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High quality cassava flour, promising raw material for bread, biscuit and pastry industries: lessons from a pilot study in Madagascar

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Abstract

Cassava is the second most important staple crop in Madagascar after rice, in term of production volume and area cultivated. Traditional cassava processing techniques are rudimentary and provide insignificant market opportunities to the smallholder cassava farmers. On the other hand, market survey showed that the high price of wheat flour in the retail market high, 0.9 to 1.08 US$ per kg, and bakers desired a substitute raw material. The potential market demand for High Quality Cassava Flour (HQCF) by local bakeries, a biscuit factory, and the caterers in Antananarivo was about 9,400 tons a year. A project to vertically integrate the cassava sector through the processing and supply of HQCF to bakers was implemented in Madagascar from 2003 to 2007. The HQCF technology was introduced at pilot-scale to farmers in Ambatomanoina locality of Madagascar. The technology introduction was accompanied with training of farmers in all aspects of business enterprise management. The pilot farmers produced 24.3 tons of high quality cassava flour a month from the first year. Annual cost of production for HQCF was estimated at US$ 17,328. Profitability analysis revealed profit about US$ 18,783.

Keywords: Cassava, high quality cassava flour, profitability index, French bread, biscuit, pastries.

Introduction

The cassava is the second most important staple crop after the rice in Madagascar. Annual production and area harvested are 2.4million tons

and 357,370 ha per year respectively while the total value of cassava produced in 2007 was about US$173 million (FAO, 2009). In the past, cassava was a neglected crop considered as food for poor. During the last 15 years, the attention of Malagasy government was draw to the importance of through the research and development work on cassava by the regional networks such as the East African Root and Tubers Network (EARRNET) and Postharvest and Marketing Research Network for Eastern and Central Africa (FOODNET). Political support for the development of cassava has therefore been strong and national taskforce was formed to further popularize cassava production and utilization in Madagascar (UPDR, 2008). In line with government objectives of increasing the utilization of cassava, a pilot test was carried out in Madagascar with a group of smallholder farmers, processors and a biscuit factory from 2004 to 2007 to evaluate the technical and economic feasibility of the high quality cassava flour technology (HQCF) developed in 1995 by the International Institute of Tropical Agriculture (Abass et al, 1998, 2009). A market led approach was used to establish link between smallholder cassava farmers, new generation of cassava processors in Ambato-manoina village using the new processing technology and machinery, end-users of the HQCF and marketers who are based in Antananarivo, the capital of Madagascar. The lessons from the pilot activities were used by the national project implementation agencies for policy advocacy, strengthening of the cassava sector through supports to all categories of stakeholders along the cassava value chain, dissemination of results and out-scaling. This paper reports the organization of the pilot activities, results obtained and the lessons learned during the pilot testing.

Methodology for pilot plant set-up

The technology for production and use of HQCF was new to Madagascar. There were no processors of HQCF, and bakers had no knowledge of use of HQCF for baking. A step-wise approach was adopted for the establishment of the pilot operation in a village near Antananarivo to ensure market access by the smallholder processors since more than 92% of total wheat imported is utilized for baking bread and biscuits, and for making pastries and the largest number of bread bakers, caterers and the main biscuit factory in Madagascar are located in Antananarivo. The steps include an analysis of the cassava value chain and the market. Information from the analyses was used for the strategy formation. The strategy formulation involved *i*) sensitization of smallholder farmers on the need to develop their capacity to process the highly perishable cassava into an easy to store commodity that meets the quality and quantity requirements of end-users, *ii*) importance of and group formation, *iii*) sensitization of potential end users and market formation, *iv*) partnership building for pilot system set-up, *v*) training of farmers, processors and end-users, *vi*) marketing strategy development and market linkage, vii) fostering of relationships between processors and end-users. The lessons from the pilot activities were used by the national project implementation agencies for policy advocacy, strengthening of the cassava sector through supports to all categories of stakeholders along the cassava value chain, dissemination of results and out-scaling.

Analysis of the cassava value chain, market analysis

A study by Mbwika (2000) to gain an understanding of what was the status of the cassava industry in Madagascar in order to identify the technological and policy environment in which the sub-sector operates, information gaps and constraints in the sub-sector, opportunities for immediate investment and research programming found that cassava is grown all over Madagascar. It is the main staple food in the Southern parts. About 70% of cassava produced in Madagascar is consumed directly at home by the smallholder producers, 16% is marketed, and 11.5 % is used as food reserve and 3% as animal feeds. Previous studies showed that during the colonial days, cassava was a cash crop mainly grown as a plantation crop and processed into cassava chips, which were exported to Europe for manufacture of animal feeds. Cassava is now a smallholder crop intercropped with beans and considered a poor man's food crop. Cassava mosaic disease, lack of clean planting material, poor agronomic practices, limited processing technologies and lack of market have been identified as major constraints of cassava in Madagascar leading to a decline in total production. Marketing of cassava is largely unorganized. The limited processing technologies and labor intensiveness at the home/ cottage level contributes to the limited market access after the collapse of export oriented processing plants. The main stakeholders in the cassava sector were identified as farmers, household processors and traders of dried chips, flour, crisps and starch.

Secondary stakeholders include; NGOs, researchers, extension agents, root-crop networks, donor agencies and policy makers. However, links between these stakeholders, particularly between producers and potential users of cassava based products such as the livestock feed industry, pharmaceutical industry, and flour millers were not established. Cassava has a relatively higher potential to feel the food supply gap in Madagascar due to its high food yield. Although cassava occupies only about a third of the area occupied by rice, its production is more than half of rice. The predominant processing of cassava in Madagascar is through sun-drying of the peeled or unpeeled roots and milling to flour which is sold in local markets by retail traders and used for preparation of different dishes and products. Processed products of cassava compete in market with products from cereals but lowering costs of production is a key factor in enhancing their competitiveness. The virulent form of cassava mosaic disease is devastating cassava production in Madagascar. However, there were only two agencies involved in the multiplication of planting materials in few locations in Madagascar. These were Care International in collaboration with FOFIFA and in Mid-West by PMMO. The major challenge in the promotion of high-yielding technologies for cassava is the lack of market to absorb excess production. At the same time, a number of industries expressed interest in use of cassava in their production processes. However, the level of potential demand for cassava products in the industry and the consumer perception of use of cassava in industrial products were not established as was done in Uganda, Nigeria and Ghana where the quality of cassava raw materials and consistency of supply have been established to be constraints in the industrial use of cassava starch and flour (Abass et al 1998; Graffham, *et al*., 1999). Research into appropriate processing technologies for increasing the quality of cassava products and their shelf life have been requested in Madagascar (Mbwika, 2000). Policy measures that give recognition to cassava as both a food crop and commercial crop were identified as a way to increase market for cassava. These was to encourage food processing industry such as flour millers and confectionery manufacturers to get involved in the use of cassava products, sale in supermarkets and in retail outlets in ready to cook/eat forms.

Previous attempts to link farmers with potential markets were not successful, the potential market demand for cassava, the quality and the type of products needed by each market segment were not established. The negative image of cassava among some social groups as a poor man's food contributes to its poor acceptance as a suitable raw material by some end-users. The problem is further compounded by the poor policy support and lack of public awareness on the importance of cassava. There were also concerns about nutritional value of cassava and the potential negative health effects cassava foods could cause due to residual cyanide if not properly prepared. The bulkiness of cassava and poor road and transport infrastructure hinders marketing efficiency. Processing technologies that minimize the processing time and reduce the bulkiness of cassava are needed to increase utilization and improve marketing efficiency, particularly if the technologies would increase the range of cassava products, enabling consumers to have a wide range of choices.

Strategy formation and pilot operation

Sensitization of smallholder farmers, group formation, and partnership building for pilot system set-up

Ambatomanoina village was selected to establish the pilot activity because of the nearness to Antananarivo; it is located northeast of Antananarivo, has the highest number of smallholder farmers and is the largest cassava producing village around Antananarivo. Annual cassava production in Ambatomanoina village is up to 44,000 tons annually. A group of twenty resource poor farmers, Cooperative Aintsoa, was selected at Antananarivo village for the pilot testing of HQCF technology. The farmers were sensitized on the potential benefits of processing cassava into novel products for use by a diverse range of end-users. Partnerships were formed with national and international institutions, NGOs, etc to establish the pilot processing plants. The Ministry of Agriculture leased a building to the farmers' group to be used as processing center. The building, 180 m^2, was designed and renovated to have an office (3.8 x 3.8 m^2), peeling and processing area (150 m^2) including a washing basin (0.5 m^3); and a store (6.0 x 4 m^2). A deep well was dug by Rano Fisotro Fidiovana (RFF). Processing machines, a grater, press, and mill were installed and the maintenance was handled by Ecole Supérieure Polytechnique of Antananarivo. An extension office from the Ministry of Agriculture was responsible for coordination of most of the activities

Training of farmers and processors

The twenty (20) members of Cooperative Aintsoa were trained on high quality cassava flour processing, quality assurance and hygiene as described by Onabolu *et al* (1998) and Dziedzoave et al (2006). Pilot operation for processing fresh cassava to HQCF was initiated by helping processors to get used to the manufacturing process including the use and cleaning of processing equipments, training to optimize processing operation targeting the installed capacity of 20 tons HQCF per month (Figures 1 & 2). Selected members of the group were trained on food factory management, covering bookkeeping, how to maintain the machines, yield calculations, raw material handling, factory cleaning/hygiene, personal hygiene, etc. The pilot farmers were also trained on basic principles of business management, market identification, entrepreneurial skills, leadership, business ethics, business planning, marketing, record keeping, costing and pricing. In order to increase product quality, the group was also trained on product quality, grading, and food standards. The book on "Methods for Assessing Quality Characteristics of Non-Grain Starch Staples" (Bainbridge, et al 1996)" was made available by the Natural Resource Institute and used for setting up quality control measure for HQCF at the pilot centre.

