countries in West Africa. It also trained over 200 postharvest researchers from 12 countries across Africa in the area of postharvest technology and product development from cassava and other root and tuber crops (Abass et al 2009). The results of the tests showed that the technologies had high potentials for income generation and poverty reduction for farmers at rural levels. For the purpose of promoting cassava industrialization and increasing farmers' income earnings, the Common Fund for Commodities (CFC) selected the novel technologies in 1998 for promoting production, expanding processing and diversifying cassava utilization in the developing and least developed countries. Partnerships were formed between the CFC, FAO, IITA, national institutions and other stakeholders in Madagascar, Mozambique, Tanzania, Uganda, and Zambia to develop the income generating potential of cassava.

The novel IITA processing technologies and other technologies from West Africa were to be tested under pilot systems in a way that promotes cooperation in the solution of problems facing the cassava commodity, particularly those of international scope and significance in East and Southern Africa. It was hoped that the successful adaptation of those technologies would promote the use of cassava for applications where it had clear competitive advantage, but which was underutilized (CFC/FIGG/XII/MDA appraisal report). Similarly, the industrial policy Mozambique gave priority to the cassava sector, particularly investments in small- and medium-scale agro-processing. Availability of scale-able agro-processing technologies was therefore necessary to attract private sector investment into the sector. Hence, critical information and evidence of profitability of such technologies are needed to take investment decisions.

The paper reports the results obtained in a research for development project conducted from 2004 to 2007 to contribute to the improvement of the traditional *rale* processing subsector in Mozambique and to provide necessary investment data to local entrepreneurs. Quality assurance techniques for gari processing in West Africa were adapted for rale processing and tested at pilot scale in Nhanombe area within Inharrime district of Inhambane province, southern Mozambique (Fig 1). Links were established between farmers, processors, marketers and consumers of the high quality rale to ascertain its acceptability. The adaptability and potential profitability of the new processing technology were compared against the traditional practices.

Fig 1: Mozambique showing Inhambane province

Materials and Methods

Value chain analysis

IIAM and IITA, in partnership with the national extension service, SG-Global 2000, SARRNET, and the provincial directorate of Inhambane, carried out value chain studies including SWOT analysis (strength, weakness, opportunity and threat) of the cassava subsector in Inhambane to understand the cassava production system, traditional processing methods, the marketing systems, and the stakeholders characteristics. The studies were done with emphasis on understanding the major constraints to the improvement of the cassava sector and the opportunities that exist.

Based on the results of the SWOT analysis, some farmers and traditional *rale* processors, the Josina Machel farmers' group, comprising of six male and eighteen female smallholder farmers already involved in *rale* processing in Nhanombe was selected to take part in the pilot study. The group was located near the Inhambane research site of IIAM and the national extension office which provided prompt technical assistance when needed. The Ministry of Agriculture (MADER) earlier provided a motorized grater, presses, processing shed and roasting or frying stoves**.** NGOs and other service providers from the private sector such as CTA, ORAM SG_2000 and Agro-Alfa GPSCA provided after-sale services on the processing machinery. The IITA and IIAM introduced the new processing technology, quality assurance techniques and market innovations to the national extension institutions - MADER/ DNER, MADER/DAP and NGOs through staff training. In turn, the extension institutions organized the pilot farmers to facilitate the knowledge transfer. The new processing technology and quality assurance methods were introduced to the farmers' group through a series of demonstrations and learning by doing. They were further trained on business management, book keeping, and accounting procedures.

Marketing strategy and monitoring: IITA and IIAM provided technical support in technology and market innovations to farmers, processors, marketers and all other agents along the whole rale chain and also monitored progress of the action research. New marketing innovations introduced included product grading, packaging, branding and coding. Traditionally rale is sold by the road-side in unregulated open containers known as *lata*. Printed 50kg polypropylene bag was adopted for long distant transportation and printed 1kg and 5kg transparent polythene bags of 0.55mm thickness were adopted for retail marketing. Supplier-buyer relationship was established between the pilot farmers and supermarkets within the capital city of Maputo, which is 250km away from the pilot village.

Input and output data for both traditional and improved (high quality) *rale* processing operations were collected for two years to compare their technical feasibilities and economic viabilities. Market data were collected to gauge market acceptability.

Results and Discussion

Value chain analysis: The most widely grown cassava varieties in Inhambane are *Gangassol*, *Chinhemba* and a high cyanogenic potential variety, Munhassa. Cassava Brown Streak Disease (CBSD) and Cassava Mosaic Disease (CMD) are prevalent in the area. However, some varieties tolerant to both CBSD and CMD have been selected by the national root and tuber research program and recommended to the farmers. The varieties include -Nikwaha, Nachinyaia, Chigoma mafia, Macia 1, Likonde, N´xincole, Baadge, MZ 89001, MZ 89192, MZ 89 186, and TMS 30001. The planting materials are distributed through farmer-to-farmer exchange but the national agricultural research and extension services and some NGOs such as Helvetas, CARE Mozambique, UN Volunteers, Save the Children, and the Lutheran World Federation have been involved in the multiplication and distribution of new cassava varieties to farmers.

Fresh roots prices fluctuate throughout the year but increases significantly from November to May, in the rainy season, when food supplies are low and new crops are being planted. There is significant increase in the marketing of cassava products such as flour, chips and *rale* from June-September; the increase which peaks from June to August drops the prices of cassava roots and products (Fig 2). The major buyers of processed cassava products in Inhambane province are travelers (60%), traders (26.7%) and consumers (13.3%) (Abudula, 2003).

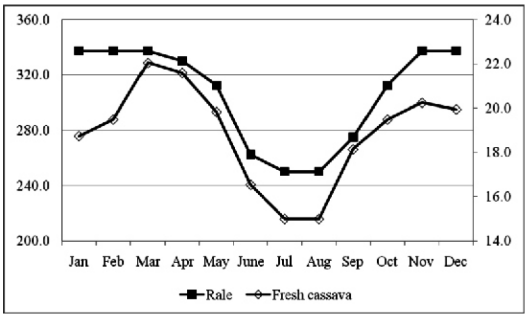

Fig 2: Prices of cassava roots and *rale*

Inhambane province is the only place on the East African coast where traditional cassava processing involves grating and roasting similar to the processing method for *gari* in West Africa and *farinha de mandioca* in Brazil. *Rale* is consumed mostly by low income earners in Gaza, Maputo, and Sofala. The quality, particularly the granular sizes of traditional *rale* differ considerably from processor to processor. Although the demand for rale was increasing, the middle-class in Maputo preferred the substitute product imported from Brazil. Nonetheless, the demand for better quality *rale* from neighboring countries in the region, Swaziland, South Africa, etc, is growing.

Traditional processing of cassava to *rale* involves peeling of fresh cassava roots, washing and manual grating. Most times, washing is skipped due to acute water shortage in most rural farms. Manual graters are made up of thin metal sheets perforated with 3-4mm diameter nails, to make series of protruding sharp surfaces, and nailed on flat wooden boards (Oguntimein *et al* 1994, Francisco 1995). The manually grated cassava mash is put into polypropylene bags and pressed with heavy objects such as logs or stones to remove water for 6 to 7 days, during which fermentation occurs. In a parallel process, cassava flour is processed through drying of peeled roots, and pounded into flour (Fig. 2). The pressed cassava and the flour are subsequently mixed before roasting to rale.

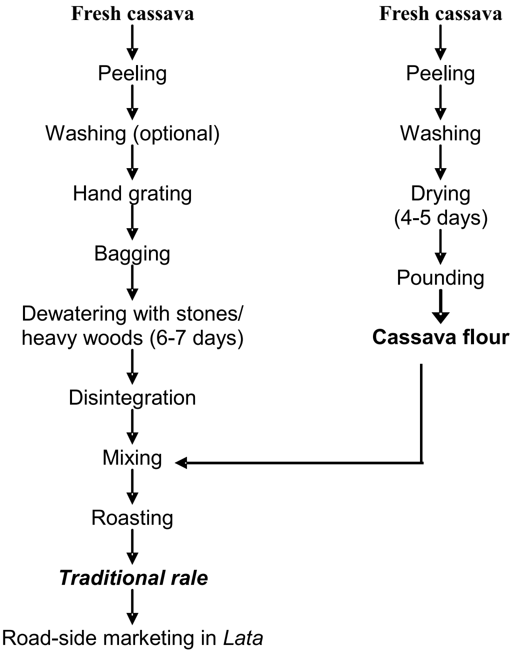

Fig 2: Traditional method of *rale* production

An analysis of the traditional *rale* processing and trade in Inhambane province suggests that **the t**raditional techniques are fraught with several challenges while market opportunities exist for sale of *rale* for food security and income (Table 1). The manual grating method exposes the processors, mainly women and children, to finger-injuries by the sharp grating surfaces of the hand grater, possibly the cassava mash is thereby contaminated. The mixing of the dewatered cassava with cassava flour is to lower the high residual moisture, from the inefficient traditional dewatering method, to the level required for proper roasting. The traditional dewatering method does not guarantee reduction of the residual moisture to the level required for proper roasting. Mixing of cassava flour with the mash therefore increases the processing time and the labor input since cassava flour would have to be processed separately. Sometimes, the dewatered cassava is sun-dried first to reduce the moisture contents to the levels suitable for roasting.

