CROP POST HARVEST PROGRAMME

MARKETING AND PROCESSING OF BAMBARA GROUNDNUTS (W. AFRICA)

R7581 (ZB0232/233)

FINAL TECHNICAL REPORT

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Executive Summary

The purpose of the project was to develop and effectively promote strategies that improve food security of poor households through increased availability and improved quality of cereals and pulse foods, and better access to markets. The expected outputs are that improved methods for cooking bambara, which significantly reduces both time and resources required are developed for small-scale farm families, and production and market potential for bambara assessed.

Research activities undertaken in pursuance of the set objectives include a nation-wide survey of the production, processing and marketing of bambara groundnut in Ghana, studies to determine market potential of bambara in Africa and elsewhere, studies on the use of a local rock salt, kawe, as a tenderizer for bambara to reduce cooking time, development and quality evaluation of an acceptable high quality bambara flour, farmer participatory testing of the high quality bambara flour, as well as development and testing of recipes based on the high quality bambara flour.

The main outputs of the project were as follows:

- Marketing opportunities for bambara in Ghana, Africa and globally have been identified and the constraints to the marketing system established.

- Production, processing, storage and utilization of bambara in Ghana have been established and the constraints limiting the increased utilization of the crop identified.

- A method has been successfully developed and assessed through participatory testing for the effective reduction in cooking times and enhanced utilization of bambara. The method, involving the use of low concentrations of a locally-available natural rock salt, *Kawe*, ($Na_3CO_3.NaHCO_3 .2H_2O$) for pre-soaking and cooking, has been established as an effective means of reducing the cooking times by half, of the most difficult-to-cook varieties of bambara.

- A processing technology has been developed and proven through participatory field tests for the preduction of an acceptable high quality bambara flour for use in the preparation of various traditional foods and recipes, as well as in weaning foods.

- Extension materials on the technologies developed have been produced and a stakeholders' workshop held in northern Ghana as a means of providing a forum for information exchange to promote the new processing techniques for bambara. A total of seven technical reports and three extension brochures were produced from the results of the study.

All the outputs set out in the project document have been achieved; and these can contribute significantly to meeting the project's goal of having poor people benefit from new knowledge applied to food commodity systems in semi-arid areas. The new methods developed to facilitate processing of bambara will enhance bambara utilization and potentiate improvement in production levels that will lead to enhanced income, thus contributing to alleviating the livelihood constraints.

Background

Bambara groundnut has been ranked as the second most important grain legume in Ghana after cowpea (Doku and Karikari, 1971). West Africa produces 45 – 50% of the world production (Coudert, 1984), estimated at 330,000t, although most countries, including Ghana, do not collect accurate statistics on internal agricultural production and marketing of this crop. For many years in Ghana, production and utilization was slightly ahead of cowpea (Doku, 1996) but introduction of high yielding varieties of cowpea and improved methods for controlling cowpea field pests led to the neglect of bambara. Doku states that "It is a paradox that an indigenous African crop, which produces an almost completely balanced food, is one of the most drought tolerant, easy to cultivate crops, which makes very little demand, if at all, on the soil, should be relegated in its own countries …..". However, when the effort and time required to process bambara is considered, together with the large quantities of water and fuel that are needed, this gradual decline in production is not so paradoxical.

Bambara is a crop that in Ghana and other African countries is cultivated by rural poor farmers, particularly by women, and is a significant source of income for senior wives and female-headed households. It is not too difficult a crop to cultivate and it stores well on the farm. In semi-arid areas bambara is an important source of edible protein, particularly lysine, and is complementary to staple cereals which are low in this amino acid. People like the flavour, preferring it to cowpea, and food preparations have changed very little since the crop first gained popularity in the Middle Ages (Lewicki, 1974).

The decline in bambara production is mainly the result of the poor cooking characteristics. In a previous study to identify qualitative and quantitative losses in the storage of cowpea and bambara by small-scale farmers in Ghana, it was realized that the main concern of farmers was not storage but rather processing; and that farmers were reducing production, and had less for sale, because of processing constraints. Reversing production trends will benefit poor families as surplus production could be sold. It is likely to find ready markets both at home and abroad. At a meeting of the International Bambara Groundnut Network (BAMNET), held in Accra in December 1998, interest was expressed by foreign commercial enterprises in canning bambara for western markets (Begermann, F. *pers. Comm*..). However, a major constraint to this type of development is that supplies of the legume cannot be guaranteed. Neither areas of production nor production levels in most African countries are known to any degree of accuracy. Such information must be obtained if the market is to develop and bambara exploited as a source of income for farmers living in more arid climates.

Several studies funded by DFID in 1995 and 1996 (Golob *et al*., 1996, Gudrups et al., 1996) demonstrated the concern farmers have regarding the storage, processing and marketing of grain legumes. Among these concerns was highlighted the problem of cooking bambara. During the first phase of project R6503 (Improvement in the storage and marketing quality of legumes) research was undertaken to investigate the factors which might be responsible for this problem. Observations indicated that the water absorption capacity of bambara was very poor relative to cowpea, and that the very thick testa could be responsible for this characteristic (Plahar *et al*., 1998). It is likely that

cooking could be improved or be facilitated by increasing the sorptive capacity of the grain, either by removing the testa or making it more permeable.

The International Institute for Tropical Agriculture spearheaded a re-interest in bambara by initiating a germplasm collection, describing and characterizing acquisitions, and researching temperature and photoperiod responses (Doku, 1996). During the last ten years, the International Bambara Groundnut Network (BAMNET) has refocused attention on bambara and has stimulated research particularly on plant physiology, agronomy and germplasm acquisition. The European Union has recognized the need to rejuvenate the crop by supporting a research programme to assess its potential. Among the outputs of this research was the knowledge that production could be significantly increased above typical farmers fields. Currently, the focus of bambara groundnut research is essentially within three broad areas: environmental ovulation of reproductive development; germination and seedling growth; and growth, biomass accumulation and adaptation to drought (Sesay, *et al*., 1996).

Such research on production attributes is essential if the crop is to regain its relative importance as a food source. However, production will remain stagnant or decline further unless improvements are made to post-harvest characteristics, particularly those concerning processing. Furthermore, without market opportunities and knowledge and stimulation of demand, research on production will be of no consequence. The BAMNET meeting, held in December 1998, recognized the paucity of information concerning post-harvest issues and its members have agreed to concentrate on processing and marketing, information and communication as well as crop improvement and breeding (Bergemann, BAMNET Newsletter 19/10/98 *internet comm*.). The requirement for this type of knowledge was provided by an example from the BAMNET mailing facility in the form of a request from the Tulimana Company in Zimbabwe, which provides canned bambara, for information regarding production and supplies of the crop in Africa in order that the Company could justify boosting production.

Project Purpose

The Programme Output is that strategies are developed and effectively promoted which improve food security of poor households through increased availability and improved quality of cereals and pulse foods and better access to markets. The research objectives were therefore to:

a. Identify traditional processing methods for bambara in Northern Ghana, then to adapt these methods or, if necessary to develop alternative technology, so that the cooking process is improved;

b. Conduct studies to determine the market potential of bambara in Africa and elsewhere so that opportunities which could facilitate the increase in production are identified.

Selling bambara provides an important source of income for rural poor households. It is not regarded as a crop of major importance and as such is frequently relegated to production, processing and sale by women. At local markets, bambara commands high prices in comparison with other grain crops but its production has decreased in recent years because it is a crop that is difficult to process by cooking. The development of improved technology will allow bambara to be cooked more easily and efficiently. Promotion of the developments will stimulate resurgence in the popularity of the crop and provide women with confidence to enable them to increase its cultivation. Additional cash from sales will improve food security of households in rural northern Ghana and in other bambara producing areas. The opportunity for achieving sales will be strengthened by the identification of potential markets both in Ghana and elsewhere.

Research Activities

As a means to accomplish the set objectives and achieve the desired output of the project, eight major activities were undertaken. These comprised of various research studies on technology development, surveys, participatory field evaluation of developed technologies, development of recipes and production of extension materials, and a stakeholders' workshop. The sub-sections that follow provide detailed descriptions of all the research activities to achieve the output of the project.

Activity I.

Survey of the production, storage, processing and utilization of bambara in Ghana

Production areas of bambara in Ghana were identified through information obtained from agricultural officers and traders. Based on this, the southern and northern sectors of the country were selected for a survey on the production, storage, processing and utilization of bambara. Farmers and traders involved in bambara cultivation and processing were identified with the help of agricultural extension agents, chief farmers, opinion leaders and key informants. Pre-tested conventional questionnaires, secondary data sources and informal interviews were used to obtain both quantitative and qualitative information on bambara in Ghana through random selection of respondents. The objective of the study was to investigate the production, storage, processing and utilization practices of bambara producers as well as identify the constraints with these practices, with the main focus on identifying the processing methods used in the Northern sector of the country. A total of 178 bambara producers, 90 in the Southern sector and 88 in the Northern sector were selected randomly for the study. Coded responses obtained from the conventional survey instrument were analyzed and results presented in simple frequencies, percentages, bar charts and pie charts.

Activity II

Marketing of bambara in Ghana

This research activity was undertaken to facilitate analysis of the marketing system of bambara groundnuts in Ghana. An extensive survey was undertaken to identify the deficiencies in the marketing of bambara groundnuts and analyze how the marketing system works for the crop. The findings of the research were used to make recommendations concerning how to develop appropriate quality systems for the production and marketing of bambara groundnuts.

Survey methodology: The survey covered bambara producing areas in the northern savanna and southern coastal areas of Ghana, as well as some urban markets. In the coastal areas, bambara groundnut is produced in some parts of the Dangme District of the Greater Accra region (notably in the Ada area) and Adidome District in the Volta region. Production in the savanna areas stretches to all the three northern regions. There is no production in the forest belt of Ghana. A total of 153 farmer-sellers and marketers were interviewed in the two zones with 77 respondents

in the coastal areas and 76 in the savanna zone. Due to the scattered nature of production in the coastal belt, any identified production village was selected and the farmer-sellers randomly sampled. In the northern parts of Ghana, Damongo, Tamale and Bawku districts were identified as places where bambara is grown. The farmer-sellers were also sampled randomly and interviewed.