Figures 1 and 2: Small-scale processing of HQCF

Ensuring consistent supply of fresh cassava

The East Africa Root-crop Research Network (EARRNET) and the pilot group in collaboration with the extension service of Ambatomanoina established a cassava multiplication site. Sixty (60) new IITA clones were planted on a farm owned by the corporative group near the pilot center with the objectives of selecting the most adapted variety for Ambatomanoina and appropriate for HQCF processing. Ambatondrazaka, one of the IITA cultivars adapted to Madagascar was one of the disease tolerant clones multiplied on the farmers' field. At evaluation, nine clones gave higher yields compared to the local land races and have more tolerance to diseases. The clones were TMS 40160 P6-1, TMS 85/00066, TMS 84776, TMS 81/00110, TMS 91934, and TMS 31/01635. The selected clones were replanted on the farm to serve as both a source of planting materials for more individual farmers and a model for commercial planting material production in order to solve the problem of lack of planting materials.

Sensitization of potential end users, training and market formation

In order to increase market opportunity for HQCF, bread bakers needed to be convinced about suitability of HQCF for bread baking with the hope that demand for the products would thereby be created. Three trials on bread baking with cassava flour (15% of substitution) and training of bakers on how to use HQCF were carried out with a local bakery called Boulangerie d'Avaradrano with the participation of members of Association des Boulangers Professionnels (bakers association). Loaves of bread baked were used to determine the perception of bread baker on the use of HQCF.

Marketing strategy development and market linkage through fostering of relationships between processors and end-users

Meetings were organized between farmers, processors and potential end-users. The meeting enabled the farmers' group (Cooperative Aintsoa) and the end-users, Biscuiterie JB and Association des Boulangers Professionnels, to discuss all issues relating to cassava flour production, quality, supply, prices and payment systems. Bread and biscuit bakeries were willing to accept the HQCF as a raw material because the high price of wheat flour while the government pegged the price of loaf of bread at about US$ 0.1. Consequently, bread bakers have reduced loaf volume to the

disappointment of consumers, which resulted to low demand. As a marketing strategy, the price of HQCF was set at maximum of 75% of the price of hard wheat flour used for bread baking. The farmers' group was of the opinion that members would be comfortable if they were able to sell HQCF at about 1,000 Ar (US$0.5) which is 62.5% of the price of bread flour 1,600 Ar (US$0.8). The collaborating biscuit factory, BISCUITERIE JB, had use wheat flour for biscuit baking wafer manufacture. 1-2 t of wheat flour (8-10% protein, 9% gluten) was used daily for wafers while 8-10 t/day of soft wheat flour was used for biscuits. Baking tests were done with the biscuit factory to determine potential inclusion rates. Test results showed that wheat could be substituted with cassava in the two product lines up to 25%. Hence the company planed to use 2-4 t HQCF in wafers and 10 t in biscuits per month.

Profitability analysis of small scale processing of cassava to HQCF

In order to fully evaluate the economic viability of the pilot operations, data collection at the pilot processing center, from farmers supplying fresh cassava to the plant and traders around the pilot area was undertaken by the Département Industries Agricoles et Alimentaires of l'Ecole Supérieure des Sciences Agronomiques d'Antananarivo. The techniques used for the economic feasibility study has been described by Abass *et al* (2009).

Results and lessons learned

The estimated potential market in Antananarivo was about 9,400 tons a year (Anonym, 2006). Bread bakers and biscuit factories are the main users of wheat flour. In fact, the Institut National des Statistiques showed that the average consumption of French bread by Malagasy was 50 g per day (INSTAT, 2007). Therefore substitution of wheat with HQCF would add value to cassava, to create jobs and to save foreign exchange for Madagascar.

The small-scale HQCF processing technology was easily adaptable by the pilot farmers. The production capacity of the processors grew from 1 ton fresh root (250kg flour) daily during the first month to 8 - 10 tons per day before end of first year. The characteristics of the high quality cassava flour produced by the pilot farmers/processors include 160 µ particle size, 10-15% moisture and less than 10ppm cyanogens.

Profitability analysis of the pilot operation shows that the total capital investment was US$ 5,680 which includes steelyard, cassava grater, press machine, flour milling machine, water supply system, renovation, etc. The total investment for 10 years periods which includes the maintenance and an interest (10% p.a) was US $ 11, 928 (Table 1).

Table 1: Profitability and return to labour for intermediate processing, for 10 years with 250 tons of high quality cassava flour per year.

	Cost US $
Initial investment	
Equipment	1,680
Grating	780
Dewatering	900
Building and store	4,000
Total investment for 10 year period	5,680
Maintenance	568
Interest (10 years 10 % p.a)	5,680
Grand Total investment 10 year period	11,928
Annual cost of production	
Fixed cost, depreciation, interest per year	1,193
Labour cost	0.361
Raw material procurement	11,111
Diesel	1,165
Water	0.116
Bags	1,111
Interest on bank overdraft (19% p.a)	2,748
Annual cost production	17,328
Cost of delivery (cost/ton)	5,555
Cost delivery	22,883
Sales price, marked based	41,666
Profit/loss, incl. labour	18,783

The fixed cost, the depreciation and the interest per year were US$ 1,193; the labour cost was evaluated about US$ 0.361. The raw material procurement was estimated about US$ 11,111; while the others costs (fuel, water and bags) were assessed about US$ 3,913. The annual profit in taking account loss and labour was US$ 18,783 (Table 1).

Perception of bread bakers on use of cassava

The trials of utilization of HQCF as substitute for wheat flour in French bread and biscuit baking and wafers production showed encouraging results. Twenty three (23) bakers were involved in the bake tests. Loaves of bread were made at one of the members' bakery (Boulangerie d'Avaradrano) using 10% HQCF in wheat flour (Figures 4, 5 and 6). A taste panel made up of the bakers was constituted to evaluate the cassava-wheat bread

samples: 13.04% of the bakers scored the loaves very pleasant, 52.15% pleasant, 26.08% pleasant enough, and 9.73% no comment.

Figures 4, 5 and 6: French breads, pastry products and biscuits made with HQCF substitution

For biscuits, previous study by Ranaivoson (2000) showed that while 100% HQCF biscuit made with addition of ginger, sugar, powder milk, and vegetal butter was not acceptable to Malagasy tasters, the biscuit was acceptable to foreign tasters (5%). During the current industrial test, biscuits baked with 25% and 50% HQCF and wafers made with 10% HQCF were acceptable to the taste panel (Figure 7). Shortly after the industrial testing, the biscuit factory and bread bakers in Antananarivo began to order for 10-15 t HQCF per month from the pilot farmers. Eight bakeries in Antananarivo have requested for up to 425 tons HQCF per year while pastries makers in Antananarivo might require even more.

Figure 7: Wafers made with 10% HQCF substitution

Challenges

Although well made HQCF was acceptable for bread, biscuit and wafers manufacture, the quality of HQCF was found to be negatively affected by the sun-drying technique. Inadequate sun-energy led to insufficient drying while the HQCF is also contaminated by wind and honey bees, which were found to always invade wet cassava grits during drying. Microbial analysis of a batch of cassava flour produced in Dec 2004 and kept till March 2005 showed that the flour had high loads of microbes. HACCP was carried out to determine sources of contamination, the water source and drying were found to be responsible. On the basis of this experience, the biscuit/wafer factory insisted that a new system of drying must the used to ensure that the microbial load of the HQCF to be supplied to the company would remain low.

Information dissemination andout-scaling

Although few challenges were encountered in the implementation of the pilot activities on HQCF in Madagascar, the activities were successful (http://www.common-fund.org/ Projects? Project_id=3; http://www.common-fund.org/ News?news_id=84).

Several policy makers (Senators, Deputies, Mayors, Special Delegation President) were sensitised about the potential of cassava as income generator for farmers through processing and supply of HQCF to the baking industry. Training on cassava processing and products development

was requested by many policy makers for more groups of processors and end-users across Madagascar. Project experience was shared in different scientific meetings, through newspapers articles, radio program of the extension radio service of the Ministry of Agriculture, and discussions with the private sector. Handbills, posters and a short video titled: The high quality cassava flour of Ambatomanoina were also made and distributed widely. The development of standard for HQCF was identified as critical to improve the image of cassava with end users and to ensure acceptance by the bread bakeries and biscuit factories. In order to further enhance the confidence of end-users to adopt HQCF, collaboration was established with the Bureau de Normes des Madagascar to develop standards for HQCF. Other national institutions and projects, such as the MCA-Madagascar have identified and assisted more cooperative groups to utilize HQCF in biscuit baking, in pastries and mayonnaise production.

Conclusion and Recommendation

The HQCF is a promising raw material for bread bakers, food factories and pastry makers in Madagascar. Majority of poor rural farmers can benefit from a national adoption of HQCF as import substitute for imported raw materials like wheat, starch, etc. On the basis of 10 % import substitution for wheat only, the HQCF could save Madagascar about US$ 5.4 million annually from foreign exchange expenditure. However, such benefits can only be derived with a systematic development of cassava production in Madagascar. Yields are low and the HQCF processing machinery still not known common. The targeted policy and investments to develop the cassava sector through the use of HQCF in the baking industry will benefit the population.