Table 1: SWOT analysis for cassava and traditional *rale* production

Strengths	Weaknesses
• Cassava is the most important crop in Inhambane province and the highest income earner in Inharrime district. • Cassava processing to rale is a tradition, a common practice in Inhambane province. • There are many groups of farmers involved in various agricultural activities which have been supported by other NGOs and the Ministry of Agriculture. • A group of smallholder farmers, the Joisna Machel, already owned a mechanical grater, presses and sieves for rale processing. • Rale is sold in the rural areas, the high quality grades are demanded in the cities. • Small-scale women traders play a crucial role in the collection of rale from villages, bulking in specific collection points or local markets along the main inter-provincial highway (N1) and transporting for sale to retailers in the open food markets of Maputo, northern part of Inhambane, and Beira in Sofala province	• Rale processing is done as a backyard activity. • Farmers are in remote villages far from any major roads, they are constrained by inadequate farming implements, lack access to vehicles to transport roots and rale for processing or marketing. • Processors lack knowledge of appropriate technology for rale processing but rely on rudimentary or non-mechanized traditional methods such as manual grating and dewatering of cassava with heavy logs and stones. • Traditional methods are inefficient, labor demanding and pose health hazards to the processors. The grating and pressing operations expose processors, mostly women, to finger and leg injuries. • The output and quality of rale from these processes are both low. • Due to lack of quality assurance or standardization, rale quality is inconsistent and varies from processor to processor depending on the fermentation process, grating material used, or inclusion of cassava flour before roasting. • Processing areas are improperly ventilated, the mostly women, processors are at risk of health hazards from wood smoke inhaled during rale roasting. • Poor demand and low prices are offered for the rale by consumes. As a result, traders offer low prices to the processors and the farmers are underpaid for fresh cassava. • Many existing farmers' associations prefer to work as social groups and unwilling to maintain bank accounts partly because of little incomes. • Farmers, processors and traders do not have access to any form of credit facilities to up-scale or expand the rale trade. • There is inadequate supply of labor and lack of potable water for processing. • Processors have limited market access and no market information to verify prices offered by traders.

Opportunities	Threats
• There is abundant land for cassava expansion and for establishment of cassava multiplication farms. • Bulking house system for rale is well established by local traders for collection and storage of rale, mostly along the main interprovincial roads. • The Josina Machel farmers' group is 7 km to the main inter-provincial highway (N1) leading to the capital city of Maputo; transportation to the market was easier for the group than for others. • The group is close to the national agricultural research station and the national extension office where extension services could easily be offered.	• Poor network of roads within farms impose major limitations to the volume of cassava that could be processed daily since the bulky fresh cassava roots have to be transported from the farm to the processing center by foot. Unreliable transport system increases the transportation time to the markets; traders often wait along the roads sometimes up to 10-15 days before securing transportation to take rale to the city markets thereby increasing transaction costs. • Lack of prompt transportation of already low quality rale to the market could further reduce quality on arrival in the market. This negatively affects rale marketability and therefore reduces the market price.

The manual mixing of the lumpy dewatered cassava and flour is inefficient; pieces of cassava are left in the mixture and roasted. The resulting roasted granulates are often of inconsistent coarseness. Rale is often sundried and sometimes not properly cooked and may contain high moisture contents after roasting, causing rapid spoilage during transportation and marketing. Improper fermentation leads to *rale* with objectionable color and taste. Rale could be sandy because sometimes roots are not properly washed or the mash is soiled during the pressing and drying operations. These contribute to the low pricing. In West Africa however, mechanical dewatering eliminates the need for flour. The dewatered cassava cake is sifted to remove lumps of cassava roots and the uniformly sized granules are roasted, producing much uniform and less coarse *gari*.

The peak season for rale marketing is from June to August and the main markets are in Inhambne, XaiXai, Maxixe, and Maputo, etc. The analysis of the input and output costs showed that fresh root prices vary from $15.9-43.0/t in different provinces of Mozambique. During certain periods of food shortages, *rale* sells for $127/t to 342/t and fresh cassava roots at $159/t to 430/t.

R*ale* is mostly sold in unregulated open containers along rural roads. Traders, mostly women, purchase *rale* from the small villages, bulk in some major villages along the main inter-provincial highway, and pack into 50-100kg bags for transportation to the cities. The traders wait at least one week on the highway to secure transportation of the *rale* to main towns and cities. The time duration to secure transportation and the associated costs are often unpredictable. This increases the transaction costs. The quality of rale, which was already poor from the time of processing further, deteriorates before arrival in the city markets. These factors influence traders to offer prices as low as US$50-140/t to farmers with the explanation that the cost of transportation to the urban markets is high and the final retail price is low.

Although a processor would require minimum of 4kg of fresh cassava to produce 1kg of *rale*, prices of cassava roots and products surveyed in five provinces showed that 1kg of traditional rale sometimes sells at the same price as 1kg of fresh cassava (Table 2). Implicitly, the rale prices are below the raw material costs and much below processing costs.

Table 2: Prices of cassava roots and products in five provinces in 2005 ($/t)

Provinces					
Product	Nampula	Zambezia	Inhambane	Gaza	Maputo
Fresh roots	276	159	225	430	342
Dried cassava chips	279	245	306	300	313
Leaves	167	276	325	92	-
Rale	-	102	127	229	342

Consequently, farmers and processors in most cassava dependent communities are further plunge into poverty even when they sell cassava in the fresh form or after processing.

Adaptation of gari technology from Nigeria: Working with the pilot farmers through training and mentoring, the mechanized gari production technology from Nigeria was adapted for *rale* processing (Fig 3). The following quality assurance, grading and packaging steps were introduced: 1) replacement of the hand grating of fresh cassava roots with mechanical grating using the motorized grater; 2) the dewatering of the grated cassava mash using stones and heavy objects was replaced with a mechanical pressing system using screw presses; 3) the pressed cake was disintegrated to uniform sized wet granules by using the mechanical grater and sifting in a 50cm x 50cm wooden framed sieve of 3-5mm aperture size; 4) a stove specially designed to prevent both heat and smoke from entering into the roasting environment was introduced; 5) the high quality *rale* was further graded into three with a set of two sieves; namely: coarse grade (overs of 5mm sieve aperture size), medium grade (passes through 5mm aperture sieve but not through 2mm aperture sieve) and fine grade (passed 2mm); 6) the three grades were packaged in specially designed 50kg polypropylene bags for long distance transportation, and in transparent 0.50mm thick polyethylene bags of 1kg and 5kg sizes for retail marketing.

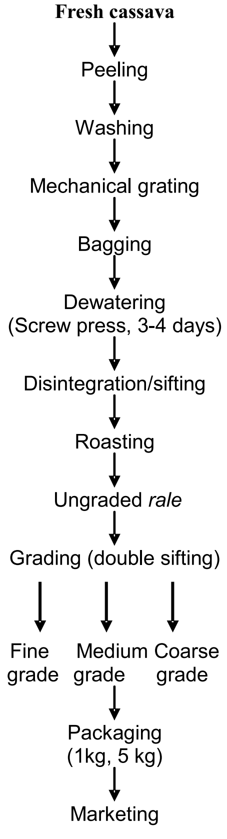

Fig 3: Adapted technique for *rale* production

The use of mechanical grater significantly increased the processing capacity from 250kg fresh cassava per day to 1 ton per hour or 8 tons per day. Mechanical pressing ensures proper reduction of the moisture to the 35% content required for proper roasting (IITA, 1990). The mechanical dewatering eliminated the traditional practice of sun drying or mixing cassava flour with the inadequately dewatered cassava mash; it also helps to prevent contamination which occurs during sun-drying and cross contamination through improperly processed cassava flour used in the traditional process. Mechanical disintegration and sifting technique replaced the traditional manual winnowing method and ensures that cassava granules of uniform particle size are roasted while the big lumps are excluded from the roasting operation; the technique reduces time and labor used in the traditional winnowing technique. Lumps of non-grated pieces of cassava roots are more easily, quickly and hygienically removed than the traditional method. The special gari roasting stoves increased the efficiency of roasting operations and reduced the health risks of smoke which characterizes traditional rale roasting.