At the market centres, due to fewer bambara groundnut sellers in the markets, every bambara seller was interviewed. This was done to ensure that the few number of traders in the bambara trade were covered to make it as representative as possible. The surveys were conducted in Tamale, Bawku, Kassei Junction, Mafi Kumasi and some rural markets where the few bambara wholesalers as well as traders were interviewed. The study used agricultural extension agents from the Ministry of Food and Agriculture as enumerators and they were advised to handle only bambara groundnut sellers so as to give some accuracy to any information gathered. The survey took place during the months of June and early July 2000.

The questionnaire modules consisted of open, half-open and pre-structured questions covering information on seller demographics, transportation, transaction costs, farm-gate and market prices, market information, price structure, and constraints. Each interview took approximately thirty minutes per seller and they were conducted on market days at the market centres in the urban areas. In the rural areas, farmers who were sellers, and traders who were selling bambara on the market were interviewed in order to maximize the collection of data.

Data Analysis: Responses were coded and the Statistical Package for Social Science (SPSS) and Microsoft Excel were used to process the data. The statistical analysis involved simple pie charts, frequency counts, and percentages that were used to present the results and the relevant inferences made.

Activity III

Studies on the market potential for bambara groundnut

The main objective of this study was to try and assess the production and commercial potential of bambara groundnut. Production and trade estimates were obtained from both interviews and

from literature searches, including gray literature. Nevertheless, the output, trade and price estimates contained in this study have to be treated with considerable caution, in part because of the subsistence nature of much of bambara production and thus the very limited volumes entering trade. Attempts to estimate likely potential production capacities are even more difficult, if not impossible. These will depend on a range of factors which are difficult to quantify including land availability and suitability, bambara's competitive advantage with other crops, trends in market demand and prices, and the ability to improve the processing of bambara. One source of information has been the International Bambara Groundnut Network (BAMNET), which over the past decade has refocused attention on bambara and has stimulated research particularly on plant physiology, agronomy and germplasm acquisition. However, other than the occasional price and production data there has been very limited data available on the markets for bambara.

The presentation of the information gathered from the study was divided into six sections. An introductory section provides background information on the origins of the study and on various aspects of bambara groundnuts and their production. The second section briefly reviewed the research methodology used and the very limited data sources that were available for analysis. A third section provides broad estimates and discussion of global, regional and country production, along with a discussion of the major constraints to production. A fourth section discusses the various ways in which bambara is processed and consumed. The fifth section reviewed marketing structures and methods and contained limited data on market size, prices and exports. The concluding section summarizes some of the major findings of the previous sections and makes some recommendations as regards possible strategies to be pursued to expand production and markets.

Activity IV

Studies on the effect of kawe treatment on water absorption and cooking characteristics of bambara groundnut varieties

The purpose of this study was to evaluate the effect of a locally available natural rock salt, *kawe,* on the water absorption and cooking characteristics of Bambara varieties as a means of developing an

effective method of reducing the cooking time of the hard-to-cook varieties. *Kawe* is used for many culinary purposes in Ghana and is believed to impact on the textural characteristics of various foods. Five varieties of bambara used in this study were obtained from markets in Northern Ghana. The varieties were Dark brown, Cream pinkeye, Cream blackeye, Maroon and Black. Two kilograms of the natural rock salt, *kawe* ($Na_2CO_3.NaHCO_3.2H_2O$), were also purchased from an open market in Accra. The physical and chemical characteristics of the bambara varieties were first determined, after which they were analyzed for their cooking and water absorption characteristics in different concentrations of the natural rock salt, *kawe,* ($Na_2CO_3.NaHCO_3.2H_2O$). Cooking time and texturometer readings of a hard-to-cook and a relatively easier-to-cook bambara variety in different concentrations of *kawe* were also compared.

Determination of physical and chemical characteristics of Bambara varieties: The seed coat thickness of five varieties of bambara was measured using a pearl chrome-plated micrometer (Moore and Wright, Sheffield Ltd., England). Average seed weight for each bambara variety was determined and recorded as 1000 seed weight in grams. Moisture, protein, fat and ash were determined by the AOAC (2000) standard methods while iron, calcium and phosphorous were determined by AACC (1983) methods. Carbohydrates were calculated by difference. The tannin content of whole raw bambara seeds was determined by the vanillin-hydrochloric acid method of Price *et al*. (1978). Blank corrections were applied and extraction performed within four hours of milling. A reference standard curve was prepared with catechin using concentrations of 0.0 – 0.4 mg/ml and extrapolating to greater concentrations. Tannin content was expressed in terms of catechin equivalents (mg CE/g sample).

Preparation of Kawe solution: *Kawe* ($Na_2CO_3.NaHCO_3.2H_2O$) being a crude, natural rock salt contains a high level of impurities, especially insoluble particles such as sand and stone. In order to avoid an overestimation of the actual concentration used, there was the need to determine the degree of purity of the *kawe* samples. The approximate purity of the *kawe* used was established by dissolving, in triplicate, known quantities of *kawe* in a litre of distilled water. The undissolved residue after filtration was dried and weighed and the level of impurity calculated as a percentage of the original weight of *kawe* used. The percentage insoluble impurities were found to be 11.6 ± 0.3. Concentrations of *kawe* solutions for the experiments were prepared taking into account the

correction factor for this level of impurities.

Determination of water absorption properties: The effect of *kawe* on the water absorption properties of whole seeds was determined by steeping 20g samples of seeds in 0.0, 0.1 0.2, 0.3 and 0.5 % solutions of *kawe* (1:5 w/v) at room temperature (28°C) for 1, 3, 6, and 12 h. Triplicate determinations were made and at the end of each soaking period the seeds were removed from steep water, wiped gently and weighed. Water absorption was recorded as g water absorbed per 100g solids. The combined effects of pre-soaking and boiling in different concentrations of *kawe*, were determined using two bambara varieties representing not hard-to-cook and hard-to-cook samples. Soaking times were 0.0, 3.0 and 3.0 h, while subsequent boiling was undertaken for periods of 30 min. and 1h.

Estimation of ease of cooking: Ease of cooking was estimated using the method of Dovlo (1977). Ten-gram lots of two bambara varieties representing relatively easy-to-cook and hard-to-cook samples, were soaked (1:5 w/v) for 0, 3 and 6 h. The samples were then boiled and the beans hand-tested for softness at frequent intervals. Softness was determined subjectively by mashing grains between the fingers and cooking time recorded as the time at which grains could be easily mashed between fingers.

Texture measurement: A Texture Analyzer model TA-XT2i (Stable Micro Systems, Vienna Court, Surrey, UK) with the Texture Expert Software version V1.14, was used to measure the softness of cooked Bambara samples. A Multiple Pea Test Rig accessory provided with a 5kg-load cell, was used at a test speed of 2.0 mm/s covering a compressed distance of 20 mm. The average force required to penetrate the surface tissue of 18 bambara seeds was used as a measure of the softness of the seeds. Higher readings of force corresponded to harder beans.

Activity V

Development of improved legume flour production technology for enhanced bambara utilization in Ghana

The purpose of this study was to develop an appropriate technique for the production of an acceptable, high quality bambara flour, and to evaluate the product in terms the nutritive value, physicochemical, functional and sensory characteristics, content of anti-nutritional factors, as well as large-scale consumer acceptability. A shelf-stable high quality intermediate product for diversified food uses of bambara will not only help enhance the nutritional status of farm families but will also help reduce hunger, and alleviate poverty through increased production of bambara.

Four varieties of bambara with distinct colour differences and two lots of mixed grains (light-coloured and dark-coloured) were obtained from open markets in Northern Ghana, and used throughout this study. The four varieties include the cream pinkeye, dark brown, maroon and the black white-eye varieties. The light coloured sample was made up of a mixture of cream black-eye and cream pink-eye, while the dark-coloured sample was a mixture of black white-eye, mottled, maroon, dark brown and light brown varieties. Varietal influence on product quality was first assessed.

Determination of varietal and processing effects on bambara flour quality: Varietal and processing effects on bambara flour quality were assessed using four varieties of bambara and three different processing methods (Fig.1). The four different varieties were the cream pinkeye, dark brown, maroon and the black white-eye types. Processing methods studied include a simple milling of raw bambara into flour (traditional method), roasting and milling, and an improved method involving a heat treatment, dehulling and milling. For the improved method cleaned grains were soaked in water for 30 min, and the soaked grains boiled for 25 min and dried at 60 – 65ºC in a hot air dryer for ten hours. The final moisture content was expected to be about 6% after drying for this period. The dried beans were then broken in a disc attrition mill and winnowed to dehull. The dehulled beans were then milled into flour. The mean particle size of all the flour samples prepared by the various methods was about 300 µm. The products were packaged in 500g lots in polyethylene bags and sealed using the Impulse Heat Sealer (Model CD-300, Dea Lun Co. Ltd., Taiwan). The flour samples were assessed for their quality in terms of proximate and

mineral content, concentration of anti-nutritional factors (specifically tannin content), as well as their suitability for specific food uses with respect to the sensory characteristics.

Development of High Quality Bambara Flour (HQBF): An appropriate processing technique was developed for the preparation of a high quality bambara flour (HQBF) based on the use of a combination of heat treatment and dehulling to enhance product quality. The quality was evaluated in terms of the nutritive value, functional and sensory characteristics, content of anti-nutritional factors as well as large-scale acceptability tests for traditional and diversified food uses. The normal product development phases involving idea generation, screening of ideas, technical development processes for optimization and prototype refining by sensory techniques, were applied in the development of the high quality bambara flour. Basically, the technique used for the improved bambara flour as illustrated below in figure 1, was applied. The process was used to prepare two samples of HQBF from two mixed varieties of bambara. The composition of the mixed grains was as follows: a) Light-coloured sample termed 'white' made up of mainly cream black-eye and cream pink-eye varieties, and b) Dark-coloured sample termed 'red' that contained mostly coloured varieties, especially the brown, mottled, maroon and black varieties. The choice of these mixtures was based on the fact that bambara is usually available on the market in these forms. The two final products were evaluated to establish the quality in terms of the chemical composition, amylograph hot paste viscosity, sensory characteristics and suitability for traditional food uses.

Chemical Quality Evaluation: Samples of bambara flour developed were analyzed for moisture, protein and ash following standard methods (AOAC, 1984). Fat content of the samples was determined using the chloroform/methanol extraction technique described by Bligh and Dyer (1959). For the determination of tannins flour samples were analyzed following the vanillin-HCl method of Price *et al*. (1978) and applying blank corrections. A reference standard curve was prepared with catechin (+) (Sigma Chemical Co., St. Louis, MO) using concentrations of 0.0 - 0.4 mg/ml and extrapolating to greater concentrations. The tannin content of each sample was expressed in terms of catechin equivalents. These results could be used as a major quality index in the selection of a suitable bambara variety for utilization.