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Development and production of fermented flour from sweet potato (*Ipomea batatas L*) as a potential food security product

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Abstract
Yellow fleshed sweet potato (*Ipomea batatas L*) obtained from a local market in Nigeria was processed into fermented flour via the processes of washing and peeling, chipping (4-5mm thick), soaking in water for 0-96hrs, draining, dewatering, drying at 70^0C for 8hrs in a tray drier and milling into flour (= 250 micron). During the fermentation period, the microbial profile in the fermenting chips as well as the pH changes was monitored. The proximate analysis of the raw potato and the fermented flour were also determined as well as the pasting properties of the fermented flour proximate composition showed that the crude protein and starch content of the sweet potato flour were higher than in the raw sweet potato which were 4.27% and 34.56% respectively for crude protein and starch content in the fermented flour and 1.86% and 23.47% in corresponding sweet potato crops. However, the fat, crude fibre and ash content were significantly lower than in the raw sweet potato crops which were 0.21%, 0.06 and 1.78% respectively for fat, crude fibre and ash content in the flour with a corresponding value of 0.5% fat, 0.73% crude fibre and 2.52% ash in the raw sweet potato. The microbial profile in the fermenting sweet potato revealed that lactic acid bacteria were the predominant fermenting organisms apart from yeast and mould. Also, the pH in the mash reduced as the fermenting days increased while the microbial increased as the fermentation days increased. Pasting properties of the flour also showed that the peak viscousity was attained at 278.67 RVA with pasting temperature of 80.35^0C, pasting time of 5minutes, final viscousity of 391.58 RVA and breakdown

viscousity of 78.53 RVA. The study however revealed the potential nutritional quality of the fermented flour and its utilization as a food security crop.

Keywords: Sweet potato, fermentation, microbial profile, proximate properties, pasting properties.

Introduction

Sweet potato common name applied to perennial, trailing herbs of the morning glory family. The plant, which is native to tropical Americas, is cultivated on sandy or loamy soils throughout many warm regions of the world. Two main types are commonly cultivated, a dry, mealy type and a soft, light - to - deep yellow, moist fleshed type. Sweet potato belongs to the family *Convolvulaceae*. It is a classified as *Ipomea batatas*. It is a hardy crop that thrives in soil that cannot sustain yam production [1, 2, 3, 4].

In the tropics, sweet potatoes are consumed or marketed soon after harvesting because of their shelf life which can be as short as one week [2, 3]. Sweet potato is highly nutritious in terms of Vitamins A and C and minerals such as calcium and potassium [5, 6] than other root crops particularly the dark orange and yellow fleshed varieties [2, 5, 6, 7].

In Nigeria, orange fleshed sweet potato is widely processed into flour and found to attract higher prices by consumers than from other varieties [8, 9, 10]. Sweet potato is well patronized as a daytime snack in schools, offices and in homes [11]. It can also be eaten boiled, fried and roasted form. It can also be sliced, dried in the sun and ground to give flour that remains in good condition for a long time [12]. Sweet potato flour is also used as a dough conditioner in bread manufacturing and as a major raw material in snack and noodles production [13]. It is also used as a stabilizer in the ice cream industry [14]. Sweet potato been processed into prickles [15] and also consumed as lacto-juices by processing it with lactic acid bacteria as the fermenting organism [15]. The juice produced has been reported to be very rich in minerals and vitamins [15, 16]. Sweet potatoes have also been processed into chips in much the same way as Irish potato [17, 18] in Asia. It has been processed into starch which is used in the manufacturing of starch syrup and glucose [19] particularly in countries like Japan. Sweet potato have also been used as a major source of raw material for feed production for piggery [20] particularly in countries like China and Japan etc. the crop also have large potential as a carbohydrate base baby food production [21].

There is however little or no work done on the fermentation of sweet potato into flour suitable as meal for home consumption. This study therefore investigates the possibility of fermenting sweet potato into flour as a means of promoting food and nutrition security in the developing countries. It is believed that a successful development and production of good quality flour will eventually be promoted in the villages where sweet potatoes are grown in abundance. Eventually this product will assist in minimizing postharvest losses associated with sweet potato and ensure increased earnings by sweet potato farmers particularly in the developing countries in Africa. It will also lead to production of novel food products from sweet potato crops thus assisting in minimizing food insecurity problems particularly in the developing countries.

Materials and Methods

Raw materials used: Orange fleshed sweet potatoes were obtained from a local market in Egbeda, Lagos, Nigeria.

Methods: The sweet potato were washed to remove adhering soil particles and peeled. The peeled tubers were chipped into slices (4-5mm) and soaked in portable water for a period of 3 days (72hrs). after this period have elapsed, the fermented chips were drained and dried in a tray drier at 70^0C for about 8-10hrs, milled into flour (= 250 microns)

Proximate composition of raw sweet potato and fermenting flour: This was determined in the raw sweet potato and the fermenting sweet potato flour using established procedure. Parameters such as crude protein, crude fibre, ash, fat, starch, total carbohydrate and energy were determined in the sample [22].

PH determination: The pH of the fermenting chips was determined from day 0 to day 4 using a pH meter which has been previously adjusted with buffer solution of pH 4 and 8 [23].

Isolation of fermenting microorganism: This was determined in the fermenting sweet potato using standard procedure as described by [24] and [32]

Pasting properties: The fermented sweet potato

flour was subjected to pasting property determination using rapid visco analyzer (RVA) method as documented by [25]. Parameters such as pasting temperatures, pasting time, peak viscousity and final viscousity were determined.

Results

Table 1 shows the proximate composition of raw sweet potato and fermenting dried sweet potato flour. The moisture content was high in the raw sweet potato and was 63.19% in the raw tuber and 5.87% in the corresponding dried fermented flour. There was also a reduction in the ash content in the raw tubers from 2.52% in the raw tubers to 1.78% in the dried fermented flour. The crude fibre content was higher in the new tuber which was 0.73% that in the dried fermented flour which was 0.06%. However, the crude protein in the raw tubers was lower (1.86%) than that in the dried flour (4.27%). The Fat content in the raw tuber was 0.59% while it was 0.2% in the dried fermented sweet potato flour. The starch content in the raw tubers was 23.44% and it was 34.56% in the dried fermented flour.

Table 1: Proximate Composition of Dried Fermented Sweet Potato Flour Raw Sweet Potato

Parameter	Dried Fermented Sweet Potato	Raw Sweet Potato
Moisture (%)	5.87	63.19
Ash (%)	1.78	2.52
Crude fibre (%)	0.06	0.73
Crude protein (%)	4.27	1.86
Fat (%)	0.21	0.59
Starch (%)	34.56	23.47

Va lues are average of three determinations

Table 2 shows the microbial activity in the fermenting sweet potato chips. Total viable count increased from 0 to 72 hrs of processing from 4×10^2 to 82×10^6 cfu/g, yeast and mould count also increased from 0 cfu/g at zero hour to 64×10^6 cfu/g at 72hrs. Lactic acid bacteria count also increased from 0 at zero hour to 96×10^6 cfu/g at 72 hrs. However, there was no coliform growth between the zero hour and 72hour of fermentation. The pH reduces from 6.32 at to4.11 at 72hrs of fermentation.

Table 2: Microbial Population of Fermented Sweet Potato and pH Changes

Fermentation Days (Hrs)	Total Viable Count cfu/g	Yeast/ mould Count cfu/g	Coliform Count cfu/g	pH
0	4×10^2	Nil	Nil	6.32
24	17×10^3	5×10^3	Nil	4.61
28	36×10^5	28×10^5	Nil	4.30
72	82×10^6	64×10^6	Nil	4.11

Values are average of three determinations

Table 3 shows the pasting properties of dried fermented sweet potato flour. The peak viscousity in the flour was 278.67 RVA at peak time of 5minutes. The breakdown viscousity was 78.83 RVA, trough viscousity was 199.83 RVA, the final viscousity was 391.58 RVA, set back viscousity was 191.75 RVA and the pasting temperature was 80.35^0C.

Table 3: Pasting Properties of Fermented Sweet Potato Flour

Parameter	Values
Peak 1 (RVA)	278.67
Trough 1 (RVA)	199.83
Breakdown (RVA)	78.83
Final Viscousity (RVA)	391.58
Set Back Viscousity (RVA)	191.75
Peak Time (Mins)	5.10
Pasting Temp (^{0}C)	80.35

Values are average of three determinations

Discussion

The results of the proximate composition of raw sweet potato and fermented dried sweet potato flour showed that a considerable level of water has been removed as the sweet potato was processed from crop to fermented flour (at least 90.71%). Consequently, the moisture content in the fermented dried sweet potato flour was 5.8% which is low enough for storage purpose [26].

Also there was a reduction in the ash content of the fermented dried sweet potato flour as compared with the starting raw sweet potato crop. It is believed that the processes of fermentation as well as drying may have contributed to reduced level of ash content in the fermented flour. It is however possible that some of the available minerals in the raw potato are utilized by the fermenting organisms in the sweet potato mash [27].

Heat produced during the drying operation i.e. drying the fermented mash into dried cake could also bring about a reducing effect on some minerals such as calcium, phosphorus and iron which are strongly negatively affected by heat and this may then result into reduction in the ash content [26]. The crude fibre content of the fermented dried flour was also lower than and that may be due to the activity of the fermenting organisms and on the processing technique employed as the peels have been removed prior to fermentation. The peels may also contribute to the crude fibre of the sweet potato.

The crude protein was higher in the fermented dried sweet potato than in the raw sweet potato possibly due to the concentration effect on drying due to the removal of water [28].

The fat content in the fermented sweet potato was lower than in the raw sweet potato and this may be due to the processing technique used in which after fermentation of the sweet potato, it was pressed mechanically to remove water. During the process of removing water mechanically, fat and other water soluble contents may be released and removed as well. Some microorganisms may also require some level of fat to thrive [27].

The starch content in the dried fermented flour was much higher than in the raw sweet potato and this is likely due to the concentration effect of drying [27].

The microorganism responsible for the fermentation of the sweet potato are identified to be mainly lactic acid bacteria, yeast and mould; with lactic acid bacteria being the predominant micro-organisms. Lactic acid bacteria particularly *Lactobacillus planetarium* have been extensively used in some part of Asia to produce 'Lacto beverage' which have been reported to be highly nutritious [15, 16].

Bacteria, yeast and mould generally require nutrients for growth and development [24, 26] and this may partially account for reduced level of ash content in the fermented flour as compared with the raw sweet potato and may also be partially attributable to process of peeling, washing, soaking in water and the entire fermentation process as well as dewatering of the chips. During the dewatering process, water soluble vitamins and minerals may be leached out [25].