Uniform grating surfaces as used for the manufacture of grating machines ensure that the cassava mash would undergo uniform fermentation and develop appropriate aroma characteristic of gari or rale. More effective dewatering and sifting processes contribute to better roasting and proper gelatinization of the rale with the characteristic uniform color and finer granule sizes. There are the prerequisite for high quality grades.

Market linkage and market testing: The pilot group was linked with some *rale* marketers who purchased high quality rale and sold to consumers and supermarkets in three grades (fine, medium and coarse) at a price range of US$400-600/t.

Consumer feedback confirmed the high quality *rale* had better taste, color, and aroma compared with the traditional *rale* which is coarse, non uniform in size, poorly cooked and sold in buckets. The grading and packaging contributed to an increased acceptability and increased the market value as the different grades met different consumer requirements. The fine grade was preferred by the high income consumers. This category of consumers was willing to pay higher prices, thereby improving the profitability of the enterprise. The medium granule was more acceptable to low and medium income consumers because it can be used as a substitute for rice or maize flour in the Mozambican diet. Some consumers mix the fine grade with sugar and roasted peanuts, and blend to make pasta-like product called *liffet*.

While the farm gate price of traditionally processed *rale* was about US$150/t, consumers of the high quality *rale* were willing to pay as much as US$750/t. The demand for the high quality *rale* grew due to the increasing demand for differentiated cassava products, the changing consumer preferences and the demand for *rale* by other Africans resident in Mozambique particularly West Africans familiar with gari and Brazilians who were buying imported *farinha de mandioca* from the supermarkets. Consequently, supermarket signed a contract with the pilot cooperative farmers for a monthly supply a total of 500kg of two grades of the high quality *rale*, fine and medium. Shoprite, a chain of supermarkets which originated from South Africa, listed high quality *rale* as a product of interest. A certification code was obtained from South Africa and a supply contract was signed with Shoprite. Soon after this, more supermarkets in Maputo city, **e.g Infulene,** Maputo city belt, began to sell high quality *rale* at US$800/t. To optimize transportation and reduce costs, a minimum economic volume for transporting the rale to the supermarket was estimated at 1.5 tons per trip.

Therefore, grading of *rale* increased its differentiation thereby increasing the market share since the different grades met the requirements of a wider range of consumers. The packaging helped to introduce standard measures in *rale* marketing; it increased the keeping quality, aesthetic appeal and the market value. Finally, branding and coding made marketing of *rale* by the major supermarkets possible. These innovations if applied in more processing communities in Mozambique can increase the demand for rale and fresh cassava in other provinces such as Cabo Delgado and Zambezia having about 50% of the country population.

Investment and profitability analyses for the traditional and the high quality rale processing: The cost of investment for the mechanized *rale* processing was estimated at US$ 9,542 (Table 3). This is made up of the grating machine, dewatering machines, fermentation stands, roasting stoves, weighing scales, sifters and processing shed. The machinery and facilities have service lives of 4-10 years and a minimum combined processing capacity of 1 ton of fresh cassava per hour or 8 tons per day.

Table 3: Estimated investment cost of mechanized rale processing

Machinery and facilities	Capacity	Total Price (US$)	Service life
Grating machine (1ton/hr)	8 tons/day	726	6
Dewatering machines	4 screw presses; 2 tons/day/press	3,640	8
Fermentation platforms/stands	series, 8 tons capacity/day	496	4
Roasting stoves	4 stoves; 1 ton rale/day/stove	1,600	4
Weighing balances, scale and sealers	Set	400	10
Grading or sifting screens	Set	120	4
Washing vessels, tools, etc	Set, 8tons/day	560	4
Building and store		2,000	10
TOTAL		9,542	

Source: CFC/IITA/IIAM/UEM, 2005

The input and output data collected during the processing and marketing activities of the farmers over a period of two years are shown in Tables 4-5.

During the pilot testing, farmers had about 117 days per year devoted to rale processing since there were other farming activities they did each year. An average of 29.24 tons of fresh cassava roots either from their farms or purchased at an average price of US$25 per ton from other farmers were processed per year. The most significant cost was US$25/t for the fresh cassava and for transportation of graded rale 250km from the pilot area to Maputo. However, the cost of fresh cassava was lower in some villages in Tanzania surveyed recently (Abass et al 2009a) and higher in Nigeria due to the higher level of commercialization (Abass et al 2009b).

Table 4: Input and output data for high quality *rale* processing and marketing.

Fresh cassava price (US$/t)	25
Rale produced per ton of fresh cassava roots (t)	0.21
Labor cost for transporting to processing site (US$/t fresh cassava)	10
Labor cost for peeling and washing (US$/t fresh cassava)	10
Labor cost of operators (grating and pressing, US$/t fresh cassava)	10
Labor cost of winnowing/sifting and roasting (US$/t fresh cassava)	1.79
Cost of water (US$/t fresh cassava)	1.34
Cost of pressing bags (US$/t fresh cassava)	0.45
Other costs (fuel, firewood, machine repairs etc; US$/t fresh cassava)	2.1
Labor cost grading/sieving (US$/t of rale)	5
Labor cost for packaging (US$/t of rale)	7.1
Cost of packaging material (US$/t of rale)	7.1
Cost of transporting final product to market (US$/t of rale)	25
Price range for packaged high quality rale delivered to Maputo supermarkets	400-600
Price of Traditional rale in Maputo	342

Analysis of profitability outlook for a small business enterprise based on the tested mechanized rale processing shows that the enterprise could be financially profitable but must be operated at a capacity higher than smallholder farmers' ability. In this pilot test, the installed capacity was 1440 tons per year while the farmers processed only 29.4 tons per year, a capacity utilization of only 2%. However operating the plant at full capacity for only 180 days would guarantee significant profitability (Tables 5 &6). Unlike in West African countries of Ghana and Nigeria where cassava is harvested and processed throughout the year, the analysis takes into consideration that significant supply and low cost of fresh cassava occur for about 6 months in a year in Mozambique.

Table 5: Profitability data for high quality rale processing

Item	Quantity	Costs at operating capacity US $
Installed processing capacity (tons of fresh roots) per day	8	
Number of permanent Staff	5	
Number of working days p.a	180	
Installed Capacity p.a. (t)	1440	
Operating Capacity (tons per day)	8	
Price of fresh cassava ($/t)		25
Roots needed and price at Operating capacity p.a. (t)	1,440	36,000
Rale output per year (t)	302	
Capacity utilization (%)	100	
Labor costs		
Labor requirements at capacity load (man-days p.a.)		49,450
Manager and Supervisor, other types of labor		6,800
Other variable costs		
Water cost at operating capacity		1,930
Other costs (fuel, firewood, machine repairs etc.)		3,024
Cost of pressing bags		648
Cost of packaging materials		2,160
Cost of transporting rale to supermarkets		7,560
Road tax		3,024
Total variable costs p.a. at current capacity utilization		110,595
Processing and marketing cost/t of rale		366
Price per ton of rale sold to supermarkets		500
Revenues at current operating capacity (capacity load)		151,200

However, to attain a selling price of US$500 per ton, the enterprise must undertake transportation and delivery of rale to the supermarkets as part of the business, thereby excluding the participation of traders.

Table 6: Profitability indices for high quality raleprocessing

Item	US $
Total fixed costs p.a.	3,113
Total production (variable) costs p.a.	110,595
Total revenues p.a.	151,200
Total gross margin	40,605
Rale production (t)	302
Gross margin/t rale	134.28
Gross margin/t fresh root equiv	43.10
Profits (overall) at present possible capacity load	37,492
Breakeven point	
In rale equivalent (t)	23
In fresh roots equivalent (t)	110
Net present value (NPV)	107,237
Internal rate of return (IRR)	57%
Bank Interest rate	28%

At total processing and marketing cost of US$ 366 and selling price of $500/t, the enterprise can generate US$40,605 profit by processing 302 tons of rale per year. The gross margin would be about US$134.28 per ton while the breakeven volume would be 23 tons. Therefore the minimum raw material requirement to guarantee the success of the processing enterprise is 110 tons. In addition, the internal rate of return of 57% compared favorably with 28% bank interest rate in Mozambique, implying that the enterprise is bankable.