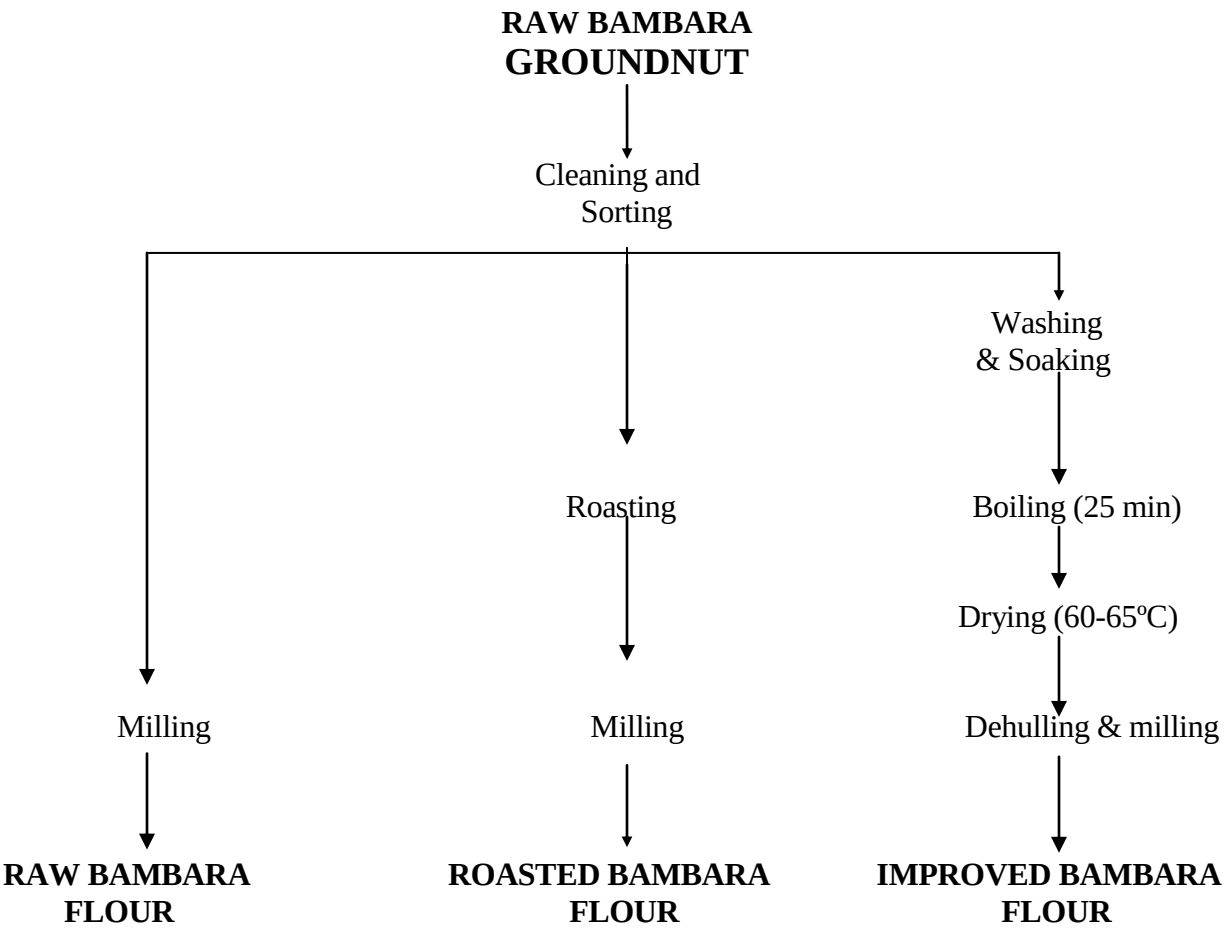


Fig. 1. Flow diagram for the preparation of Bambara flour samples

Amylograph Hot Paste Viscosity Measurements: The pasting properties of the bambara flours were determined with a Brabender VISCO/amylo/GRAPH (Model VA-VE, C. W. Brabender Instruments, Inc., South Hackensack, NJ) equipped with a 700 cm-g sensitivity cartridge. Ten percent slurry of the flour sample was prepared with distilled water and the slurry was heated uniformly (1.5°C per min) from 25°C to 95°C, held at 95°C for 15 min, and cooled at the same rate to 50°C. The resulting amylograms provided pasting temperatures, peak viscosities, viscosity at 95°C, stability, cooking times and setback viscosities.

Sensory evaluation and consumer acceptability tests: Laboratory sensory evaluation of cooked food products from the bambara flour samples was conducted at the Food Research Institute laboratories

using a taste panel consisting of workers at the Institute. Foods tested include traditional bambara foods such as *akla* and *tubani*, as well as formulated weaning foods based on the bambara flour. A 15-member trained panel of judges was used in the laboratory sensory tests. The preference tests were conducted using the nine-point hedonic scale to determine relative preferences for the various sensory attributes of colour, texture, aroma, taste, mouth feel and overall acceptability.

Statistical analysis: The data were analyzed using SPSS/PC + version 8.0 statistical software. Statistical parameters were estimated using analysis of variance. Differences between means were evaluated by the least significant difference (LSD) test. Significance was accepted at $p<0.05$. For the analysis of the sensory evaluation data, the probability associated with the Student's t-test was calculated to determine significance of observed differences.

Activity VI

Participatory field testing of High quality bambara flour in Northern Ghana

Traditional small-scale food processors in the Northern Region of Ghana were used to assess the suitability of the two samples of HQBF for traditional food uses on commercial scale. Thirty women processors from the Gushiegu and Gambaga districts in the Northern Region were used as the core group in the evaluation. The women were given ten kilograms each of the 'white' and the 'red' bambara flour samples for use in the commercial preparation of 'tubani' and 'koose'. The 'white' bambara flour was prepared from the mixture of the light-coloured beans while the 'red' flour was obtained from the mixture of the dark-coloured varieties. The comments of the women as regards the quality of the flours in terms of their suitability for the commercial preparation and sale of the two traditional foods were obtained. This field activity was undertaken in collaboration with CARPSAD, an NGO in Tamale, Northern Ghana.

Activity VII

Recipe development based on high quality bambara flour

The processing technology developed for the preparation of a high quality bambara flour under research activity V, brought about the need to broaden the utilization base through recipe development, as a means to address livelihood constraints through enhanced utilization of bambara in Ghana. The objective of the present recipe development activity was therefore to

facilitate diversified uses of the improved bambara flour by households, traditional cooked food vendors, the hospitality industry and catering establishments in the preparation of delicious and highly nutritious dishes. The use of the flour in the preparation of high protein weaning foods was also found to be necessary in helping to alleviate the protein-energy malnutrition problems prevailing in most farming communities in the country. The normal recipe formulation phases involving idea generation, screening of ideas, technical development processes for optimization and prototype refining by sensory techniques, were applied in the development of recipes based on both traditional and new dishes. A recipe brochure was prepared from the final recipes developed for extension purposes.

Activity VIII

Stakeholders' workshop

A one-day stakeholders' workshop was held in Tamale, Northern Ghana on marketing and processing of bambara groundnuts, on the 26th of February 2002, as a final activity of the project. The theme for the workshop was "*Making Better Use of Bambara to Help Address Livelihood Constraints of Farmers*". The purpose of the workshop was to provide a forum for information exchange to promote new processing techniques for bambara. The programme consisted of an opening session, followed by a technical session. An exhibition of bambara foods was mounted by traditional food processors/cooked food vendors in Tamale who participated in the field tests conducted on the high quality bambara flour.

Opening session: At the opening session, addresses were delivered by the project leader, Dr. W.A. Plahar, the Regional Coordinator of DFID CPHP & CPP, Dr. Ben Dadzie, an Associate of Natural Resources Institute, Dr. Peter Golob, and a representative of the Director Of the CSIR-Savanna Agricultural Research Institute, Dr. Atokple who chaired the function. Mr. S.A. Adongo, the Northern Regional Director of the Ministry of Food and Agriculture, delivered the keynote address.

Technical Sessions: Dr. Andrew J. Graffham of the Natural Resources Institute, UK and Dr. W.A. Plahar, Director of the CSIR-Food Research Institute, Accra, Ghana, chaired the technical

sessions. The rapporteurs were Mr. Yawson (Scientific Secretary), and Mrs. W. Quaye, both of the CSIR-Food Research Institute, Accra, Ghana. The following papers were presented:

Paper 1. Production, processing and utilization of Bambara in Ghana. Presented by Mrs. P.M. Larweh, Food Research Institute, Accra, Ghana.

Paper 2. Production and quality characteristics of High Quality Bambara Flour (HQBF). Presented by Dr. W. A. Plahar, Food Research Institute, Accra, Ghana.

Paper 3. Effect of 'kawe' treatment on the water absorption and cooking characteristics of Bambara groundnut. Presented by Mrs. N.T. Annan, Food Research Institute, Accra, Ghana.

Paper 4. Marketing of Bambara in Ghana and an overview of the global prospects. Presented by Ms. Claire Coote, Natural Resources Institute, UK):

Paper 5. Traditional Food Processors/ Cooked food vendors' views on the High Quality Bambara Flour. Presented by Mr. Suleman Stevenson, CAPSARD, an NGO, Tamale.

GROUP DISCUSSION: Prospects and constraints for the production and utilization of High Quality Bambara Flour in the traditional food delivery system in Ghana.

There were discussions and general recommendations to end the workshop.

Outputs

The outputs of the project are presented here as individual separate results from the research activities conducted. In all, seven internal reports, three extension materials and one workshop report have been produced in addition to this Final Technical Report. All the outputs outlined in the project document have been achieved. The following sub-sections provide details of research results of the various activities.

Output 1.

Survey of the production, storage, processing and utilization of bambara in Ghana

This study was undertaken to investigate the production, storage, processing and utilization practices of bambara producers as well as identify the constraints with these practices, with the main focus on identifying the processing methods in the Northern sector of Ghana. It was

expected that the findings of the study would help establish the current status of the crop in Ghana and also identify traditional processing methods, which could be adapted, or alternatives developed to improve the cooking quality of bambara in order to enhance utilization. The findings are presented in the sub-sections below.