Lactic acid bacteria as well as some yeast and mould e.g. *Geotricum candida* have been reported to be primarily responsible for the fermentation of tuberous crops such as cassava into some commonly consumed fermented products such as 'Gari' ,'Lafun' and Foufou [28,29] which are widely eaten in some countries of West Africa [30]. Lactic acid bacteria apart from mould are the major micro-organisms isolated in the fermenting sweet potato.

The pH changes in the fermenting sweet potato showed that as the time of fermentation increases, the isolated micro-organisms i.e. lactic acid bacteria, yeast and mould as well as the total viable count increased while the pH value decreased from day 0 to day 4. Previous workers on fermented tubers such as cassava have reported that lactic acid as well as some flavouring compounds such as aldehydes (30, 31) was produced during fermentation and that the pH reduction in the fermenting cassava mash was essentially due to the presence of lactic acid bacteria [30-32].

The peak viscousity obtained upon reconstituting the fermented flour was quite high [278.67 RVA] and was lower than that reported for sweet potato starch [30, 33]. The set back and break down viscousity were also high and were 191.75 RVA and 78.73 RVA respectively with a peak time of 5minutes and pasting temperature of 80.35^{0}C. This clearly shows that the fermented flour upon gelatinization will not readily retrograde particularly if it intended for a meal which is desirable for a dough-like meal. The peak time also was low [i.e. 5 minutes] similar to that reported for sweet potatoes starch showing that the starch in the terminated sweet potato flour imbibes water readily gelatinize readily and within 5 minutes a dough-like meal can be obtained which is a desirable quality attribute particularly in terms of convenience for the ultimate consumers of the product. Also the final viscosity obtained for the fermented sweet potato flour was quite high and was comparable to that of the fermented cassava flour [29, 30] but lower than that of the new crop. This shows its potential high suitability for meal as this is a desirable quality attribute for dough like meal which often involves reconstitution of the flour in water, cooking with stemming until smooth dough of desired consistency is obtained [29, 30]. The dough can be ultimately consumed with soups, stews as desired.

This study however reveals the potential of utilizing fermented sweet potato flour as meal and this product could serve as an alternative to fermented cassava flour which is conventionally utilized in form of meal. It can also be included in the menu-list of people living in places where sweet potato is widely grown in abundance. The fermented sweet potato flour could be introduced in the menu-list in places where hunger, food and

nutrition and security is prevalent [5, 8].

Conclusion

It is possible to produce fermented sweet potato flour that is very suitable for human consumption. The process technology involved required minimum processing equipment of fermentation vessels, peeling and chipping equipment as well as a tray/ cabinet dryer. In place of a dryer, sun drying on wooden stands covered with black polyethylene could be used as well as a hammer mill to pulverize the fermented dried chips into flour.

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Storage and nutritional evaluation studies of extruded white yam (*Dioscorea rotundata*) and Bambara groundnut (*Vigna Subterranean*) blends

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Abstract

Two flavoured extruded products were developed by co-extruding yam grits (750 micron) obtained from white yam (*Dioscorea rotundata*) and bambara groundnut flour (250 micron) in 160:40 respectively obtained from white bambara groundnut with added flavouring agents of salt (1 3%) and sugar (4 - 6%) in the feed blends at screw speed of 70rpm, 17.5%, feed moisture and at the barrel temperature of 145°C. The extruded products were packaged in low density polyethylene bag (0.02 micron gauge size) and stored at room temperature (28°C ± 2°C) and at refrigeration temperature (9 ± 2°C) for a period of twenty weeks. The microbiological changes in the extruded products as determined by the total plate under both storage conditions showed that maximum total plate counts were 0.5 x 10^4 and 5.4 x 10^4 cfu/g at 9 ± 2°C and 28 ± 2°C, respectively. Nutritional, the evaluation studies of extrudates were comparable ($p \geq 0.05$) with standard casein diet with minimum crude protein content of 13.51% providing 1707.2 KJ energy per 100g of diet and supported weight gain and growth of laboratory animals.

Keywords: Co-extrude, yam grits, bambara flour, total plate count, nutritional evaluation, weight gain, growth.

Introduction

Extrusion cooking has been described as an important technique for modification and manufacture of a wide variety of traditional and novel foods and food blend[1]. Expanded snack food, ready-to-eat cereals, and dry pet foods are manufactured from cereals and starches by high temperature short time extrusion cooking[2].

Yam (*Dioscerea rotundata*) which is a good source of carbohydrates, vitamins, and minerals[3] as well as same essential amino acids is traditionally eaten in Nigeria as fried yam slices, cooked a boiled a even eaten in roasted form. It is also processed into flour cooked as a stiff porridge called 'Amala' a processed into Instant pounded yam flour. Bambara groundnut is of immense nutritional value to Africans[4] as detailed composition study of the beans showed that they contain up to 24% protein with a good balance of the essential amino acids and relatively high proportions of lysine (6-8%) and methionine (1-3%). The other major component of the beans is carbohydrate which is mainly starch as high as 30%. This crop is often processed into flour, salted with oil added to it, mixed together and steamed in banana leaves and eaten as a snack food popularly kunnu as 'Okpa' in the Eastern parts of Nigeria.

There is, however, need to develop a new product from yam and Bambara groundnut. Consequently, in this work, yam being a rich source of carbohydrate was fortified with Bambara groundnut. The fortified yam products were flavoured with salt and sugar, packaged and stored for storage studies. Also the flavoured fortified extruded yam products were subjected to nutritional evaluation studies in order to determine the nutritive value of the extruded products when they are eventually consumed by experimental animals. The results obtained at this stage, however, will reveal the potential utilization of the flavoured extruded yam-bamabra extrudates as potentials food products for consumers.

Materials and Methods

Materials used: White yam (*Dioscorea rotundata*) was obtained from National Root Crop Research Institute, Umudike, Abia State, Nigeria while white Bambara groundnut was also obtained from a local market in Lagos, Nigeria. Common salt and granulated sugar were obtained from a local market in Lagos, Nigeria.

A laboratory sized single screw extruder (Komet Extruder, 1993 Model Made in Germany) was used in this study requiring a minimum input of 0.2kg as feed raw materials for extrusion cooking.

Extrusion Cooking. Yam grits (<750 micron) obtained by processing white yam through various operations of washing peeling, pre-gelatinizing, drying and milling into grits and Bambara groundnut flour obtained by processing while Bambara groundnuts through processing operations of manual destoning, cleaning, milling into flour (< 250 micron) were co-extruded in a single screw extruder at ratio 4:1 yam grits and bambara flour respectively with added flavouring agents of salt (< 1%) and sugar (23%) respectively. The extrusion cooking process occurred at the screw speed of 70rpm, barrel temperature of 145°C and 17.5% feed moisture. The resulting extrudates were allowed to cool after exiting from the extruder die, packaged in 0.002 micron gauge size high density polyethylene bag and stored at room temperature (28 ± 2°C) and at refrigeration temperature (9 ± 2°C) for storage and nutritional evaluation studies.

Storage Studies

Microbiological analysis of extrudates. The total plate count of the flavoured extrudates was determined using established procedure[5]. One gram of each sample already milled into flour was weighed into 9ml of sterile normal saline solution. The mixture was thoroughly homogenized and diluted serially from 10^{-1} to 10^{-5}. About 0.1ml of 10^{-3} diluted sample was spread evenly with sterile horse stick on each media used, namely Malt extract agar, Maconkey agar (MAC) and Nutrient agar (NA) and incubated at 37°C for a period of 24 hours. The colonies that grew on each plate were then counted manually. The extrudates were stored at room temperature (28 ± 2°C) and in a refrigerator and the microbiological test was done on each sample monthly for a period of twenty weeks to be able to determine their storage stability.

Determination of Trypsin Inhibitor Content of Extrudates

This was determined in the extrudates using the method of Kakade *et al*, 1974. One gram of samples was weighed and 50ml of 0.01N NaOH was added to each sample. The pH was adjusted to 8.8 using 1NHCl to reduce pH to the required level. The sample was allowed to stay for 3hrs and stirred continuously to maintain the sample in suspension.

One ml of extract was withdrawn in 33mls of distilled water for dilution. From the diluted extract, 2mls of the diluted sample was taken and poured into 3 test tubes each. Approximately 2mls of Trypsin solution was added to two test tubes while no trypsin solution was added to the third test tube.

Also, 2mls of distilled water was withdrawn in 3 test tubes and 2mls of trypsin solution was added to the test tube and was not added to the test tube, the sample in the test tube were returned to the water-bath and warmed for 10minutes.

After 10mins, 5mls of BAPA solution (Benzoyl-DL-arginine-p-nitroanalide hydrochloride) was added to all the test tubes, vortexed and warmed again for 10mins. After 10mins, 1ml of Glacial Acetic acid was added to all the test tube and vortexed. Then 2mls of trypsin solution was added to all the test tube except the third test tube that did not contain Trypsin initially.

The samples were filtered using Whatman No 2 filter paper and the absorbance read at 410nm using a spectro-photometer.

Calculation:

$$\text{T.I (mg/g)} = \frac{\Delta \text{ Std} - \Delta \text{ sample X Dilution Factor of Sample}}{0.019 \text{ X Sample Wt (g) X Sample Size (ml)}}$$

Nutritional Evaluation of Products. The nutritional values of the flavoured extruded products (diets) were evaluated using various parameters as stated below:

For proteins the following parameters were computed:

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Weight gain}}{\text{Protein Intake}}$$

$$\text{Net protein ratio (NPR)} = \frac{\text{Weight gain on diet}}{+\text{Weight loss on protein}} - \frac{\text{Free diet}}{\text{Protein intake from diet}}$$

$$\text{Biological value (BV)} = \frac{N_i\ (M_e N_{ef})\ (N_u\ N_{eu}) \times 100}{N_i - N_f}$$

Where Ni = Nitrogen intake
Nf = Faecal Nitroge
Nef = Endogenous Faecal Nitrogen from Rats fed with Diet
Nu = Urinary Nitrogen
Neu = Endogenous Urinary Nitrogen.