For the ungraded traditional rale, total processing cost would be at least US$292.63/t. This would exclude the additional costs incurred for the improved rale processing such as costs of labor for grading, sieving and packaging, the costs of packaging materials, transportation of rale to supermarkets, and road tax. Therefore, at the US$127/t price of traditional ungraded cassava, the smallholder farmers and processors make losses of up to US$165.63 for every ton of *rale* sold. After bulking of traditional *rale* from many smallholder processors and transporting to the markets, traders sell to retailers at US$342.00/t. The women traders play critical roles in the marketing of rale in the cities which are often at distances of 100km to 500 km from the *rale* processing villages. Nevertheless, it is likely the traders make very little profits because of the high transaction costs involved in the marketing of rale. The unavailability of vehicles, high cost of fuel, and poor roads might mean that traders incur unpredictable costs on storage, subsistence, etc over several days whilst awaiting vehicles to transport the *rale* to the city markets. Yet, they remain suspects for poor income status of smallholder farmers.

Conclusion

Low pricing of the traditional rale is a reflection of low quality compared with imported substitute. Low quality negatively affect rale prices in the consumer market and the incomes of low income producers and processors who do not have any better knowledge of processing and still do not have access to the markets nor information on pricing and price trends. Farmers and processors in most cassava dependent communities seem to be further plunged into poverty even when they sell cassava in the fresh form or after processing. Although inadequate processing knowledge, poor rural infrastructure, and others factures which are out of the control of the farmers are mostly responsible for the situation, rural traders or 'middlemen' are often blamed for poor prices offered to farmer. However low quality of cassava products poses major financial risks to the traders as well as such products are priced low in the retail market. In addition, the traders have significant marketing or trade constraints which often lead to unpredictable expenditures. Unpredictable marketing expenditures are the consequences of difficult marketing logistics, poor transport infrastructure and the related high transportation costs, and high taxes. Therefore, the high uncertainties in marketing costs influence the traders' price bargain at farmers' or processors' gate. In the current unfavorable circumstances of most cassava dependent communities, it would require new approaches to bring smallholder farmers out of the desperate situation.

Nevertheless, the study demonstrated an approach for improving traditional processing technique and uplifting the status of a poorly made product often sold to low income earners into a higher quality product acceptable to city supermarkets and higher paying consumers. The introduction of processing innovations to rale processing, including processing machines and facilities, standardized unit operations and grading has demonstrated that improvement of rale quality can lead to higher demand at higher market prices. Rale business enterprise based on the tested mechanized technology would be financially profitable but must be operated at a capacity higher than smallholder farmers' ability. It could therefore be argued that in addition to farming activities smallholder farmers are engaged in, it would be difficult for them to operate a successful rale processing enterprise at the high capacity required for the enterprise to be profitable. Therefore private investment by local entrepreneurs into rural based agro-processing enterprises would be necessary for the development of the cassava sector. The sale of high quality rale in the main super markets within the main cities such as Maputo, Beira and Nampula where other cassava products from Brazil are sold provides huge high income opportunities to small producers, improved opportunities for the development of the cassava industry and will save Mozambique foreign exchange expenditure spent on importation of cassava based foods. However, it was very clear that for the use of the new technology to lead to sustainable growth, processors must be able to produce large volumes of rale cost effectively and sell at higher prices than the prices offered for traditional rale in the rural markets.

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Cassava value chain development in West Africa: success stories

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Abstract

The initiative of cassava value chain in West Africa has provided sustainable opportunity for transferring best bet agronomic, processing and marketing practices to less privileged small holder enterprises in Nigeria, Benin and Sierra Leone. This project which started 2008, sponsored by Common Fund for Commodities, supervised by FAO and implemented by IITA has been an avenue to improve key players of cassava enterprise in the selected countries to boost their output qualitatively and quantitatively. The selected beneficiary processors individually and in groups were provided with well equipped renovated processing centers and business plans in 13 locations, thus creating enabling environments for maximum production of cassava products. They also received sound processing trainings on quality and competitive cassava products in addition to the introduction/development of new commercial cassava products for market diversification. The processors were as well provided with storage facility for finished products to enable an all year round access to products. The capacities of local fabricators were enhanced as they were used in fabricating all the equipment at the centers while markets were linked for the processors at all levels. From the assessment of the projects so far, appreciable and sustainable progress had been reported in term of processors' increased productivity, expanded utilization of cassava and capacity enhancement in processing and equipment management. The processing centers are being used as reference for academic and development purposes.

Keyword: Cassava, value, development, West Africa, success stories

Introduction

Cassava is the most important food staple in Nigeria and Benin and ranks second after rice in Sierra Leone. Presently, cassava is seen as a food security crop, fighting poverty and improving livelihoods for many households, especially the marginalized women in the rural sectors. However, traditional methods of processing are predominant in the region and these offer a low value, poor quality product and storage with a low investment drive to limited range of consumers. This restricts the contribution of cassava to economic growth and poverty reduction, making the crop a partially tapped resource.

The value chain system (production, processing, and marketing) needs to be developed. Fresh cassava roots are highly perishable, with a shelf life of less than 3 days, processing is necessary for longer shelf life and value addition. The roots are also very bulky, about 70% water, implying that processing close to the source of supply is critical for cost-effective value addition in reducing transport costs. Cassava production is mainly undertaken by widely dispersed small-scale farmers; the increased cost of bulking tends to undermine the economic feasibility of processing by large-scale enterprises. Failure to adequately develop the value chain system for cassava has been a serious limitation for many years. However, if low-cost value addition can be introduced to small and medium scale farmers/processors living in marginal areas, then significant impact can be achieved now and in the future. Strengthening the cassava value chain in West Africa will therefore promote sustainable enterprises in these countries.

The overall objective of the project on Common Fund for Commodities is the development of new market opportunities and supply lines for cassava farmers and small and medium scale processors in West Africa. This was achieved by Supporting Processing and Value Addition by Small and Medium Enterprises through development of Supply Lines for High Quality Cassava Flour (HQCF) for Bakery and Confectionery Markets, upgrading Traditional Processing Practices to make products for defined markets and effective project management. This paper shows success stories of the cassava value chain development in Benin Republic, Sierra Leone and Nigeria since 2008 till date.

Methodology

The project components are divided into development of supply lines for high quality cassava flour (HQCF) for the bakery and confectionery markets; upgrading traditional cassava processing plants for defined markets; and Project coordination and backstopping, monitoring and evaluation, exchange and dissemination of results. CFC-WA project worked with National Coordinators and NGO for ownership and sustainability. A selected pilot group of small and medium cassava processing enterprises (amongst them also smallholder cassava farming co-operatives) were established. Based on approved criteria, the selected project beneficiaries signed agreement to comply with project implementation. The selected beneficiary processors were provided with well equipped renovated processing centers-6 in Sierra Leone, 4 in Benin Republic and 3 in Nigeria. Farmers were clustered round the processing sites and received best agronomic trainings and superior cassava stems. The processors received trainings on quality processing, business enterprise while operators and fabricators received training on equipment operations and maintenance. The processors were as well provided with storage facility for finished products to enable an all year round access to products.

The project exit strategies were spelt out right from the commencement of the project in 2008 as follows:

- The project executing agent (PEA), which is the IITA, will ensure active participation by stakeholders in planning, execution, monitoring, and evaluation.
- National Coordinators, farmers, processors, and marketers will have freedom of choice before, during and after the commencement of the projects.
- PEA will ensure adequate capacity building, mentorship of factory operation and maintenance, record keeping, profitability analysis, and will scale-up strategies during the execution of the project.
- The supervisory team (FAO/CFC/WUR) will ensure strict compliance into the approved tasks and reporting systems.