Production capacity and trends in yield: Generally, bambara was cultivated on a smaller scale as compared to other legumes like groundnuts cowpea and soybean in all the areas surveyed. On the whole, an average of about 3 acres of land was cropped for bambara. As indicated in figures 1.1 and 1.2, in both the Southern and Northern sectors, the minimum acreage cultivated for bambara was 0.25 of an acre. Maximum acreage was 6 and 25 acres for the Southern and Northern sectors, respectively. The overall average yield/acre as observed in the study was 3.53 maxi-bags in a year. In the Southern sector, majority of the respondents produced between 4 and 6 maxi-bags per acre while in the Northern sector, 1-3 maxi-bags/acre was produced by most farmers (Figs 1.3 and 1.4).

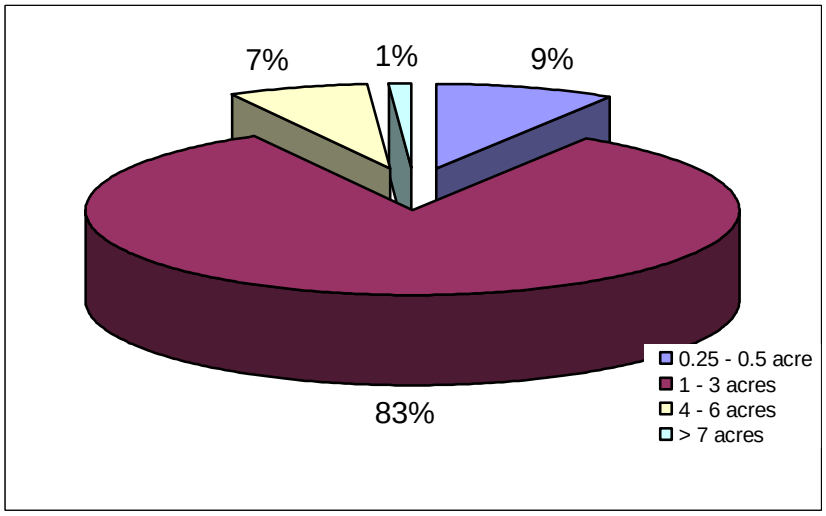


Fig. 1.1. Percent distribution of land size under bambara cultivation by farmers in Southern Ghana

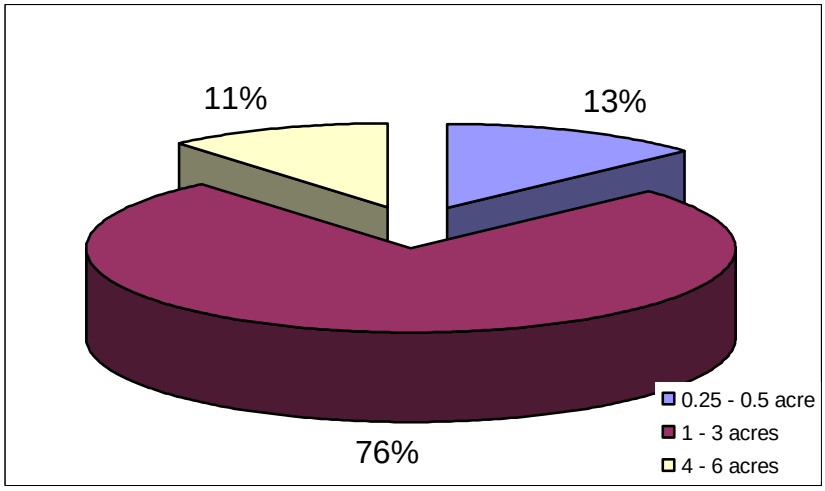


Fig.1. 2. Percent distribution of land size under bambara cultivation by farmers in Northern Ghana

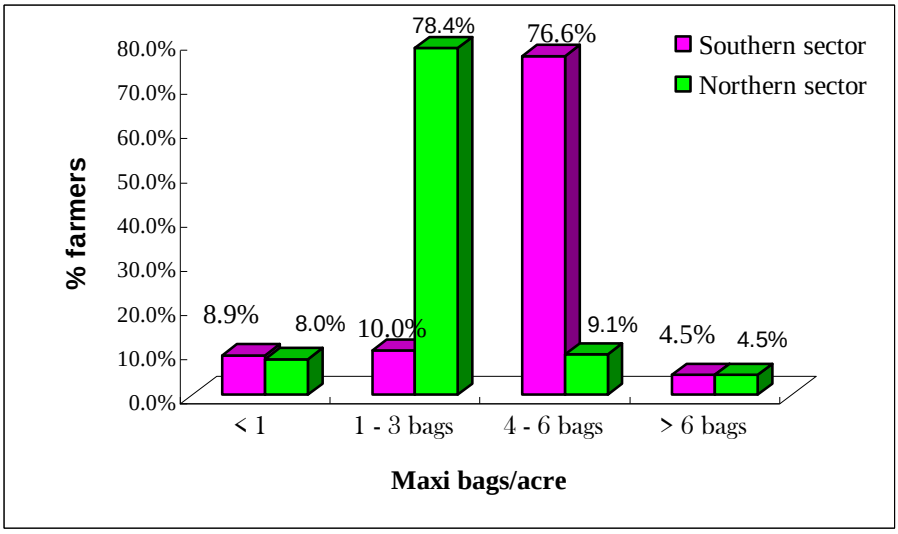


Fig. 1.3. Percent distribution of yield/acre of bambara in the Southern and Northern sectors

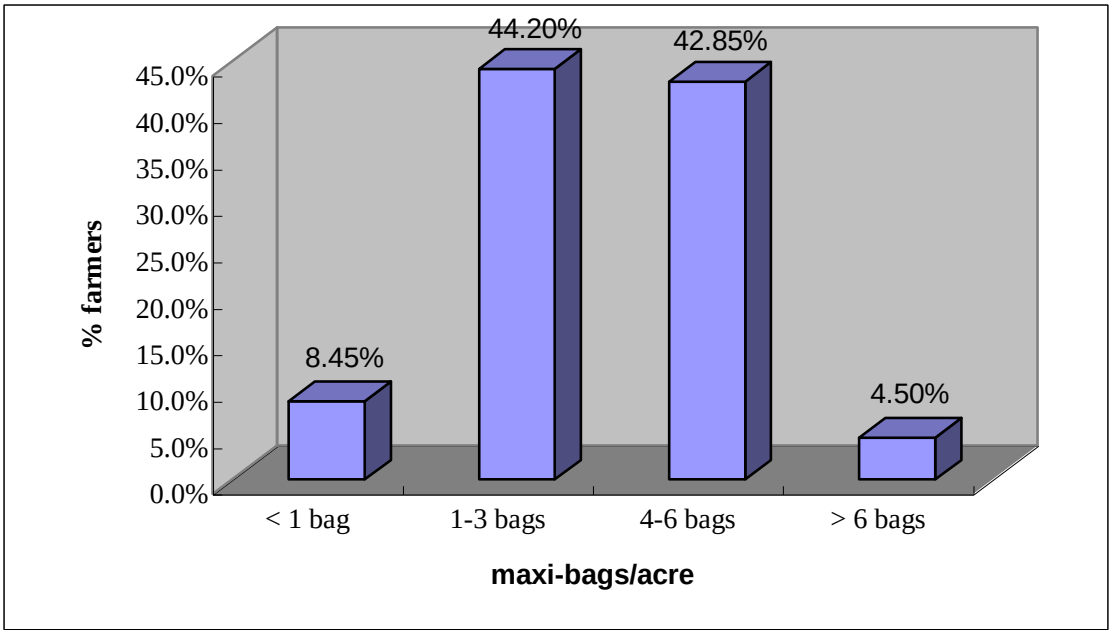


Fig.1. 4. Percent distribution of overall yield/acre of bambara groundnuts

Seasonality of supply: In the Southern sector of Ghana, bambara was said to be in high supply between August and September, and also between October and February. The two bumper seasons may be accounted for by the two possible cropping seasons in the sector. In the Northern sector, bambara supply is high between October and January, peaking in December. From June to August, and sometimes September, bambara is scarce in the Northern sector.

Income generation from bambara: Bambara was produced in the survey areas both for subsistence and income generation. For almost 16% of respondents in the Southern sector, bambara was cultivated solely as a subsistence crop while it served as a cash crop for about 31% of the respondents. A lower percentage of respondents in the Northern sector (19.3%) cultivated bambara solely to raise income, with the majority of respondents (60.7%) growing the legume for both reasons of subsistence and cash. On the average, 30% of the bambara produced was kept for household consumption while the rest was sold to raise income for the household.

Constraints to bambara production: In the Southern sector, the four most important constraints stated in order of decreasing importance were poor climate, lack of processing equipment, limited access to land and high labour cost (Table 1.1). In the Northern sector, high cost of inputs was the most important constraint, followed by limited access to land and other problems such as low yield, insect infestation, weeds and poor soils.

Table 1.1. Constraints to bambara production in Ghana

	Southern sector		Northern sector		Overall	
Most important constraint	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Climate	33	36.7	8	9.1	41	23.0
Limited access to land	12	13.3	20	22.7	32	18.0
High cost of labour	10	11.1	5	5.7	15	8.4
High cost of inputs	5	5.6	24	27.3	29	16.3
Poor storage	2	2.2	12	13.6	14	7.8
Lack of processing equipment	22	24.5	0	0.0	22	12.4
Others	3	3.3	16	18.2	19	10.7
None	3	3.3	3	3.4	6	3.4
Total	*90*	*100.0*	*88*	*100.0*	*178*	*100.0*

Storage of bambara: Results of the study indicated that bambara groundnuts were stored up to 8 months either shelled or unshelled. Traditional pre-storage treatment was the most common practice. In the Southern sector, the most common traditional treatment practiced involved mixing shelled nuts with dry warm sand before storage in barns. The base of the barn is often fumigated to prevent insect infestation. In the Northern sector, shelled nuts were stored traditionally by mixing with wood ash, dry warm sand, or a combination of these. Out of a total of 178 producers interviewed, 40.5% practiced traditional pre-treatment, 21.8% applied agro-chemicals, while 38% did not apply any treatment before storage. Over 70% of respondents stored their bambara in barns while about 25% stored in baskets or sealed pots.