Chemical composition of raw materials and flavoured extrudates. The chemical composition of the extrudates determined includes crude protein, crude fibre, carbohydrate by difference and moisture content. These were carried out using established procedures[6].

Total mineral content in the extrudates and faeces was determined by ashing in a furnace at 550°C and individual minerals (calcium, Iron and Phosphorous) were determined in the ash solution on 10% HNO_3 as follows:

Phosphorus by colorimetry using the ammonium phosphate vanadium molybdate method.

Calcium and iron by the ortho-pheno-throline method[7].

Determination of energy: Energy content of the flavoured extrudates (DF_1 and DF_2) as well as the protein free diet was determined by calculation[8, 9] as follows.

Energy value (KJ/100g) = (% Available carbohydrate x 17) + (%protein 37) + (% Fat x 17).

Determination of carbohydrates: Carbohydrate content of samples was determined by difference:

% carbohydrate = 100 (% moisture + % fat + % protein + % crude fiber + % ash)

Determination of protein quality: The biological value (BV), protein digestibility (PD), net protein utilization (NPU), protein efficiency ratio (PER) of the flavoured yam-bambara extrudates DF_1 and DF_2 as well as the casein diet (CD) and protein free diet (PF) were determined according to the methods[10, 11]. Also the method described by Obizoba[12] was employed in determining the mineral digestibility of the extrudates and the other diets. Each extrudate/diet was prepared in bulk and stored at 4°C in the dark. Some weighed quantities were drawn daily and mixed with distilled water into a paste containing 40 50% dry matter before feeding to rats.

Animal and experimental design: Weanling albino rats of the Wister strain were used. Three rats (2 males and 1 female) were assigned to the casein-based diet and each of the yam-bambara extrudates/diet under investigation. Rats were divided into groups with similar average weights (70 $\pm$ 1g) and growth rates and were housed in individual polyethylene metabolic cages in a room at about 28°C and 60% relative humidity and with a 12 hours light/dark cycle.

Rats were fed with the diets (i.e. flavoured extrudates DF_1, DF_2, casein diet and protein free diet) for 7 days (adaptation period) and then for further 10 days (experimental period) during which feed intake were measured. They also received distilled water and libitum and were weighed every 3 days of the experimental period to determine average daily weight gain or loss.

During the last 5 days of the experimental period, daily collections of the total urine and faeces of each rat were made separately, posted together and frozen until analysis. A 0.5ml sample of 4.8M HCl was added to recipients before urine collection to prevent nitrogen loss in the form of ammonia.

Formulation of rat diets: The rat diets casein control and protein free diet were formulated[10]. The various ingredients used include some amino acids such as L -Threorine, DL-Methionine, L-Cystine and L-Lysine, Mineral mix, soya oil, potassium carbonate, magnesium citrate, Zinc sulphate, copper sulphate, vitamin mix and starch. The details of the formulation as shown in Table 1.

Table 1: Formulation of Rat Diets

Ingredients	Casein Diet Control (CD) (gkg^{-1}) DW	Protein free diet (PF) Gkg^{-1}) DW
Amino Acids:	99	-
L Threonire	0.60	-
DL Methionine	1.80	-
L Cystine	1.13	-
L Lysine	1.06	-
Mineral Mix	39.7	39.7
Soya Oil	5.0	5.0
K_2C0_3	5.2	5.2
$MgC0_3$	3.4	3.4
Ammonium (III) Citrate	0.35	-
$ZnS0_4.7H_20$	0.07	0.07
$C0S0_4$	0.02	0.02
Vitamin Mix	1.73	1.73
Starch %	-	98.0

Source: Lape (1994).

Notations of Experimental Samples

DF_1 - Extrudate made from feed containing 160:40 yam grits and bambara flour, respectively with 4g sugar, and 3g salt.

DF_2 - Extrudate made from feed containing 160:40 yam grits and bambara flour, respectively, with 4g sugar and 1g salt.

CD - Casein Diet.

PF - Protein Free Diet.

T9 Extrudates stored under refrigeration condition.

T28 Extrudate stored under ambient condition.

Results

Figure 1 shows the microbiological changes as measured by the total plate count in the flavoured extrudates stored at different conditions of temperature. The microbiological load as measured by the total plate count per gram of sample was generally low in all the samples stored under refrigeration conditions. This shows that temperature has a significant effect on the growth of micro-organisms. Generally as the storage time increased, the measured total plate count at room temperature steadily increased while for samples stored in the refrigerator, there was a much lower rate of increase in the total plate count. The total plate count of the extrudates on week 0 showed that the extrudates had on initial total plate count of 0.2 x 10^4 cfu/g. On storage in high density polyethylene bag (gauge size 0.003gm), there was a steady increase in the total plate count among the extrudates both at room temperature and at refrigeration temperatures. As the storage time further increases to 8 weeks, there was a continuous increase in the total plate count particularly at the room temperature. A similar trend was observed when the extrudates were stored at 12, 16 and at 20 weeks.

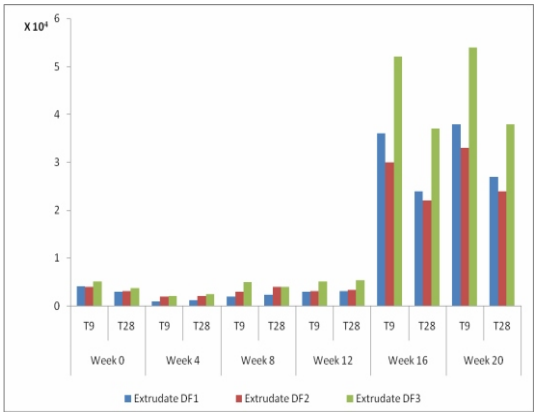

Figure 1: Microbiological changes in stored flavoured yam bambara extrudates

Based on the results, Extrudate DF3 was discarded because of the relatively higher microbial loads when stored under both conditions investigated in this study as compared with the other extrudates (i.e. DF1 and DF2)

Table 2 shows that there was significant difference among all the experimental diets at ($P \leq 0.05$) in terms of the protein concentration in the

different diets fed to the experimental animals with the casein diet (CD) containing the highest value of protein followed by the extrudate/diet DF_1.

Also there were significant differences among the yam-bambara extrudates in terms of the protein concentration in faeces of rats fed with the different flavoured extrudates ($P \leq 0.05$) with the casein diet recording the highest value of protein. This was followed by the protein concentration in the faeces of rats fed with extrudate DF_2 ($0.38gg^{-1}$) followed by extrudate DF_1 ($0.34gg^{-1}$) and lastly by the protein free diet, PF which had a protein concentration in the faeces of the rats of $0.17gg^{-1}$. The study also revealed that in terms of the total protein intake by each rat, there were significant differences between the protein intake in group DF_1, DF_2 and casein diet by the rats fed with the experimental diets ($P \leq 0.05$). However, there were significant differences among the total protein intake by each rat fed with extrudate/diet DF_1, DF_2, CD and PF; which was supposed to be an almost protein free diet ($P \leq 0.05$). However, the casein diet remained the best diet in terms of the total protein intake by the rats as it had the highest mean protein intake value of Diet DF_1 with a mean protein intake value of 7.26g in the fed rats. A mean protein intake of 3.99g was obtained for extrudate/diet DF_2 while the least protein intake value of 0.11g was obtained for the protein free diet. A maximum protein intake of 8.97g was recorded in the casein diet used in this study.

Generally there were significant differences ($P \leq 0.05$) among the extrudates and diet fed to the experimental animals in terms of feed consumed, faeces excreted, urine excreted and weight gain in the rats. Flavoured extrudate DF_1 was better consumed by the animals than flavoured extrudate Df_2.

In terms of faeces excreted rats fed with extrudate/diet DF_2 had the highest excreted faeces followed by extrudate DF_1. In terms of urine excreted, rats fed with extrudate DF_2 produced the highest level of urine followed by the rats fed with flavoured extrudate DF_1. It appears that flavoured extrudates/diet (DF_1) is better than flavoured extrudate/diet (DF_2) from the standpoint of feed consumed, faeces excreted and weight gained by the laboratory animals during the study.

Table 2: Nutritional qualities of yam-bambara extrudates

	Extrudate DF1	Extrudate DF2	Protein Free Diet	Casein Diet
Feed Consumed (g)	52.00 ± 0.02	45.30 ± 0.02	42.33 ± 0.02	53.67 ± 0.02
Weight Gained (g)	5.70 ± 0.03	4.88 ± 0.02	2.47 ± 0.02	5.20 ± 0.02
Protein Concentration in Urine (g/100ml)	0.69 ± 0.03	0.50 ± 0.01	0.81 ± 0.01	0.47 ± 0.03
Volume of Urine (ml)	21.33 ± 0.12	23.66 ± 0.10	12.87 ± 0.03	19.00 ± 0.01
Protein Concentration in Feaces (g/g)	0.38 ± 0.02	0.34 ± 0.01	0.17 ± 0.01	0.48 ± 0.01
Weight of Feaces Excreted (g)	5.11 ± 0.01	5.46 ± 0.01	3.43 ± 0.03	5.07 ± 0.40
Total Protein Intake (g)	7.26 ± 0.02	3.32 ± 0.02	-	8.75 ± 0.10
Protein Concentration in Different Diet (gg^{-1}diet Weight)	0.73 ± 0.03	0.69 ± 0.01	-	0.96 ± 0.02

The chemical composition of the flavoured extrudates (DF_1 and DF_2) as shown in table 3 showed that they contained 13.31 and 14.20% crude protein respectively while the protein free (PF) diet contained 0.1% protein. The starch content were 60.83, 58.95 and 98% on DF_1, DF_2 and PF diets respectively white the fat content was 1% and 1.28% in DF_1 and DF_2 respectively, the trypsin inhibitor level was 4.76 and 4.28mg/g in the flavoured extrudates DF_1 and DF_2 respectively. The crude fibre was 2.04% in the flavoured extrudate, DF_1 and 1.09% on the flavoured extrudate DF_2, 2.63 and 2.90% ash in DF_1 and DF_2, respectively, while the energy value was 1707.21KJ/100g in the flavoured extrudate, DF_1, 1724.24KJ/100g in the flavoured extrudate, DF_2 and 1671.4KJ/100g in the protein free diet.