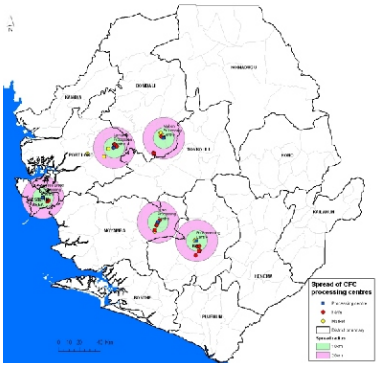
Success Stories

Geo-referencing of project sites and markets in CFC project countries

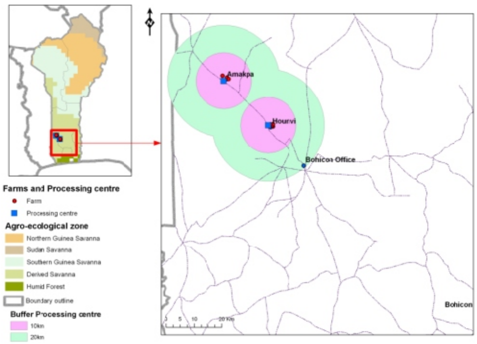
CFC project locations-covering farms, processing centers and markets in Sierra Leone were geo-referenced. In all, a total of 19 farms were geo-referenced, 13 markets were covered, and 5 processing centre were visited.

Measuring distances between the processing centres and market locations

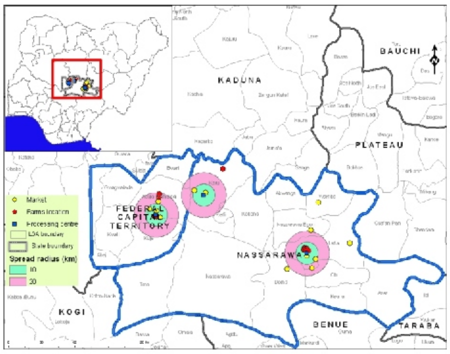
Most of the farms are within the 10km radius from the processing centers except very few that are within 20km radius. According to year 2004 population censor of Sierra Leone, about 207, 582 people are within the 10km radius of all the processing centers and about 886,365 people are within the span of 20km radius to all the processing centers. This put about 18% of the country's population within the 20km radius of the CFC processing centers. The findings are advantageous to the project in the sense that there is easy access to market product(s) from the centers and no much cost would be incurred on transportation considering proximity of the centers to farms.



Sierra Leone



Benin Republic



Nigeria

Raw material supply lines: Farmers received high yielding disease resistant cassava bundles. Following the introduction of 17 improved cassava varieties from IITA to processing sites in Benin, Hounvi and Amakpa in 2008 and the selection of 12 of these varieties by farmers during the first evaluation in 2009, further evaluation in collaboration with farmers was done in 2010 to select and recommend varieties to farmers in these target sites. Selection emphasized major commercial traits like yield and quality without compromising environmental and safety traits like multiple pest resistance and cyanogenic potential. The average performance of the 12 varieties, harvested 10 months after planting, in the two communities is shown in the table below:

Stem distribution to farmers

Table 1: Farmers Se lection of superior cassava varieties in Demo Trials in Benin

Varieties	No of plants harvested	No of tuberous roots	Average Root Size	Ave. no. of rotted roots	Average Root Wt (t/ha)	Farmers remarks
TME 419	10	70	Medium	0	16.5	Good
95/0289	10	65	Medium	0	15.3	Good
98/0505	10	58	Large	0	22.2	V. good
96/1632	10	55	Medium	0	16.0	Good
92/0057	10	62	Medium	0	16.0	Good
91/02324	10	65	Medium	0	17.0	Good
92B/00061	10	44	Medium	0	16.0	Good
98/0581	10	41	Medium	0	16.8	Good
4(2)1425	10	36	Medium	0	14.5	V. good
92B/00068	10	54	Medium	0	18.0	V. good
98/0510	10	45	Medium	0	14.0	Good
92/0326	10	58	Medium	0	15.6	Good
RB (Local)	10	41	Small	0	9.0	Poor

All the improved varieties produced significantly higher yields than the local check and farmers did not reach a consensus on which varieties should be dropped. They were however able to rank the varieties relative to each other, thus providing a rank sum estimate that was used to select the farmers' best. The following six varieties (TMS 98/0505, 92/0057, 96/1632, 92B/00068, 98/0581 and TME419) were the most preferred by farmers in the two communities.

Farmers selecting their choice varieties

Farmers estimate yield in participatory evaluation

SME for high quality cassava flour (HQCF) for the bakery and confectionery markets

The project enhanced the capacities of CFC SME Factory in Nigeria through: Refurbishment of civil works, repair and replacement of processing machines, setting up of Standard Operating Procedures (SOPs), Good Manufacturing Practices, improved product branding, and production/sales record keeping. An improvement was made on the packaging and storage of the final products (gari and fufu). The products were separately packed in polyethylene sack, stitched and stored on a raised wooden platform. The fufu flour is now packed in well designed 1kg transparent polythene nylon and sealed before sale to the consumers. Gari is also now packed in well designed 5kg polyethylene sack for sale. 100 pieces each of polyethylene sack (5kg) and polythene nylon (1kg) has been designed for the purpose of NAFDAC registration. The facilitation of product standardization process was done by taking samples of gari and fufu for laboratory analysis in IITA Ibadan. This was continued for subsequent production in order to ascertain compliance with standards of the regulatory bodies (NAFDAC and SON).

SME Factory

Upgrading traditional cassava processing plants for defined markets

Appropriate prototypes plants for production of traditional cassava products have been designed validated by users and are feasible for commercial replication. To date, the project had designed, installed and commissioned 13 appropriate prototype plants in Benin, Nigeria and Sierra Leone to enhance capacities of the traditional processors.

Nigeria (2 Processing Sites)	Sierra Leone (6 Processing Sites)	Benin Republic (4 Processing Sites)
Abuja: Kuje Nassarawa State: Lafia	6 Districts: Bo, Makeni, Lunsar, Njala, Waterloo, Walihun	4 locations: Hounvi Amakpa Lantha Adjourmey

Before

The Workers

After: The Farm

The Commissioning

The Factory

The project ensured completion of civil works, equipment procurement/installation and test running, which made the sites ready for commissioning. The MPCs were also painted, not only for aesthetic appeal but also in conformity to the requirement by the regulatory agencies for registration. The commissioning of the sites was also achieved as planned.

Business plans with project beneficiaries

Development and implementation of business plan was found necessary for all the CFC sites in this project. The plan provides an opportunity to determine the viability of these centers and provide sustainability plan afterward. It projects future opportunities for the centers, identifies markets and potential customers and maps out the marketing, operational, organization and management strategies. At the end, the expenditure and finances required for each center were projected in a cash flow analysis, which gave room for the projected revenue and cost over one year period to be synthesized. Information that generated the projections in the business plans was resolved together with the owners of the businesses. Developed business plans for project beneficiaries showed projected return on investment (ROI) of 14.16% to 84.69%.

Project management

One of the most successful components of CFC-WA is the sustainable approach in the co-ordination, monitoring and evaluation, exchange and dissemination of results of various outputs of the cassava value chain development in Nigeria, Sierra Leone and Benin republic. The project Executing Agency ensured adequate caution was taken to ensure efficient and effective implementation of project activities. Country Coordinators and other partners planned and executed commissioning of the processing sites with technical backstopping from the Project Executing Agency (IITA).

Participants at the commissioning Site, 29 June 2010

These attracted dignitaries and cassava stakeholders as well as community leaders, with various speeches that poured more encomiums on CFC-IITA-FAO-NARs for a good gesture to leverage sustainable livelihood of poor resource farmers and processors.

Trainings

Training of trainers was organized for farmers in the project locations on best practices for increasing cassava root yields competitively. The trainings focused on stem handling, density management in sole and intercropping systems, varietal characterization and identification, sustainable land use practices and business opportunities in agriculture. To date, all the commissioned processing sites in all the locations had received operators' on-the-job training on equipment handling, quality safety and maintenance given by the CFC. The trainers developed a training manual for this purpose and key steps in equipment maintenance were pasted on the factory walls for their regular use. Processors also received trainings of production of high quality commercially competitive gari, *and fufu* flour.

Staffs were refreshingly trained on how to peel cassava roots with the complete removal of the peels and how to hygienically handle peeled roots to prevent contamination of mash and finished product. In *fufu* production, use of muslin cloth in wet sieving mash was taught against use of basket for good quality finished product. Staff members were informed of the importance of cleaning before and after use of all the equipment. This was facilitated by the introduction of water hose for flushing the graters and pressers (before and after use) as well as the processing floor.