Table1. 2. Pre-treatment of bambara before storage

	Southern sector		Northern sector		Overall	
Pre-treatment	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Agro-chemicals	24	26.6	14	15.9	38	21.3
Traditional	33	36.7	39	44.3	72	40.5
None	33	36.7	35	39.8	68	38.2
Total	90	100.0	88	100.0	178	100.0

Processing and Utilization of bambara: The study revealed that processing of bambara groundnuts was more prevalent in the Northern sector than the South (Table 1.3). All respondents in the Northern sector indicated that they processed bambara into flour and/or paste, with only 7% in the Southern sector processing bambara into other products. Cooking of whole bambara nuts was identified to be the most common mode of preparation in the South. The method of processing depended mainly on the traditional food uses of the bambara in the particular area.

Table 1.3. Distribution of bambara processing methods

	Southern sector		Northern sector		Overall	
Processing method	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Mill into flour	1	1.1	72	81.8	73	41.0
Process into paste only	1	1.1	6	6.8	46	3.9
Both flour and paste	4	4.5	10	11.4	14	7.9
Not applicable	84	93.3	0	0.0	84	47.2
Total	90	100.0	88	100.0	178	100.0

The utilization base of bambara was found to be much wider in the Northern sector where it formed an important part of their traditional diet. Utilization of bambara in the Southern sector was found to be limited to cooking whole dry nuts into a sauce. The relative frequencies of consumption are given in Figures 1.5 and 1.6 below. Major bambara dishes were identified to

include bambara sauce, bambara stew, tubani, koose, and cooked fresh bambara in pods. Long cooking and lack of adequate processing techniques were the most important constraints limiting its utilization.

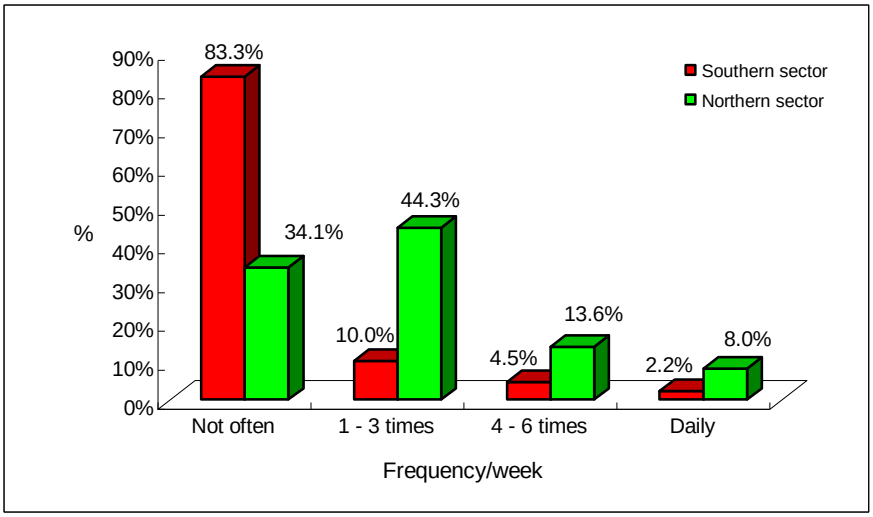


Fig. 1.5. Frequency of bambara consumption in the Southern and Northern sectors of Ghana

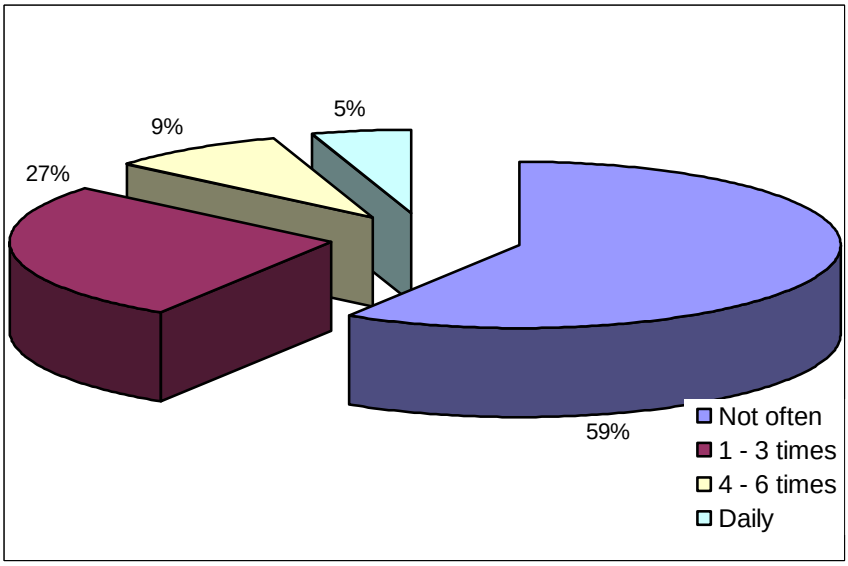


Fig. 1.6. Overall frequency of bambara consumption in the survey areas.

Summary of main findings and conclusions: 1. The major bambara producing areas in the Southern sector of Ghana are the Dangme East and North Tongu districts of the Greater Accra and Volta regions, respectively; 2. In the Northern sector, the Bawku East, Tolon-Kumbungu, West Gonja districts as well as most districts in the Upper West Region were identified as major producing areas; 3. The primary source of income for respondents in both sectors surveyed is farming; 4. Bambara is generally cultivated on a smaller scale compared to other legumes like groundnuts, cowpea and soybean; 5. Sole cropping of bambara is hardly practiced by farmers who produce bambara; 6. An average of 3 acres of land is cropped by each farmer, with an overall average yield of 3.5 maxi bags in a year (4.6 and 2.5 maxi bags respectively in the southern and northern sectors); 7. Bambara is produced both for subsistence and cash, with families in the Northern sector depending on bambara as household food stock more than those in the Southern sector; 8. On the average, 30% of bambara produced is kept for household consumption; 9. The most important constraints to production faced by bambara farmers in Ghana are poor climate, lack of processing facilities, limited access to land, pest infestation and high cost of labour and inputs; 10. Bambara is usually stored shelled or unshelled over an average period of 8 months; 11. Traditional pre-storage treatment is more commonly used than the application of agro-chemicals; 12. Generally, processing of bambara is limited to the production of flours and pastes, using simple traditional techniques; 13. Bambara plays a more important role in the diets of households in the Northern sector than in the South; 14. The major constraints to bambara processing and utilization identified in the study are long cooking periods and inadequate processing techniques.

Output 2

Marketing of bambara in Ghana

The marketing of food crops in Ghana is quite a neglected area and, with bambara groundnuts in particular, action to deliberately improve marketing is non-existent. This has acted as a major hindrance to any bambara development programme. Bambara production in Ghana is on a small scale and farmers tend to incur higher transaction cost than other larger production units, because the quantities of inputs they need and output they sell are smaller. They are often less informed

and have less bargaining power and also are faced with frequent price fluctuations, wastage due to poor handling and storage and poor transport systems. The present study was undertaken to address this situation by identifying the deficiencies in the marketing of bambara groundnuts and to analyze how the marketing system works for bambara groundnuts. The findings of the research were used to make recommendations concerning how to develop appropriate quality systems for the production and marketing of bambara groundnuts.

In Ghana, the major players in bambara marketing are the producers, bambara traders (in the producing centres), wholesalers, retailers and consumers. Most of the bambara sold in the city of Accra are produced mainly in the Northern sector of Ghana, namely Northern, Upper East and Upper West Regions. In the southern sector of Ghana, some bambara is also produced in the Ada and Adidome Districts of the Greater Accra and Volta Regions.

Producers: The producers of bambara sell the groundnut to bambara traders in the producing areas from whom most of the retailers in the urban markets such as Techiman, Tamale and Bawku buy to sell directly to customers in the producing areas. The surplus is then sent to the urban markets for sale to traders who have come to buy them.

Retailers: The retailing takes place in most of the urban markets such as Kpassa, Kasseh junction, Tamale, Bawku, Techiman and the Agbogbloshie markets. Mainly market women, mostly of low educational level, do retailing in the market places. In these markets, the opportunity costs of trading are low since women have low earnings in other fields; traders move quickly in search of even small gains. The survey shows that 21.6 percent of the bambara traders have no formal education whereas 24.9 percent of the respondents have some form of education. Bambara groundnut is usually sold alongside other commodities such as cowpea, groundnut, soybean and other types of beans. Female population among the traders interviewed forms 94 percent whereas only 6 percent of them are males (Figure 2.1).

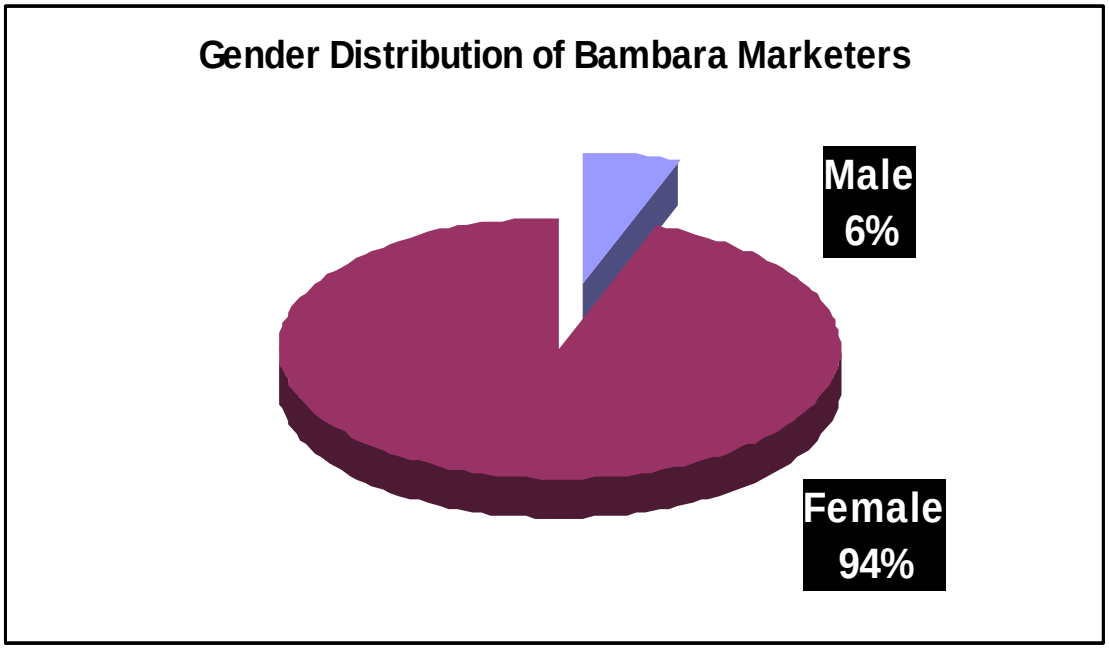


Figure 2.1: Gender Distribution of Bambara Traders

The retailers use the *olonka* (American tin), rubber bowl and the margarine tin as common measures for bambara groundnuts. Most of the retailers have pushed in the base of these tin measures to maximize their margins. Larger measures are often used for traders who are buying large quantities and very small ones by retailers. Some traders have both types of measure where the large measure is used for customers and smaller ones for non-customers.