Both flavoured extrudates contained appreciable levels of calcium, iron and phosphorous as shown in figure 2.

Table 3: Chemical composition of flavour extrudates

Parameters	Extrudate Df_1	Extrudate Df_2
Carbohydrates (%)	69.74 ± 0.02	69.32 ± 0.03
Crude Protein (%)	13.51 ± 0.02	14.20 ± 0.01
Starch (%)	58.88 ± 0.02	58.95 ± 0.02
Total Sugar (%)	3.46 ± 0.01	3.48 ± 0.02
Fat (%)	1.28 ± 0.01	1.20 ± 0.01
Calcium (mg/100g)	0.72 ± 0.02	0.76 ±0.01
Iron (mg/ 100g)	0.05 ± 0.01	0.06 ± 0.01
Phosphorus (Mg/100g)	0.28 ± 0.01	0.30 ± 0.01
Crude Fibre (%)	0.97 ±0.02	0.90 ± 0.02
Ash (%)	2.63 ± 0.02	2.49 ± 0.02
Energy (KJ/100g)	1707.21	1723.24
Moisture (%)	9.87 ±0.02	9.87 ± 0.01
Trypsin Inhibitor (Mg/g)	6.49 ± 0.02	6.47 ± 0.01

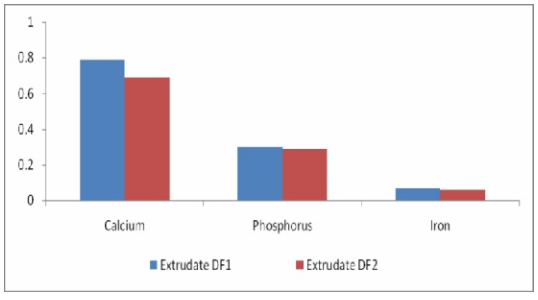

Figure 2: Retained iron, calcium and phosphorus levels in yam bambara extrudate

Discussion

The maximum permissible level of total aerobic colony count of ready-to-eat foods as given by Fylde Borough Council[13] extracted from Public Health Laboratory Service Guidelines (2000)[14] was 10^4 to less than 10^5 cfu/g of ready-to-eat food products. This therefore, shows that the extrudates were stable under the different storage conditions investigated in this study. The microbial load of the extrudates as measured by the total plate count per gram of sample was generally low (0.5×10^4 to 10^5 cfu/g) in all the samples stored under refrigeration conditions showing that temperature had a significant effect on the growth of micro-organisms[14] Micro-organisms have been reported to be inhibited by the inclusion of salt, sugar and spices[15], [16] in food. The microbial load of any food material is however, a useful index of quality in the extrudate as well as revealing the safety status of the extrudated products from human consumption point of view. Total counts have been reported to be useful monitor in processing of food products and may therefore reflect poor handling or storage at retail level[17]. Also Bacillus cereus and califorms have however been identified to be the major organisms causing spoilage in extruded cooked product while the mould count must also be very low in order to rule out the possibility of formation of preformed toxins in the extruded food products.

The potential value of a food for supplying a particular nutrient can be determined by chemical analysis, but the actual name of the food to the animal can be arrived at only after making allowances for the inevitable losses that occur during digestion, absorption and metabolism. The digestibility of a food is defined as that portion of the food which is not excreted in the fasces and which is therefore assumed to be ascribed by the animal.

The protein efficiency ratio (PER) normally uses growth of the rat as a measure of the nutritive value of dietary proteins. It is defined as the weight gain per unit weight of protein eaten. The extrudates produced supported the growth of the laboratory animals used with flavoured extrudate evident DF_1 giving a better growth in the experimental rats used then the flamed extrudate or diet Df_2.

Biological value shows a direct measure of the food protein which can be utilized by the animal for synthesizing body tissue and compounds and may be defined as the percentage of the nitrogen ascribed which is retained by the animal. The biological value is both flavoured extrudates were

very high showing that most of the nitrogen was absorbed by the animals. Part of the nitrogen of the faeces, the metabolic faecal nitrogen, is not directly deemed from food. Urinary nitrogen also contains a proportion of nitrogen known as endogenous urinary nitrogen which is not directly produced from the ingested food by the test animals.

Both extrudates (DF_1 and DF_2) produced moderate quantities of urinary protein and faecal protein. Urinary nitrogen/protein and faecal nitrogen protein have been reported to be totally directly produced from the ingested food nitrogen by the animals, but it is nitrogen derived from expendable tissues and secretions together with waste nitrogen arising during normal catabolism and resynthesis of tissue proteins.

The existence in both faeces and urine of nitrogen fractions whose excretion is independent of food nitrogen is most convincingly demonstrated by the fact that some nitrogen is excreted when the animal is given a nitrogen free diet[18], [19] as revealed by the urinary nitrogen/protein and faecal nitrogen/protein produced by the experimental animals feed with non-protein diet in this study.

The study also indicated that extrudate DF_1 was better consumed than extrudate DF_2 by the experimental animals employed in this study. This might be due to the salt to sugar ratio in the feed blend. Sugar and salt have been reported to enhance flavour and sensory acceptability of certain foods[16], [26].

Rats fed with the flavoured extrudate DF_2, however, had the highest excreted faeces and lower levels of protein in urine excreted than the flavoured extrudate DF_1 implying that rats that were fed with the flavoured extrudate DF_2 did not make use of the extrudate properly in the digestive system thereby getting rid of them as faeces.

This, in turn, affected the weight gain of the experimental rats fed with extrudate/diet DF_2 resulting into lower weight gain by the rats than in the rats fed with extrudate/diet DF_1. Similar studies on extruded products have shown similar observations[19], [20], [24], [25]. The study has shown that extrudate/diet DF_1 was better than extrudate/diet DF_2 based on the positive feed consumption, faeces excreted and weight gain pattern obtained in this study. High protein efficiency ratios of 0.74 and 0.79 have been reported in the extrudates DF_1 and DF_2 with high biological values of 0.99 and 0.96, respectively. A similar observation in extruded corn-soya mixtures had been documented[20]. It has been reported that extrusion cooking improves the protein digestibility of extruded food products[19], [22].

The challenging performance of rats fed extruded diets to those fed casein diet was attributable to the effect of extrusion cooking as a form of heat treatment to the mixtures. Heat is known to improve the availability of some nutrients, inactivate enzymes that speed up nutrient damage and destroy undesirable microorganisms and food contaminant[16], [19], [22]. It also favourably changes the physical attributes of food such as colour, texture and flavour[21], [23] and improves palatability and digestibility due possibly to higher starch damage[19], [20], [22], [24], [25].

The urinary output of rats fed with yam-bambara extrudates DF_1 and DF_2 were higher than those from casein diets. Rats with lower urinary nitrogen output showed higher nitrogen retention[18]. Low urinary and faecal nitrogen indicate high protein quality of fed diets/extrudates[19], [22]. Also the biological values of 0.99 and 0.96 obtained for extrudates DF_1 and DF_2 were, however comparable to that obtained in extruded bread fruit soya blend of 0.94 which was comparable to that reported by Nwabueze[18], [19]. While the standard casein diet had a biological value of 1.0, lower biological values of diets fed to rats may be due to lower nitrogen intake by the fed rats and higher urinary output, which could be indicative of poor utilization of digested/retained nitrogen[22].

The protein efficiency ratio (PER), is an index of protein quality in the extrudates which shows the relationship between weight gain by the test animals, and the corresponding protein as nitrogen intake[11], [16], [17], [21].

The trypsin inhibitor content of the extrudates were however low and may have contributed to high biological values and PER recorded in the extrudates[22], [23].

Extrusion cooking of yam-bambara mixtures has, therefore proved to support growth and weight gain in weanling rats. The implication of this research therefore is that a careful selection of indigenous plant protein sources, could be of nutritional benefit in terms of consumer weight gain and nitrogen utilization that may be comparable to casein diet when correctly blended and processed using a single screw extruder.

Conclusion

It is possible to produce nutritious and shelf stable extruded food products from blends of white yam and bambara groundnut that supported growth and

weight gain of laboratory animals. A similar principle can therefore be adopted for developing food products for growing children and even adults using blends of indigenous food crops. This will in turn help in developing an array of nutritious meals and/snacks and did reduction in hunger related diseases particularly suitable developing countries.