Capacity building of NARs: In order to enpower the NARC research staff in the measurement of areas and distances in respect of the activities and programmes of the centre and to make such initiatives sustainable, they were trained in the use of the Global Positioning System equipment (GPS).

NARC staff getting theoretical and practical instructions on the GPS

Enterprise management training

Project beneficiaries, Enterprise experts of National partners, and NGOs were trained on concept of micro enterprise, causes of success or failure of micro enterprise, business plan preparation, financial indicators, practical interpretation of completed business plans, business plan analysis, plan to implement the developed business plans and foreseen bottlenecks/constraints. The participants were further enlightened on record keeping and how to go about it. With these new capacities, it was envisaged that the present production capacity of less than 10% would be raised to 40-70% respectively.

Monitoring visits: The FAO supervisory body played very good proactive and passionate contribution towards the successful implement of CFC-WA. The body visited project locations in Benin Republic, Nigeria and Sierra Leone. FAO's timely observations on grey areas to have better project outputs were promptly acted upon by both IITA and other partners. This has led to the current success stories. FAO charged the beneficiaries to take advantage of the opportunities to improve their livelihoods while the PEA was advised about getting a working capital, in form of a loan to assist the beneficiaries in their business.

FAO SB with project beneficiaries in Sierra Leone

Outcome of the CFC Project on the MPCs

The CFC project in Benin especially Houmvi had obviously attracted attention in terms of aids/supports to the community. At the monitoring visit, a building was put up close to the processing centre. It is a piggery house, which the processors claimed to build from the proceeds from their cassava processing business. The beneficiaries said it was their counterpart contribution towards a development project on piggery brought to them by an organization, Eleveurs Sans Frontière. (See pix below) who gave them some pigs to rear. According to them, they used dried cassava peel as feed for the pigs, which they intend to be selling later to earn more money and improve their livelihoods. They also affirmatively said the profit from their cassava processing had been able to improve them economically; they claimed to eat well now, take care of their health needs, clothing and also are able to pay their children's school fees within one year of setting up the centre.

Hounvi piggery house

Lessons Learnt for future project interventions and out-scaling

Conclusion

CFC-WA project has proven once again that with careful planning, implementation and monitoring, project beneficiaries that be empowered to their level of poverty, promote income generation and employment opportunities through cassava value chain system in West Africa.

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Production et utilisation des farines de manioc dans la Boulangerie

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Resume

Le pain, un aliment de tradition, est habituellement fabriqué à partir de la farine de blé, de l'eau, du sel et de la levure. Au cours des dernières années, la consommation de cette denrée alimentaire a connu une augmentation spectaculaire dans plusieurs pays en développement du fait d'une démographie montante, de l'urbanisation et du changement des habitudes alimentaires. Cependant, pour des raisons d'ordre climatique, la plupart de ces pays ne sont pas à même de cultiver du blé. Aussi, dépendent-ils des importations onéreuses au détriment de leurs rares ressources en devises étrangères. Dans ces pays, le prix de la farine de blé est automatiquement augmenté avec le taux de change monétaire, entraînant ainsi une élévation directe ou indirecte du prix des pains. Pour économiser les devises étrangères et diminuer ou stabiliser le prix des pains dans ces pays, il serait donc utile de rechercher une plante présentant de grandes facultés d'adaptation à des situations écologiques variées, facile à cultiver et peut être transformée en farine utilisable dans la boulangerie. C'est dans cette optique que se situe ce travail de recherche, qui a pour objectif spécifique de mettre au point la production des farines de manioc et d'utiliser les farines produites dans la boulangerie. Ainsi, un mode de transformation des racines de manioc en farine la plus panifiable a été identifié. L'influence des trois facteurs technologiques (épluchage : à 2 niveaux ; réduction : à 4 niveaux et fermentation des racines : à 3 niveaux) sur la valeur boulangère des farines produites a alors été déterminée. Pour ce faire, un plan d'expérience factorielle complète 2 x 4 x 3 en blocs aléatoires complets avec 6 répétitions a été employé. Ce plan a permis de produire 24 types de farine de manioc en 6 répétitions, correspondant donc à 144 échantillons. Trois types de pain composite de manioc-blé ont été fabriqués à partir de chacun de ces échantillons de farine de manioc : pains à 10 %, 20 % et 30 % de farine de manioc. En plus de ces trois types de pains composites, un pain témoin à 100 % de farine de blé a aussi été fabriqué chaque jour de panification. Pour évaluer les qualités physiques des pains fabriqués, deux paramètres (hauteur et volume spécifique) ont été mesurés. Les résultats obtenus ont montré que la farine de manioc la plus panifiable a été obtenue à partir des racines épluchées, découpées en cossettes et fermentées dans l'eau. La perspective de substitution partielle de la farine de blé par celle des racines de manioc épluchées, découpées en cossettes et fermentées dans l'eau semble donc intéressante.

Mots clés: Manioc, blé, farine panifiable, boulangerie, valeur boulangère, pain composite.

Introduction

Le pain est un aliment de tradition (Trémolières *et al*., 1968 ; Chiva *et al*., 1999). Il est généralement fabriqué à partir de la farine de blé, de l'eau, du sel et de la levure boulangère. Au cours des dernières années, la consommation de cette denrée alimentaire a connu une augmentation spectaculaire dans plusieurs pays en développement du fait d'une démographie montante, de l'urbanisation et du changement des habitudes alimentaires (Eggleston *et al*., 1993ab). Cependant, pour des raisons d'ordre climatique, la plupart de ces pays ne sont pas à même de cultiver du blé destiné à la panification (Eggleston *et al*., 1993ab ; Bokanga, 1995). Aussi, dépendent-ils des importations onéreuses au détriment de leurs rares ressources en devises étrangères. Dans ces pays, le prix de la farine de blé est automatiquement augmenté avec le taux de change monétaire, entraînant ainsi une élévation directe ou indirecte du prix des pains.

A Madagascar, le pain était, auparavant, consommé par une faible proportion de la population d'une certaine classe sociale (Ranomenjanahary *et al*., 1995). Actuellement, cet aliment est adopté par la majorité du peuple Malagasy. A cause de cette évolution quantitative de la consommation du pain à Madagascar, et du fait de l'insuffisance de la production nationale de la farine de blé, les opérateurs économiques Malagasy sont obligés d'importer des farines de blé. Or, à présent, la monnaie malagasy est fortement dévaluée par rapport aux devises étrangères. Le prix de la farine de blé est alors devenu très cher. Par conséquent, tous les boulangers à Madagascar ont décidé d'augmenter directement ou indirectement le prix de leurs pains de blé.

Pour économiser les devises étrangères et diminuer ou stabiliser le prix des pains dans des pays importateurs des farines de blé comme Madagascar, il serait donc utile de rechercher une autre plante pouvant être transformée en farine panifiable. C'est dans cette optique que se situe ce travail de recherche, qui a pour objectif spécifique de mettre au point la production des farines de manioc utilisables dans la boulangerie. L'objectif général de cette étude est alors de valoriser une autre source de farine, tel que le manioc, une plante présentant de grandes facultés d'adaptation à des situations écologiques variées.

Materiels et Methodes

Matières premières: Des racines de manioc amélioré qui est très populaire au Nigéria, TMS 30572, cultivé sans engrais dans un champ de village Oloyin du Gouvernement Local d'Akinyale, Etat d'Oyo, Nigéria, ont été récoltées après 12 mois de plantation.

La farine de blé, de type commercial, sans additif, achetée à la maison Internationale de l'Institut International d'Agriculture Tropicale, a été utilisée pour réaliser la farine composée de manioc-blé.

Choix du plan d'expérience: Nous avons considéré trois facteurs de transformation des racines de manioc. Ce sont l'épluchage (à 2 niveaux : sans et avec épluchage), la réduction de la taille (à 4 niveaux : réduction en tranches, en cosettes, en chips et en râpure) et la fermentation (à 3 niveaux : sans fermentation, fermentation dans l'eau ou rouissage et fermentation dans des sacs en polyéthylène). Pour déterminer l'influence de ces trois facteurs sur la valeur boulangère des farines de manioc produites, nous avons choisi un plan d'expérience factorielle complète 2 x 4 x 3 en blocs aléatoires complets avec 6 répétitions. Ce plan a permis de produire 24 types de farine de manioc en 6 répétitions, correspondant ainsi à 144 échantillons de farines. Notons que la qualité des pains dépend de la valeur boulangère des farines utilisées. Selon Calvel (1978), la valeur boulangère représente les aptitudes d'une farine à donner un beau et du bon pain.