Customer relationship develops after a series of transactions. Some farmers have customer traders to whom they sell their produce and this could range between two or more customers. This creates competition among these buyers. Many traders stick to a particular market to maintain this customer relationship thus ensuring reliable supply.

Competition and Prices: The day's price for a commodity is fixed by the first trader who arrives at the market with the produce; a price which will be in line with the closing price of the previous market in that area and to which other traders align their price. Other traders quickly follow deviation from this price by one trader so that most markets have many traders selling the same produce at the same price. Bambara groundnut is sold not by weight but by measure, which is a kind of bowl. Each trader's profit is very small and is usually derived from a minor

adjustment made in the weight and quality of the produce. Bambara groundnuts may change hands several times in the course of the day according to fluctuating prices.

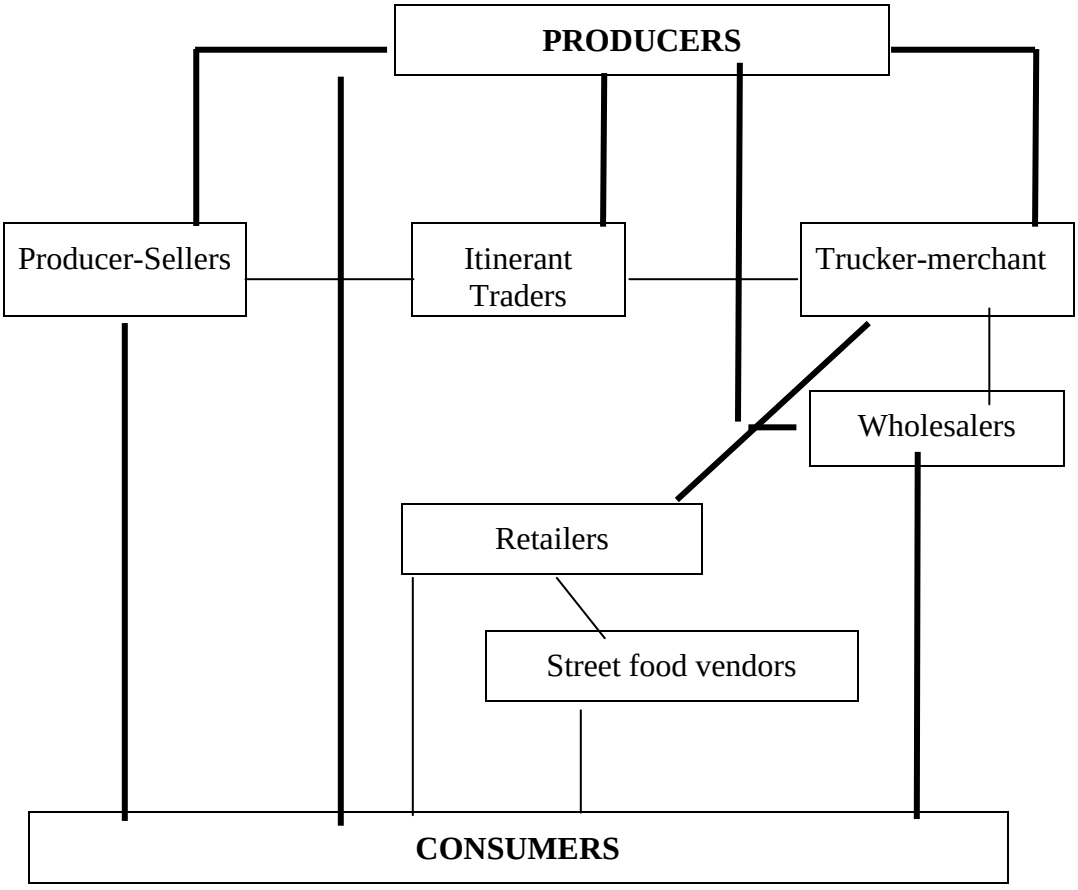
The prices of locally produced food exhibit distinct seasonal cycles which correlates closely with the high and low production seasons of the food crop in particular. Periods of price stability are inconspicuous, even over shorter periods. Seasonal changes in demand and supply associated with tradition (in the Upper East region, a meal prepared from bambara groundnuts is served at funerals) have the strongest influences upon the bargaining which eventually determines the range of prices found at any one time. The low price period for bambara groundnuts in Ghana occurs during the peak harvesting seasons of June to September. The highest price for bambara groundnut is between October to April.

The survey shows that supply and demand conditions determine bambara prices on the market. This forms 52. 3 percent of those interviewed; traders' margin forms 2 percent and mode of transportation forms only 1.3 percent. Individual traders influence prices in the markets (39.9%) with the traders association having a little hand in price movements (13.1%). Bambara prices in the urban markets are extremely high and this can be attributed partly to the supply and demand situations whereby the supply has been trailing the rapidly increasing demand caused largely by the "neglect" of the crop due to the attention researchers have devoted to cowpea. It is not on the list of crops prioritized by MOFA and the few farmers who produce it do so on subsistence. The survey shows that the mean highest price in the destination market is ¢203,700 (£22.63) per bag of 62.5kg with the mean lowest price in the destination markets being ¢99,000 (£11.00) per 62.5kg bag. Over the years, bambara has faced stiff competition from cowpea because of cowpea’s good agronomic features and short cooking time. This combined with low production levels could be attributed for its high price.

The Marketing Structure: In the food crop marketing system, the basic price level for any commodity tends to be determined at the point where the produce enters the supply system, that is, the rural market, because of the relatively small processing which most farm produce undergo. The basic price level is the market clearing equilibrium price established by the forces of demand and supply. Once the basic value is established, it becomes the pivot around which

the prices of the other grades and sizes and also for other locations are determined. There are generally several stages which comprise the distribution channel for bambara groundnuts. It is the primary wholesalers, secondary wholesalers, and retailers that are the critical links in the marketing system.

Figure 2.2: Channel of Bambara Distribution



Source: Authors

The activity encompassed within the distribution process from the time the bambara is harvested until they are sold at the retail market depends upon the state of the product. The present flow of bambara groundnuts from producer to consumer is one complex picture of inefficiency that has evolved over the years. The flow of goods along the marketing channel begins with the farmer

selling his produce to the local or farm level buyer. Then the produce is passed on to the trucker-merchant who transports it to market centers where it is sold to wholesalers. The latter deliver the goods to the retailers who in turn may pass on the product to another retailer who completes the final link between producer and consumer in the marketing channel (Figure 2.2). Three main streams of traders could be identified in food crop marketing. These are itinerant traders who operate within their own acquired geographical area.

The marketing of bambara groundnuts in Ghana falls under the traditional marketing system. This system exists purely for the marketing of food crops. Itinerant traders who could be trucker-merchants themselves are responsible for assembling, storage and transporting the purchased produce to the consuming areas where they are delivered to other traders at the current market prices. At the consuming markets, market queens covertly make sure that final consumer prices do not fall below certain prices fixed by them. They ensure that food commodities that enter the market are distributed to market based traders for sale to the final consumers. Farmers also have a strong linkage with itinerant traders and the market based traders thus making the social aspect of marketing quite strong. Informally, there is an understanding with respect to the provision of credit and other social needs, market assurance and the process of buying (MOFA, 1987).

Competition and Entry: Retail markets for foods and bambara groundnuts in particular operate with strong competition between buyers and sellers. Farmers and farmers' wives often take the bambara to the daily markets in towns or to the periodic markets in the villages which is held on a rotation of six days in the Northern savanna zone, and weekly in the coastal belt. Trading in the markets is seldom restricted and entry is unrestricted with people moving between farming and trading according to the seasonal fluctuations in activity. Many people buy bambara groundnuts from the regular markets, buying in small units after much bargaining with sellers over the size of the measure sold for the conventional price. However, competition is probably not perfect. The bambara groundnuts in the markets are of varying quality and are inspected before purchase. Buyers and sellers are often well known to each other and the final bargains reflect degrees of obligation as well as estimates of the equilibrium price. Knowledge of market trends is far from perfect as the survey results show that farmers and traders have limited or no information about prices and trade in other markets. The absence of regular and current information for bambara

traders leads to markets within a few kilometers of each other showing markedly different prices for some length of time, before a few traders move their custom and thus bring about a coordination of prices. Sellers in the urban markets are probably served with information since traders traveling round their sources of supply become aware of trends elsewhere.

Role of Storage in Marketing: The storage function is performed by both farmer, trader, private and government sector. The government sector operates modern storage facilities. Bambara groundnuts, like any other food commodity, should be stored when prices are low, and sold in periods of scarcity when prices are high enough to make storage economic. This is to increase the income of farmers without necessarily inflating the price paid by consumers. A number of itinerant traders and wholesalers operate a number of storage rooms in the market centres. The survey results indicate that bambara traders stored bambara in jute sacks in rooms and the producer-sellers keep their produce in barns. The traders in these markets do not pay rent for storing the bambara as they store all their commodities together in the rooms that attract a minimum fee of ¢500 per bag per week. None of the respondents could give the exact amount they pay since it is not on a monthly basis.

The respondents also indicated that due to lack of capital, they are not able to store the bambara groundnuts with any agrochemical. They therefore resort to traditional practices such pouring moderately heated sand on the bambara groundnuts, sun-drying the beans daily and keeping the unshelled groundnuts in jute sacks. They stated that the beans could be kept in this way for about three months depending on the demand situation.

Transport: The road system in Ghana is relatively good between the capital and the regional capitals as well as some districts; but even then the link between Accra and some urban centres are in various stages of disrepair. The situation is worse on the roads linking the various rural producing areas to their district capitals. The feeder road system has been improved in these areas. The assembly points in the savanna zone are linked to the first class roads by second class roads, which are usually untarred and unmotorable during the rainy season. Some few feeder roads radiate from the marketing centres and these connect the market centres to some bambara

producing villages. These feeder roads are motorable in the dry season. In the savanna zone, the primary markets are mainly reached by foot, donkey cart, and bicycle or by vehicle.