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Out scaling of improved cassava processing technology - Uganda lessons

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Abstract

Cassava (*Manihot esculenta* Crantz) has an immediate potential for use in food and feed industry in East and Central Africa (ECA). However, its industrial utilization in the region remains low, partly due to lack of improved processing technologies, lack of awareness of the alternative uses of cassava and technical know-how for commercialization. To tap the potential of cassava in feed industry of Uganda, EARRNET and its partners, NARO, Ugachick and farmers, established in 2005 two pilot processing sites in the districts of Bukedea and Masindi. Site selection was based on the levels and potential for increasing cassava production, existence of farmer groups/association, storage facility, availability of reliable clean water supply and ease of access to market. The objectives of the project were to a) increase awareness on the benefits of using high quality cassava chips in feed industry, b) introduce and promote use of improved processing and drying technologies c) assess the quality of cassava chips and d) develop better marketing strategies for cassava chips. The technology was introduced in a participatory manner through mobilization, sensitization, trainings, quality assessment, collective marketing, monitoring and evaluation. As a result, farmers got to know the potential benefits of cassava chips usage in animal feeds. The introduction of the improved drying facilities enabled farmers reduce drying time from 7-10 days as reported in traditional set-up to 1-2 days. The moisture content of the chips (10-12%) processed using the new technology was significantly ($P<0.05$) lower than that of

traditionally processed cassava chips (14-18%). The aflatoxin contamination of well stored processed chips was significantly ($p<0.05$) lower (>1ppm) than those traditionally processed (15ppm). Cyanide levels in traditionally processed chips (17-35ppm) was significantly ($p<0.05$) higher compared to chips obtained from processed chips and well stored (1-6ppm). Cost-benefit analysis showed that the average cost of producing 1kg of high quality cassava chips was 175/=. The farm gate price of 200/= per 1kg of dried chips offered by the feed miller was found to give a profit of 14% to farmers. Collective marketing through a centralised store has enabled farmers to have stronger bargaining power and bulk selling (>5 tonnes). Due to anticipated income generation from improved processing, acreage under cassava production in the project area increased by over 50%. However, though farmers embraced the improved technology, there still exist some hurdles that are discussed in this paper. The lessons learned from the study will help to improve further out scaling of production and utilisation of cassava technologies in the region.

Keywords: Awareness, participatory, processing, moisture content, aflatoxin, cyanide, cost-benefit, collective marketing, production.

Introduction

Cassava (*Manihot esculenta* Crantz) is a major source of food for more than 500 million people in Africa, Latin America and Asia. In Sub-Saharan Africa, about 40% of the population depends on cassava as a staple food and food security crop (Nweke *et al*., 2002). The ability to adapt to marginal and sub-marginal environments, its contribution to household food security and income generation, potentially make cassava very important in improving the livelihoods of the rural poor (Nweke and Ezumah, 1992; Kebe *et al*., 2001).

In the ECA region, cassava has an immediate potential for use in feed industry (Mbwika, 2004). The biggest challenge however, lies on the availability of constant supply of high quality chips. The traditional method of splitting/slicing and drying cassava chips on bare ground is unreliable and compromises the quality. Industrial utilization of cassava within the region remains low, partly due to lack of improved processing technologies, lack of awareness on the alternative use of cassava, lack of technical know-how and lack of a supportive policy for commercialization. Furthermore, the absence of a clear marketing chain, lack of entrepreneurship skills among farmers and processors as well as scattered nature of cassava producers also contribute to the low utilization of cassava chips at industrial level. However, the introduction of high yielding improved CMD resistant varieties has boosted the production above subsistence levels. To tap the potential utilization of cassava in feed industry in the ECA region, proper mechanisms must be put in place to guarantee a regular supply of high quality cassava chips. In collaboration with NARS and private sectors in Kenya, Rwanda and Uganda, EARRNET embarked on promoting improved cassava chipping and drying technologies to produce high quality cassava chips acceptable to the feed millers with the followings objectives:

a Increase awareness on the benefits of using high quality cassava chips in feed industry
b. Introduce and promote use of improved processing and drying technologies
c. Assess the quality of cassava chips
d. Develop better marketing strategies for cassava chips.

Methodology

EARRNET project on promotion of improved cassava processing technology targeted five countries within East and Central Africa viz. Ethiopia, Kenya, Madagascar, Rwanda and Uganda but pilot processing units were established only in Kenya, Rwanda and Uganda. These were considered to have comparative advantage in production and utilization of cassava in the region. Within each of the three countries, 2 pilot sites were set up for production of high quality cassava chips for the feed industry. These sites were expected to produce high quality chips and create a linkage between producers, processors and feed millers.

Selection of pilot sites

An extensive baseline survey was conducted in the most promising cassava producing areas. Selection of the pilot sites was based on the existing levels and potential for cassava production, existence of cohesive farmer groups/association with storage facility, availability of reliable clean water supply and ease of access to market.

Introducing processing technology

This was introduced in a participatory manner through mobilization, sensitization, trainings, quality assessment, collective marketing approach,

monitoring and evaluation.

After identification of farmer group/ association, each site was provided with a motorized chipper, drying facilities, a weighing scale and packaging materials. In addition, the group storage facility was renovated and equipped with pallets to meet the standard required for proper storage of chips.

Sensation was done through community mobilization, electronic (radio) and print media (newspaper and leaflets). Members of selected groups were also trained on cassava chips quality aspects, entrepreneurship skills and group dynamics, cassava production, pests and disease management techniques. At least two fabricators in the each of the participating country were trained to handling demand for the chipper in their respective country. On top of that the groups were provided with improved cassava varieties to improve their production.

Processing cassava quality chips: The process included harvesting mature cassava plants, peeling (for food) or scrapping the papery surface (for feed), washing, chipping, drying (>14% moisture content) and packaging. Drying method included sun on black polythene sheet on flat surface. Drying time was observed during processing. The mobile chipping approach is shown in Plate 1.

Plate 1. Chipping machine and drying chips at community level in Uganda.

Samples of traditional chips and that of processed were collected monthly for determining the moisture content, cyanide levels, afflatoxin and other contaminants.

Entrepreneurship and marketing

Information on the cost of producing of an acre of cassava was collected from farmers within the pilot sites. The cost included the cost opening up land, ploughing, planting materials, planting and weeding. Additional cost such as harvesting, transportation to processing area, peeling, water, washing, chipping, fuels, drying, packaging, transportation to the store and storage were obtained. In addition, through various trainings, farmers were equipped with entrepreneurship skills, production of quality chips and production techniques.

To create market linkage between farmers / processors and markets, the identified feed company were contacted and taken to the sites to negotiate with the farmers on the price, mode of payment and delivery cassava chips. However, other marketing channels were left open to farmers to explore other opportunities.

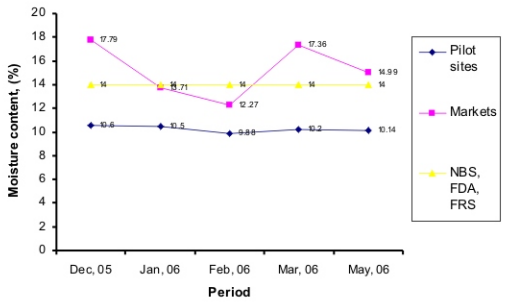
Results

Quality of cassava chips from pilot sites and local market: On the total number of members of the farmers groups, 50% adopted the technology and have processed 20 tones of cassava chips which were sold.

Moisture content (MC): The moisture content of the chips (10-12%) processed using the new technology was significantly ($P<0.05$) lower than that of traditionally processed cassava chips (14-18%) and that for National Bureau of Standards (NBS) and United State Food and Drug Administration (FDA) (Fig.1). The reduction in

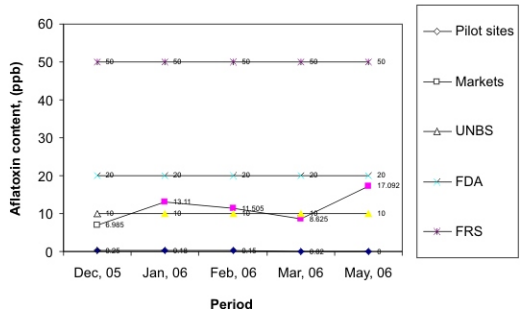
moisture content helped farmers stores their chip without getting moulded as commonly seen in the local market of traditionally processed chips.

Fig.1. Trends in Moisture content of chips, %



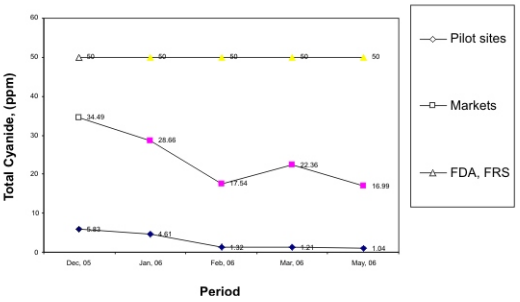
Aflatoxin: The aflatoxin contamination of well stored processed chips at the pilot site was significantly ($p<0.05$) lower (>1ppm) than those that were traditionally processed (15ppb), and that recommended for safe use by National Bureau of Standards (NBS). The levels of aflatoxin contamination in chips obtained from the local market sometimes are higher than that recommended by the National Bureau of Standards (NBS) and United State Food and Drug Administration (FDA) of 10ppb (Fig. 2).

Fig.1. Trends in Aflatoxin content, ppb



Cyanide: There was significantly ($p<0.05$) lower cyanide levels in the chips produced using the improved technology (1-6ppm) compared to traditionally processed chips (17-35ppm). The cyanide levels in both chips obtained from the pilot sites and local market are quite below the recommended maximum limit prescribed by the United State Food and Drug Administration (FDA) and FRS (Fig. 3)

Fig.3. Trends in Total Cyanide, ppm



Entrepreneurship and collective marketing

The project made serious efforts to educate farmers about the potential benefits of cassava if linked to a good market and used for alternative products, and how to approach farming as a business. The farmer groups were trained in assessing profitability through cost benefit analysis of the enterprises they are dealing in. They were shown, in a participatory manner, how to collect the relevant data and how to use it as shown in Table 1 below.