Récolte et randomisation des racines de manioc: Les racines ont été récoltées manuellement en saison sèche. Les racines déterrées, détachées de leur point d'attache et regroupées par plant ont été randomisées pour minimiser les effets des sources de variations incontrôlables. Pour réaliser cette activité, nous avons utilisé 24 sacs en polyéthylène numérotés S_1 à S_{12} et S'_1 à S'_{12}. Les racines provenant d'un même plant ont alors été reparties individuellement dans des sacs différents. Les racines contenues dans deux sacs ayant des numéros de même indice, comme S_1 et S'_1, constituent un lot de racines correspondant à un type de farines.

Transformation des racines de manioc en farines: Les racines récoltées ont été équeutées, puis épluchées (les autres lots de racines n'étant pas épluchées) et lavées. Les racines ainsi lavées (avec ou sans écorces) ont été réduites en tranches (à l'aide d'un couteau), en cossettes (à l'aide d'un couteau), en chips (au moyen d'une machine à chips) et en râpure (au moyen d'une râpe motorisée). Les produits ont ensuite été fermentés durant 72 h dans l'eau de volume V (en litres), déterminé à l'aide de la formule $V = 3\ M$ (M : masse de produits, en kg) ou dans des sacs en polyéthylène ; les autres lots de tranches, de cossettes, de chips et de râpure n'étant pas fermentés. Tous les produits humides ont été séchés au soleil sur des morceaux de plastique noir placés dans des plateaux de séchage numérotés (100 cm x 60 cm x 5 cm) fabriqué en bois. La densité initiale de chargement des produits a été fixée à 5 kg/m^2, ce qui correspond à 2,6 kg de produit humide par plateau. Les plateaux de séchage (au nombre de 150) ont été placés sur des supports (180 cm de long, 100 cm de large et 80 cm de haut) qui sont au nombre de 50 et fabriqués en bois. Chacun de ces supports (avec trois numéros) porte donc trois plateaux de séchage. Les produits secs ont été mis dans des grands sachets blancs en polyéthylène codés, puis abandonnés dans une chambre (température : 27 ± 1°C ; humidité relative : 50 % à 70 %) jusqu'au moment de leur transformation en farines à l'aide d'un broyeur électrique à marteaux fixes.

Randomisation des types de farine de manioc en vue des tests de panification : Avant de faire des testes de panification, et pour minimiser les effets des sources de variations incontrôlables, nous avons randomisé les 24 types de farine de manioc produites par répétition de l'expérience selon un plan de type ALPHA.

Tests de panification: Trois types de pain composite de manioc-blé ont été fabriqués à partir de chaque type de farine de manioc : pains à 10 %, 20 % et 30 % de farine de manioc. En plus de ces trois types de pains composites, un pain témoin à 100 % de farine de blé a aussi été fabriqué chaque jour de panification. La formulation de la pâte boulangère et les procédés de panification utilisés sont ceux d'Onabolu *et al.* (1998). Selon notre plan de type ALPHA, 13 ou 16 pains ont été fabriqués par jour de panification.

Evaluation de la qualité des pâtes boulangères: Les propriétés mécaniques et les propriétés de levage des pâtes boulangères durant les procédés de panification ont été observées et notées. A la fin du pétrissage et durant le façonnage, les propriétés mécaniques des pâtes ont été notées en utilisant l'une des deux expressions suivantes : non collante et façonnable manuellement ; collante et non façonnable manuellement. Mais, à la fin de l'apprêt, les propriétés de levage des pâtes ont été notées en employant l'une des trois expressions suivantes : bonnes (lorsque le gonflement de la pâte est très remarquable) ; moyennes (lorsque le gonflement de la pâte est peu remarquable) et mauvaises (lorsque le gonflement de la pâte est non remarquable).

Caractérisation des pains fabriqués: Après une heure de refroidissement à la température ambiante, chaque pain fabriqué a été pesé, puis son hauteur a été mesurée selon la méthode de Roussel (1984). Le volume de chaque pain a ensuite été estimé par déplacement de grains de colza dans un récipient gradué, puis son volume spécifique (exprimé en cm^3/g) a été déterminé à partir de son volume et de sa masse.

Analyses statistiques des données obtenues: Nous avons utilisé un progiciel SAS pour analyser les données obtenues.

Resultats

Caracteristiques technologiques des pains fabriques: Les hauteurs et les volumes spécifiques des pains composites de manioc-blé fabriqués sont respectivement donnés aux **tableaux 1** et **2**. Nous avons constaté que la hauteur et le volume spécifique des pains composites diminuent lorsque le taux d'incorporation de la farine de manioc est augmenté. Pour un même taux d'incorporation, les pains ayant une hauteur et un volume spécifique les plus élevés sont ceux qui contiennent de la farine des cossettes de manioc sans écorces rouies. Dans ce cas, par contre, les pains ayant une hauteur et un volume spécifique les plus faibles sont ceux qui incorporent la farine des tranches avec écorces et fermentées dans un sac en polyéthylène.

Discussion

Influence de l'epluchage des racines de manioc sur la valeur boulangere des farines produites: La hauteur et le volume spécifique des pains composites de manioc-blé sont fortement affectés par l'épluchage des racines de manioc ($P = 0{,}0001$). La pâte contenant la farine des racines épluchées est plus extensible et gonfle mieux lors des fermentations (pointage et apprêt) et de la cuisson que celle contenant la farine des racines non épluchées. C'est ainsi que, lorsque les modes de réduction et de fermentation des racines de manioc sont identiques et pour un même taux d'incorporation de la farine de manioc, le pain composite contenant la farine des racines épluchées est plus haut et plus volumineux que celui qui renferme la farine des racines non épluchées (Tableaux 1 et 2). Ces différences peuvent être attribuées à la quantité de gaz carbonique retenu qui est la plus importante dans la pâte contenant la farine des racines épluchées. Ces gaz carbonique sont formés durant le pointage et l'apprêt à cause de la fermentation des sucres présents dans la pâte sous l'action des enzymes des levures (*Saccharomyces cerevisiae*). Le gonflement de la pâte boulangère durant la cuisson est dû à la dilatation des gaz retenus et à la vaporisation de l'eau contenue dans la pâte (Cheftel et Cheftel, 1976 ; Trémolières *et al.*, 1968). Ainsi, la hauteur et le volume spécifique des pains sont théoriquement les plus élevés lorsque la quantité de gaz retenus dans la pâte est la plus élevée. Or, le pouvoir fermentaire de la pâte boulangère c'est sa capacité à retenir le gaz carbonique dégagé durant la fermentation opérée par de la levure (Delhaye *et al.*, 1984). Le pouvoir fermentaire de la pâte de farine des racines épluchées est donc plus élevé que celui de la pâte de farine des racines non épluchées. La farine des racines épluchées est alors plus panifiable que celle des racines non épluchées.

La fermentation panaire est étroitement dépendante de la composition de la farine ou de la pâte boulangère (Reed et Peppler, 1972). Les constituants solubles de la pâte boulangère peuvent jouer un rôle important dans la fermentation panaire : apporter des aliments à la levure, augmenter la pression osmotique, être directement inhibiteur (Delhaye *et al.*, 1984). Ainsi, les écorces des racines de manioc contiennent probablement des substances qui peuvent ralentir la multiplication de la levure durant la fermentation de la pâte boulangère. Cela entraîne une faiblesse de la quantité de gaz carbonique retenus dans la pâte. En effet, pour des modalités de réduction et de fermentation des racines identiques et pour un même taux d'incorporation, la hauteur et le volume spécifique du pain à farine des racines non épluchées sont généralement plus faibles que ceux du pain à farine des racines épluchées (**Tableaux 1** et **2**). L'épluchage des racines de manioc, qui élimine les substances responsables du ralentissement de la multiplication de la levure, provoque donc une augmentation de la valeur boulangère de la farine produite.

Influence de la reduction de la taille des racines de manioc sur la valeur boulangere des farines produites: La hauteur et le volume spécifique des pains composites de manioc-blé sont fortement influencés par le facteur « Réduction de la taille des racines de manioc » ($P = 0{,}0001$). Cependant, ses effets ne sont pas suffisants pour qu'il puisse être considéré comme ayant un rôle déterminant, car les facteurs « Epluchage » et « Fermentation des racines » jouent aussi des rôles très importants. L'interaction du facteur « Réduction » avec d'autres facteurs choisis détermine donc probablement la valeur boulangère des farines produites et, par conséquent, de la qualité des pains composites de manioc-blé fabriqués. D'ailleurs, les effets des interactions des facteurs « Epluchage x Réduction », « Réduction x Fermentation », « Epluchage x Réduction x Fermentation » et « Réduction x Fermentation x Substitution » sur les deux paramètres mesurés sont significatifs.