Consequently, the privatization of the petroleum industry in Ghana and the recent increases in petroleum prices has led to exorbitant transport charges. The survey shows that traders pay on the average, between ¢200 (£0.022) for those who use pull carts in the village markets and ¢2300 (£0.26) on a bag of bambara groundnuts transported to the urban market on board a minibus. The survey indicates that the highest price paid by a trader to transport a bag of bambara groundnuts to the urban market, probably from Kpassa to Accra, which according to the traders, could take 3 days because of the bad nature of the road is ¢10,250 (£1.14).

Costs of Marketing: In the competitive market system, prices, at each stage of the marketing process, are determined by the interaction of demand and supply. At the village markets, wholesalers and retailers buy the bambara groundnuts cheap and sell in high priced markets by competing with each other to keep down their own incomes. The survey results reveal that the cost of distributing bambara groundnuts between farmers and the final buyers amounted to 28 percent of the retail prices for bambara because of high cost of transport from the markets (Table 2.1).

Table 2.1: Marketing Margins

Percent of Retail Prices of Bambara groundnuts		
Retail Price at Accra	¢242,000	100
Retail Margin	¢ 25,200	10.4
Transport	¢ 18,400	7.6
Other Costs	¢ 6,400	2.6
Wholesale Margin	¢ 18,000	7.4
		28.0
Producer Price	¢174,000	72.0

Source: Author's Computations based on data from survey of June-July, 2000

Market Information: The survey results indicate that traders and farmers have little information of government policy on bambara groundnuts but do not receive any extension services from the Ministry of Food and Agriculture. They are completely left on their own as regarding production

and marketing. For instance, they receive information on prices from the market place (Table 2.2a). The importance and regular availability of these information from their sources also indicate that of the traders (29 respondents) who have any idea of a government policy, 18.8 percent says it was not adequate whereas 11 traders forming 7.1 percent indicated that it was adequate. 114 traders (74%) did not respond at all (Table 2.2b).

Table 2.2a: Sources of Market Information[2]

Type of Information	Source	Percent
Market Price	Market Place	98.6
Quality	Own Observation	32.6
Road Condition	Market Place	97.1
Supply	Other Traders	38.8
Transport	Market Place	96.7
Government Policy	District Assembly	18.8

Source: Authors Computations based on Survey Data in June-July, 2000

Table2. 2b: Sources of Market Information[2]

Type of Information	Source	Percent
Market Price	Adequate	63.6
Quality	Adequate	33.1
Road Condition	Adequate	29.9
Supply	Adequate	31.8
Transport	Adequate	33.1
Government Policy	Adequate	18.8

Source: Authors Computations based on Survey Date in June-July, 2000.

The constraints identified by the traders include lack of capital from formal sources, lack of assistance from the extension officers of the Ministry of Food and Agriculture, high costs of production among others.

Concluding comments and recommendations: This study focused on the deficiencies in the marketing of bambara groundnut in Ghana from the socioeconomic point of view. The study found that the quantities of bambara groundnut produced in the country and the acreage under cultivation is very low as compared to the other food crops. Deficiencies were identified in the

way the farmers receive their information as there is no assistance given to these farmers by the Agriculture Ministry.

The study further revealed that the storage methods practiced by the farmers and traders result in high losses of the groundnuts. The traders have to travel to far places to bring the beans to the urban centers and because of the poor condition of some of the roads, they spend days before they get to the destination markets. It is relatively expensive to produce and market bambara groundnuts as compared to other food commodities.

The study again shows that about six actors are involved in bambara marketing. These include the producers, itinerant traders, trucker-merchants, wholesalers, retailers and the final consumers. Six percent of the traders are males and these could be wholesalers. Women with no or little education mainly do retailing in the bambara trade and they use measures of different sizes. The constraints faced by the bambara traders and farmers are beyond their collective control since there is no association that caters for their needs and they also do not receive help in terms of research and improvements from any quarter. The constraints they face include long cooking time, storage losses, lack of funds, roads and transport services and lack of standardization.

Based on the findings from the study, the following recommendations are made:

i. Rigorous research should be conducted into the agronomy of bambara groundnuts and how it can be improved to suit the tastes of consumers.

ii. The Ministry of Food and Agriculture (MOFA) should accord some recognition to these farmers by extending their extension services to them. This will encourage these farmers and let them have a sense of belonging. Due to its rich protein content and the fact that it could be exported, MOFA could start gathering information on the crop as it does for other crops.

iii. The government has done so well in its road construction policies but the survey indicates that the roads used by the bambara traders are not good. They are unmotorable whenever it rains. Since harvesting of the crop also starts at the onset of the rains, steps should be taken to correct this situation.

iv. A study should be conducted into the feasible ways of meeting the credit needs of bambara farmers and traders at reduced costs.

v. Bambara groundnuts have the potential of becoming a major export crop and the government should take a serious look into its production and marketing in the country. This could provide employment for people, increase the incomes of farmers and traders as well as reduce food insecurity in the country.

Output 3

Studies on the market potential for bambara groundnut

Marketing Structures: Key features of bambara marketing are the informality and relative simplicity of marketing structures. As a result, a variety of marketing channels have been created leading to some difficulties in trying to generalize. A sizeable proportion of output does not enter the market but is consumed by the producer and her extended family. The majority of producers hold back some of their production as seed for planting next year, although some producers either consume all their production or sell it for cash and purchase close to planting. Any surplus that is marketed is often done informally by the producer (or a family member) for cash at a local market. At the market it may be bought directly by the ultimate consumer or by a small processor or trader. Sometimes bambara may be bought directly from the grower by an itinerant trader who will aggregate the small purchases made and sell on. Some traders will purchase the fresh bambara which they will then sell at a market stall. Some will be sold to itinerant street vendors.

In contrast to many commodities, no trader was identified who specialized solely in bambara. Moreover, with a few exceptions, all the traders handling bambara dealt with relatively small quantities of the product. Some large wholesale traders were identified in Zimbabwe and South Africa and these were responsible for exporting or importing several hundred tones of bambara. These larger traders either tended to have their agents operating in the producing areas who bought directly from the growers or they bought small traders. The larger traders transported bambara in 28-31 ton lorries or in containers.

For several reasons, particularly the scale, yields and uncertainly of production, there appears to be no contract or forward purchasing of bambara from growers. The only example of forward purchasing that was identified was between a large seed trader in Zimbabwe and a South Africa trading company. Each year the Zimbabwe company agrees to supply the South Africa company

with several hundred tones of bambara. By trading together for many years, both companies have developed a good relationship with a sizeable degree of trust. Thus, although a "price" is agreed each year, both companies recognized the uncertainly of supply and prices, and in exceptional circumstances when the prices rose the contract price could be increase by mutual agreement.

Bambara is available in some of the larger urban markets, such as Makola Market in Accra and Mbare Market in Harare, which implies some degree of aggregation of supply. However, supplies to these markets tend to be seasonal and the proportion of output sold through these outlets appears to be relatively small.

Bambara is retailed to the customer in a variety of forms and by a variety of methods. The retailers vary from petty informal traders who may sell tubani, fresh or packaged beans in small quantities to large supermarkets which sell packaged bambara.

However, each of the small number of supermarkets contacted in Ghana and Zimbabwe said that turnover of the dried packaged bambara was small although the volume of trade tends to be greatest at planting time and following the harvest. This was also the case with small quantities of canned bambara available in Harare.

Traders tended to differentiate between bambara sold for food and bambara sold for seed. In South Africa, the latter was sold in 10-15 kg bags. Bambara for foodstuff use is available in a range of packaged sizes from 250 kg to 5 kg as well as being sold loose in many markets.

Grading and Specifications: Bambara is invariably not classified or standardized. In most instances there appears to be no grading system and if any selection is undertaken, (and this is rare), it is invariably based on colour sorting since bambara is available in a range of differing colours. One Zimbabwe exporter removed the smaller seeds from his shipments – and these were used to feed racing pigeons. There are no definite criteria to measure quality, while a series of measures are used to measure quantity, ranging from "koko bowls" in Ghana, to bags of 50 kg in Zimbabwe.

Bambara is invariably sold in mixed colours for which there is a preference. Some years ago on Zimbabwe trader undertook research on colour variations and tried to market the colours separately but with no success.

International Trade in Bambara: No country appears to collect official export or import data on bambara, and even if it was separately specified the amounts traded would be small or negligible. Over a dozen European and US companies were contacted that traded in edible nuts and beans as well as related products and almost all of them had not head of bambara groundnuts! The major export companies in South Africa and Zimbabwe also confirmed that no exports of bambara form Africa to either North America and Europe was taking place, with the possible exception of an (unconfirmed) shipment to the West Coast of the USA. It was mentioned in Zimbabwe that a Japanese company had expressed interest in purchasing bambara but they required large regular shipments which under the present production system would be impossible to satisfy. As regards Indonesia, according to one source "there is no export in substantial amounts, since demand exceeds production; small amounts seem to be exported to USA as " ethno food". Retail packs of Indonesian bambara (known locally as Kacan Bogor or Bogor Nuts) are sold via the Internet.[6] Some decades ago, there were several unsuccessful attempts to develop exports to Europe as an animal feed.

Any international trade that does take place is in dried rather fresh bambara and invariably involves small quantities of unrecorded cross border trade with neighbouring countries. For example, bambara is traded in small quantities across the Sahelian region of West Africa; thus, Ghana sells some bambara to Burkina Faso and Togo.

The biggest international trade in bambara takes place between southern African countries especially between South Africa and Zimbabwe. This trade takes place both formally and informally. Estimates of Zimbabwe exports, and South African imports, ranged between 1,500 to 3,000 tonnes per year. South Africa was also reported to be importing small quantities from Malawi, Mozambique and Tanzania. Also, Swaziland imports bambara from South Africa with one source estimating that Swaziland's annual imports were of the order of 300 tonnes.

Zimbabwean traders also reported selling bambara seed to Angola and Mozambique, as well as exporting to neigbouring Botswana as well as Uganda. A South African trading company has recently received a trade inquiry from Kenya.

Zimbabwe is reported to be trying to establish the production of organic bambara, presumably for export. However, a major constraint to organic production and sales is the need to undergo the certification process involving foreign evaluators, which can be an expensive process.