Table 1. Cost (UG Shillings) associated with production and processing cassava into chips

Activity	Pilot sites	
	Masindi	Bukedea
1. Production activities		
Land clearing	20,045	14,383
1st ploughing	37,970	30,250
2nd ploughing	36,791	25,500
planting	19,388	27,106
1st weeding	21,433	34,199
2nd weeding	20,687	27,196
3rd weeding	24,683	23,491
harvesting	27,400	44,747
Sub total	*208,397*	*226,872*
2. Post-harvest activities		
transport to processing site	33,333	30,266
peeling	42,000	27,711
washing	26,400	16,516
chipping	44,400	9,631
drying	30,500	26,254
bagging	15,800	10,775
transport to store; including loading and off-loading	28,125	55,924
storage	2,650	31,703
machine fee	20,000	31,703
Sub total	*243,208*	*240,484*
3. Consumables		
water	21,000	9,667
fuel	28,950	15,365
bags	80,000	59,677
string	2,500	1,875
Sub total	*134,950*	*86,584*
Total cost	605,155	553,940
Fresh yield per acre	-	6341
Dried chip yield per acre (conversion ratio of 2.5:1 for fresh to chips	-	2536
Total revenue at a unit price of 300 shilling per kg	-	760,920
Gross profit		206,980 (37.4%)

Estimated average yield of cassava from the pilot site in Bukedea was 6340kg per acre. At the conversion ratio of 2.5:1, this implies that an acre of cassava yields 2536kg of chips. So on average, the cost of producing each kilo of cassava chips is 218/= (break even price). At the farm gate price of 300/= per 1kg of dried chips offered by the market, farmers were able to make 37% gross profit. It is critical for farmers to know their cost of production to enable them bargain for prices which are satisfactory to them.

The marketing approach adopted by the farmer group/association was collective marketing where by chips are sent by individual farmers to a centralized store. The quality controller and store keeper had the responsibility of ascertaining the quality and taking record of what has been brought in. The marketing group then managed to identify potential markets on behalf of the individual farmers.

The project had the original objective of linking farmers directly to Ugachick, an animal feeds processor. Ugachick offered a farm gate price of 200/= per kilo, with a demand of >10 tones of chips per month, but due to a combination of factors such as low production capacity and higher food market prices, the Ugachick market could not be satisfied.

Consequently, linkages were again established between farmers and food markets. The

markets which were accessed by farmers in Bukedea included Ugachick, Family Diet and Maganjo Grain Millers (Table 2), all from Kampala. The arrangement is such that whenever the farmers association has realized at least 5 tonnes in their store, they inform the buyer who sends a truck with cash to collect it. The table below shows the trend so far.

Table 2. Bulk sales by farmers in Bukedea

Date of sale	Market	Quantity (kg)	Unit price	Total value
May 2006	Ugachick	3667	200	733400
March 2007	Maganjo	4335	300	1300500
May 2007	Family Diet	6630	300	1989000
August 2007	Family Diet	6715	300	2014500
Total		21347		6037400

Note: The quantity supplied is a collection of chips supplied to the central store by individual farmers each supplying quantity varying between 500kg to 3700kg. In the traditional system, farmers could not supply more than 500kg at a go, due to difficulty in processing and accessing a market which could absorb such high quantities.

The income generated from chips has helped some farmers build houses and pay school fee for their children. Furthermore, income generated has enhanced the capacity of farmers to buy food items they are not producing themselves, hence food security as result of economic access. Due to anticipated income generation from improved processing, acreage under cassava production in the project areas increased by over 50%. In addition, the demand for high yielding improved varieties has gone up in the project area.

Discussion

Processing and quality of cassava chips: One of the problems in traditional drying under sun is that the drying time is long. According to Warieng *et al.* (2001), traditional sun drying during the dry season takes 7-12 days while during rainy season it takes 8-14 days. The introduced processing and drying technology has enabled farmers reduce this to 1-2 days depending on the weather. This short drying duration is prompting many farmers to adopt the use of new technology in the project area. The introduced technology has farmers achieved desirable moisture content for proper storage, reduced cyanide levels and aflatoxin contaminations.

Quality factors in cassava chips include moisture content (MC), the level of cyanogenic glucosides (cyanine), aflatoxin contamination, and contamination by foreign bodies, smell, taste and colour. According to FAO and IFAD (2004), the moisture content of cassava chips should not exceed 14 percent for safe storage. The moisture content of chips obtained from the pilot site falls within that required for safe storage. At or bellow 14% MC cassava chips can be stored for up to eight months (Ravindran and Kenkpen, 1992). This scenario was observed at both sites where the chips was stored in a store for more than five months and quality analysis reveled no significant different from those kept for few months. In Nigeria, major feed millers store chips for not more than three months to guarantee freedom from microbial infestation particularly for commercial poultry feeds.

The presence of cyanide in cassava has caused a global scare as to the safety of cassava and its products for human and animal consumption (FAO and IFAD, 2004). Brauman *et al* (1992) indicated that acceptable limit of cyanide for human consumption <50ppm (50 mg HCN/kg), while safe levels of cyanide in cassava-based rations is <100 ppm (100 mg HCN/kg, dried chips). Even at 100ppm satisfactory growth can be obtained in livestock provided the feed is adequately supplemented with protein (or specifically methionine) and iodine. Therefore, the levels of cyanides (1-16ppm) in chips obtained from the pilot sites in Uganda are quite safe both for human consumption and animal feed manufacturing.

Fungal growth is common on dried cassava products (Essers and Nouts, 1989), especially in Africa. Fungal growth occur at three stages in processing; during slow drying, during storage under humid conditions or in some specific products that are fungally fermented (Andrew, 2002) which is a common practice in traditional cassava processing in Uganda. When growth of potentially mycotoxenic fungi occurs, there is possibility of mycotoxin formation (Andrew, 2002).

Studies conducted in Uganda over years showed that there is more aflatoxin contamination of foods in markets, than those stored by farmers, with some having levels above the FDA/WHO

recommended limits of 20ppb (Kaya and Warent, 2005). Similar trend was observed in cassava samples obtained from local markets and those collected from the stores at the pilot sites. Analysis of chips from the pilot site revealed the aflatoxin level of <5ppb. A study conducted by Alpert et al (1971) found out that aflatoxins occurred most frequently in beans, followed by maize and sorghum, whereas groundnuts, millet and cassava were contaminated least.

Quality issues are important in accessing bigger markets. Therefore, out scaling of a given technology should be tailor in line with the quality specifications of a given market.

Entrepreneurship and collective marketing: Due to the predominance of subsistence agriculture, most rural farmers do not know what their break-even price is, what the markets need and how to go about promoting their products. Consequently, most of the people and certainly local farmers use the prevailing market price as the basis for comparison. One of the critical issues in out scaling improved agricultural technology is to building local capacity of the farmers to be self sustainable. Farmers capacity need to be build in the areas of business entrepreneurship, determination of the "right" price through cost-benefit analysis, product development and promotion and the infrastructural capacity to produce.

Good market opportunities are required in stimulating increased production and adoption of technologies. In developing countries, marketing chains for agricultural produce do not perform efficiently the basic marketing functions of collection, handling, transportation, storage, processing, wholesaling and retailing (Onumah and Hubbard, 1999). In Uganda, cassava chips supply chains is extensive ranging from farmers, village assemblers, mobile traders, urban traders (wholesalers and retailers) and industries (Collison *et al.,* 2003). In this long chain by many actors farmers always are cheated (150-250/=) and consumers pay highly for the final product.

The current project of liking farmers directly to bigger market has enabled farmers sell their cassava chip in bulk and at reasonably higher price (300/=) as a result of economies of scale arising from collective marketing approach. The high farm gate price observed under this approach has been a motivating factor to farmers in increasing their acreage production by over 50% within the project area. Robin *et al* (2004) noted that collective marketing enable farmers through their association improve and harmonize the quality of their product, provide incentive to increase production, improve access to credit and obtain communal equipment and services. Experience from Uganda showed that farmer groups dealing in beans in Rakai were able to receive up to 22% higher prices through collective marketing (Robin *et al,* 2004).

Challenges in out-scaling improved cassava processing technologies: Initial target was to supply feed market but due to high demand from food markets, combined with low volumes of chips produced, farmers/processors turned to the food market offering higher prices. Therefore, a competitive market where there is no legal agreement between the farmers/processors and the buyers, farmers are likely to sell to any other buyer offering better price. Processing of quality chips requires plenty of clean water which most rural settings still lack.

Most group members still look at processing as an activity which should be done mostly in the dry season. During rainy seasons farmers allocate most of their time for field work such as opening up land, planting and weeding of crops in their gardens. This aggravated by the fact that sun drying during the rainy season is difficult and requires more attention than during rainy season.

The low level of production, and partly the subsistence nature of the farming, still hinders large scale processing. This means that the motorised chipper with the chipping capacity of 500-800kg of fresh cassava per hour is being under utilised. Sun drying is highly weather dependent in that during rainy seasons farmers still find difficulties in drying their cassava. Sometime there is rewetting of chips and this affects not only the quality (colour) but as also farmers will have prolonged drying time and additional labour cost of drying.

With the mobile processing approach, chances of individual farmers compromising the quality of chips during processing and drying are high as not all farmers have the same level of experience and conditions required for processing high quality cassava chips. In addition this can be aggravated by use of drying sheet spread on the ground whereby contamination can be through soil being blown into the drying chips, insects crawling into the chips and domestic animals crossing over the during chip.

The other difficult issue has been transport cost. This has been made difficult due to the low tonnage that farmers have for sale at a time (3-6 tons). Therefore hiring a 10 ton truck from the

sites to the market which is about 350m becomes less cost effective. In addition, transporters charge flat rate per bag and this implies that the heavier the bag the less the cost per kg. Unlike maize, a well packed (the same bag size) cassava chip weigh at most 85 kg compared to maize that would weigh up to 120 kg.

Although the collective marketing has helped farmers sell in bulk and have strong bargaining power, farmer who supply to the sore first complained of delayed sale of which they had to wait until the required tonnage is realized. Other challenges include high price fluctuations, lack of capital incentives and conflict of interest arising from within the farmer group/association.

Conclusion

The potential for producing larger tonnages of high quality cassava chips exist, and the driving force for commercialization of cassava for larger markets are increasing production capacity, formation strong farmers associations, introducing appropriate processing technologies and market pricing. The collective marketing introduced by the project through a centralised store has enabled farmers have stronger bargaining power and bulk selling. Working in groups reduces product handling and transportation unit costs, and improves bargaining power for better prices.

The approach in piloting a processing site should be a market led and demand driven approach. Out scaling of processing technology therefore requires a complete understanding of production levels, farmers' interest, availability of storage facility, clean water points and market access.

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