Influence de la fermentation des racines de manioc sur la valeur boulangere des farines produites: La hauteur et le volume spécifique des pains composites de manioc-blé sont fortement affectés par le facteur « Fermentation des racines de manioc » ($P = 0{,}0001$). Ils varient donc selon le mode de fermentation des racines de manioc. Les farines des tranches, des cossettes et des chips fermentées dans l'eau sont plus panifiables que celles des tranches, des cossettes et des chips non fermentées. La farine des chips fermentées dans un sac en polyéthylène est aussi plus panifiable que celle des chips non fermentées. Toutefois, celle des cossettes sans écorces et fermentées dans l'eau est la plus panifiable. En effet, pour un même taux d'incorporation, les pains composites ayant une hauteur et un volume spécifique les plus élevés sont ceux qui contiennent de la farine des cossettes sans écorces et fermentées dans l'eau (Tableaux 1 et 2). Les pâtes boulangères incorporant jusqu'à 30 % de farine issue de ces cossettes lèvent bien lors des fermentations et de la cuisson ; elles sont comparables à celles obtenues avec 100 % de farine de blé. Ces résultats s'expliquent par le fait que la combinaison de la fermentation dans l'eau ou rouissage et du séchage solaire modifie les propriétés rhéologiques de l'amidon de façon à augmenter son aptitude à l'expansion (Dufour *et al.*, 1995). De plus, le rouissage et le séchage solaire permettent à l'amidon de manioc d'acquérir un pouvoir de panification (Chuzel, 1992 ; Chuzel *et al.*, 1995). Cette expansion est due à l'adsorption des molécules organiques formées durant le processus de fermentation (essentiellement de l'acide lactique) dans les granules d'amidon (Camargo *et al.*, 1988). La désorption de ces molécules organiques durant la cuisson conduit une force pour l'expansion (Camargo *et al.*, 1988). Le rouissage des tranches, des cossettes et des chips ainsi que la fermentation des chips dans un sac en polyéthylène, suivis d'un séchage solaire entraînent donc une augmentation de la valeur boulangère des farines de manioc.

En revanche, pour un même taux d'incorporation et lorsque les racines sont épluchées ou non, les pains composites ayant une hauteur et un volume spécifique les plus faibles sont ceux qui incorporent la farine des tranches ou des cosettes fermentées dans un sac en polyéthylène (Tableaux 1 et 2). La farine de ces produits est donc la moins panifiable. Les pâtes incorporant la farine de ces produits sont de mauvaise qualité, car elles sont collantes, non façonnables manuellement, ne gonflent pas durant la fermentation et se sont affaissées dans le four. La médiocrité de ces pains composites est probablement due aux détériorations physiologiques et microbiologiques que subissent les tranches et les cossettes durant la fermentation dans des sacs en polyéthylène. Elle peut aussi être en rapport avec la teneur en amidon endommagé, car une farine contenant trop de grains d'amidon endommagés est souvent impropre à la panification (Cheftel et Cheftel, 1976). Il semble donc que les farines des tranches et des cosettes fermentées dans des sacs en polyéthylène soient très riches en amidon endommagé. Ainsi, la fermentation des tranches et des cossettes dans des sacs en polyéthylène entraîne une diminution de la valeur boulangère des farines de manioc.

D'une manière générale, la fermentation de la râpure (par rouissage ou dans un sac en polyéthylène) provoque également une diminution de la valeur boulangère de farine de manioc. Celle-ci peut être attribuée à l'élévation de la teneur en amidon endommagé de la farine obtenue. La combinaison du râpage et du rouissage ou de la fermentation dans un sac en polyéthylène provoque donc, probablement, un endommagement d'une bonne part de granules d'amidon.

Conclusion et recommandations

A l'aide d'un dispositif expérimental de type factoriel complet en blocs aléatoires complets, il a été possible de déterminer l'influence de trois facteurs, l'épluchage, la réduction et la fermentation des racines de manioc, sur la valeur boulangère des farines produites. Nous avons pu ainsi montré que ces facteurs influent significativement sur la valeur boulangère de farine produite, mais les plus influents sont l'épluchage et la fermentation. L'épluchage des racines de manioc provoque une augmentation de la valeur boulangère de farine produite. Le rouissage des tranches, des cossettes et des chips ainsi que la fermentation des chips dans un sac en polyéthylène entraînent aussi une augmentation de la valeur boulangère des farines de manioc. Par contre, la fermentation des tranches et des cossettes dans des sacs et la fermentation de la râpure (dans l'eau ou dans un sac) provoquent une diminution de la valeur boulangère des farines de manioc. Le dispositif expérimental choisi a également permis d'identifier un mode de transformation des racines de manioc en farine la plus panifiable. Il est composé des procédés suivants : l'équeutage, l'épluchage, le lavage, le découpage en cossettes, la fermentation dans l'eau pendant 72 h, l'égouttage durant une nuit, le séchage solaire durant quatre jours, le broyage et le tamisage. Ainsi, la perspective de substitution d'une partie de la farine de blé par la farine de manioc obtenue après l'application de ces différents procédés sur les racines de manioc semble intéressante. Elle peut donc être intégrée dans la politique de valorisation des cultures locales afin de produire des pains à moindre coût.

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Tableau 1: Hauteur (moyenne), en cm, des pains composites contenant des farines obtenues après différents traitements technologiques des racines de manioc TMS 30572

MODES DE REDUCTION DES RACINES DE MANIOC	SANS EPLUCHAGE DES RACINES			AVEC EPLUCHAGE DES RACINES			TAUX D'INCORPORATION DE LA FARINE DE MANIOC (%)
	Sans fermentation	Fermentation dans leau	Fermentation dans des sacs	Sans fermentation	Fermentation dans leau	Fermentation dans des sacs	
Réduction en Tranches	8,75	8,75	7,33	8,68	8,98	7,95	10
	7,55	8,1 8	4,92	7,83	8,44	6,62	20
	6,42	7,02	4,40	7,20	7,68	5,23	30
Réduction en Cossettes	8,32	9,02	8,04	8,64	9,13	8,12	10
	7,82	8,22	6,32	8,00	8,30	6,40	20
	6,83	7,04	5,38	6,50	7,42	5,40	30
Réduction en Chips	8,13	8,55	8,68	8,20	8,97	8,80	10
	7,40	7,68	8,05	7,42	8,05	8,15	20
	6,55	6,55	7,07	6,10	7,00	7,18	30
Réduction en Râpure	8,64	8,45	8,65	8,98	8,87	9,10	10
	7,78	7,43	7,75	8,08	8,17	8,42	20
	6,80	6,22	6,85	7,05	6,87	7,22	30

Tableau 2: Volume spécifique (moyenne), en cm^3/g, des pains composites contenant des farines obtenues après différents traitements technologiques des racines de manioc TMS 30572

MODES DE REDUCTION DES RACINES DE MANIOC	SANS EPLUCHAGE DES RACINES			AVEC EPLUCHAGE DES RACINES			TAUX DINCORPORATION DE LA FARINE DE MANIOC (%)
	Sans fermentation	Fermentation dans leau	Fermentation dans des sacs	Sans fermentation	Fermentation dans leau	Fermentation dans des sacs	
Réduction en Tranches	4,84	4,75	4,11	4,81	4,86	4,54	10
	4,05	4,36	2,80	4,24	4,60	3,77	20
	3,33	3,63	2,56	3,73	3,92	2,89	30
Réduction en Cossettes	4,55	4,91	4,26	4,68	5,15	4,48	10
	4,14	4,38	3,48	4,20	4,54	3,51	20
	3,51	3,60	2,82	3,46	4,01	2,96	30
Réduction en Chips	4,40	4,61	4,72	4,56	4,86	4,73	10
	3,92	4,01	4,37	3,89	4,36	4,39	20
	3,29	3,34	3,75	3,25	3,56	3,86	30
Réduction en Râpure	4,94	4,52	4,69	4,91	4,78	4,90	10
	4,24	3,75	4,16	4,36	4,35	4,47	20
	3,64	2,97	3,45	3,90	3,52	3,88	30