Trade Procedures and Tariffs: Tariffs on bambara are negligible. However there are a number of other barriers to trade. Thus, if bambara is officially exported from Zimbabwe to South Africa an export permit is required and there are 12 or 13 steps involved in obtaining permission to export e.g. quality of seed, bank, customs, phyto-sanitary certificates. Similarly if Swaziland imports bambara from Zimbabwe then the need for a number of permits combined with the level of transport costs can seriously restrict sales. Imports into Swaziland from South Africa are much easier and almost all consumption of dried bambara in Swaziland consists of South African imports.

Bambara is exported in break bulk not in containers and invariably in 50-kg bags, which appears to be the dominant form in which bambara is shipped. Formal exports are transported in bags on lorries of 28-31 tonnes, although occasionally containers are used. Alongside official "formal" exports there are reported to be sizable quantities shipped informally particularly between Zimbabwe and South Africa over Beit Bridge. These are undertaken in small trucks and shipments can be as low as 1-2 bags. While most international trade in bambara is in 50kg bags there were reports of small retail packs of 500 gm to 5 kg being exported from South Africa to Swaziland.

Bambara Markets in West Africa:

Cameroon - Bambara is thought to have originate in northern Cameroon and it is a staple food for much of central, littoral and northern Cameroon but no estimates of marker size are available. It is mainly cultivated by women and primarily for domestic consumption. The crop is mainly

consumed fresh. It is invariably inter mixed with other crops but in the rare cases when men grow it is cultivated in a pure stand.

Ghana **-** Without a formal survey it is very difficult to obtain an accurate estimate of the quantity sold, but it is almost certainly less than half of production and could be as low as 25 per cent. [7] Sales not only take place for consumption in the region but also to traders who will transport it for sale in the urban markets of central and southern Ghana, particularly Accra and Kumasi. Consumers in these regions are likely to be urban dwellers and will require good quality produce, for which they are prepared to pay a premium. Most urban sales take place in markets where the bambara is invariably in loose form; there is at least one company selecting and packaging cream-coloured bambara for sale in supermarkets.

The marketing of bambara is almost exclusively limited to the women members of the household; and women dominated the trading activity at the local market. Wholesalers of bambara are few and far between. The amounts traded tend to be small and are combined with other grain and legume marketing activities – one trader in Bolgatanga reported buying 20-4-bags of bambara in season.

The low quantity of bambara entering trade is not because of a lack of markets or traders. Throughout the northern regions (and indeed throughout the whole of Ghana and many other African countries) there are a large number of integrated markets – village, district, regional and national markets. Alongside are a large number of traders operating at all scales of activities ranging from petty traders to large wholesalers and exporters. This, in the Northern Region there are over 100 markets held every 6 days or every 3 days. In the Upper East Region there are 36 markets operating every 3 days. According to one source (Asuming Brempong 1991) 94% of villages in Ghana are within 10 kms of a market and 54% of villagers sell at market. Thus, the lack of functioning markets is not a constraint to increased trade in bambara – neither is the problem of storage, post harvest losses, taxation or other government interventions. However, the lack of finance and credit does act as a constraint to trading activities, as well as a constraint on production.

All the villages and towns visited in northern Ghana supported the findings in Golob et al 1996, that not only is there considerable entrepreneurial activity in the region but also that this activity was not confined to trade. Small scale processing and storage of commodities were important income generating activities, undertaken by even the poorest women, who also recognized the benefits of storing for sale in the lean season.

There are no official export data on bambara, and even if it was separately specified the amounts exported are negligible – and at best would include small quantities of unrecorded cross border trade with neighbouring Burkina Faso and Togo. Even exports of groundnuts from Ghana are small, despite there being a sizeable domestic production and internal market for the product.

Bambara Markets in Zimbabwe and Southern Africa: Most of the bambara produced in southern Africa is consumed locally in both the fresh and dried form. One major Zimbabwean trader argued that the fresh trade was more lucrative but smaller, while another thought that approximately 60% of bambara was consumed in the fresh form.

As previously discussed, southern Africa countries are the largest exporters and importers of bambara with almost all the trade being inter-regional. Zimbabwe appears to be the world's largest exporter of bambara – known locally as nyimo (Shona) beans. As yet, South Africa has not been able to compete with Zimbabwe, but this could change as a result of Zimbabwe's rising production costs, especially for transport, and its stable exchange rate. Zimbabwe exports are estimated at only 2,000 to 3,000 tonnes a year and these are mainly shipped to South Africa, with lesser amounts to other countries in the SADEC region including Botswana, Angola, Mozambique and Swaziland. A small proportion of these exports was reported to be seed for planting. Most exports take place in the cooler months – June to November. While the harvest is in March/April only small quantities are available immediately after the harvest in part because possible insect attacks on other crops are greater and in part because farmers need to shell the bambara crop by hand. The above export figure is likely to relate to formal exports but, in addition, there is a sizeable informal trade. Exports are not separately specified in the export statistics.

Zimbabwe is also the only country that currently cans bambara, but production is very small and it is thought that no exports of tinned bambara are being undertaken. The tinned product appears to be predominantly marketed through supermarkets and, according to one source, is consumed mainly by the white population.

The size of the domestic market is difficult to estimate but could be anything from 7,000 to 30,000 tonnes depending on domestic production. Certainly bambara is well known throughout Zimbabwe to the extent that various recipe books are available incorporating bambara based foods. The dried market is quite competitive involving a number of buying relatively small quantities – perhaps up to 20-3- tones at a time.

Bambara is also popular in neighbouring countries and a sizeable formal and informal trade is undertaken, in both dried and, to a lesser extent, fresh bambara. Usually bambara is sold at a premium to competing legumes. Estimates of the size of the South African market range between 1,500 t0 4,000 tonnes with import supplying a sizeable share of the market. However, in view of the apparent popularity of bambara (or jugo bean – as it is more commonly referred to) in Zwa-Zulu Natal and northern South Africa the market may in fact be smaller.

The market in Swaziland could be of the order of 500 tonnes of which an estimated 300 tonnes is imported. No commercial production is thought to be undertaken, although there is certainly some production for subsistence purposes. Consumption is predominantly by the older generation.

Bambara Prices: Despite the lack of regular price series, it is apparent from discussions that bambara prices fluctuate widely, in part reflecting both the location and the large variations in production. Fluctuations in demand appear to be much small and hence have less impact on price fluctuations. As with most agricultural crops, prices invariable fall following the harvest and rise during the year. Prices tend to at their peak just prior to planting, when purchases are being made for those who have not maintained a store of seed for planting. It was suggested that on occasions prices might fall occasionally around the planting period, as more seeds became

available. A doubling of prices between harvest and planting was not unusual. Since this is the case, growers could benefit by increasing the volume of bambara that they store.

Obviously factors other than simple supply and demand will affect prices such as prices of alternative food crops, location of production, exogenous factors, such as new market entrants, purchases by relief agencies, and the quality of beans available. The neglected nature of bambara is reflected in the lack of price and other data available, which limits the ability to analyse market and price trends. For example, in Ghana the Policy Planning, Monitoring and Evaluation Department of the Ministry of Agriculture collect a large number of prices for agricultural products but prices of bambara (and cowpea) are not collected on a regular basis. Indeed no organization appears to collect prices on a regular basis and hence no regular price series are available. Therefore, one is dependent on prices collected at a single point in time. For example:

- Ghana: early 2000 buyers were offering 60-cents/Ib. fob Ghana.
- South Africa in 1998 prices were quoted as ranging from R3 to R20/kg, in July 200 wholesales prices equivalent to $355/tones were quoted.
- Swaziland; April 2000: retail 10 kg mixed colours were quoted at E45.
- US: in early 2000 US market prices were quoted at $250 to $350 per tonne but could be as high as $500 to $800.
- Zimbabwe: in July 1999 prices ranged between Z$6,000 to Z$7,500 per tonne; some farmers were selling at Z$18 per kg with individual market sales at Z$20 per kg. Prices can fluctuate by as much as 50% in a month.

Concluding remarks and recommendations: Outside sub-Saharan Africa, bambara is hardly known and consumption is negligible. Even within Africa it is sometimes referred to as the "neglected" or "forgotten" crop, despite the fact that it appears to be grown and consumed in the majority of sub-Saharan African countries. Nevertheless, even in sub-Saharan Africa, bambara is a minor crop; invariably it is produced on a small scale as a subsistence rather than cash crop by women as part of a diversified farming system involving the production of several crops. There appears to be negligible commercial production of the crop on plots in excess of five hectares. This lack of commercial production and the small-scale of existing production,

combined with the low population densities, large distances and poor transport and storage infrastructure all limit the market potential of the crop. Most of current production is consumed either fresh or in the dried form by the extended families of the women producers. Where a surplus is marketed for cash it is mostly marketed locally to supply local needs. Other than shelling and food preparation undertaken in the household, further processing of the crop is minimal. The only exception is a canning operation in Zimbabwe – and even here the canning operation is completed in a few weeks and involves the processing of small quantities of bambara, probably in the region of perhaps 10 tonnes per year.

Although several thousands tones of bambara production are traded within regions in Africa, particularly southern Africa, negligible quantities enter international trade. Remarkably it has proved impossible to identify any individual grower, company or organization – whether producer, trader, financier, processor, retailer, researcher – that specialized solely in bambara. The nature of bambara production and marketing, as well as the very limited data available, several limits the scope for detailed market analysis. The limited evidence available does suggest that production has fluctuated, and in recent times bambara appears to have lost importance partly because of competition from other crops. However, there does appear to be scope to expand production and markets in many sub-Saharan African countries. Scientists working on a recent EU funded Project concluded that "bambara groundnut is a species that has much to offer in many rain-fed production systems and for which appropriate agronomic strategies can be applied to substantially improve current production levels" (R|EU nd p.60).

Anecdotal evidence suggests that demand for bambara appears to exist but the market is small. In order to create a large market then a series of production and marketing constraints will need to be overcome, this in spite of the apparent attractive qualities of bambara. The characteristics that make it a promising crop include:

- nutritional and taste qualities
- the low utilization of purchase inputs
- the ability to grow in poor soils and harsh environments
- resistance to pests and diseases.

Alongside these positive characteristics, there are a number of constraints that include:

- very low yields
- production on marginal lands
- time and energy consuming processing techniques
- a lack of commercial production

Without the successful development and expansion of the crop then it is unlikely that sizeable domestic, regional and international markets can be developed. An increase in output would allow a growing proportion of output to enter the cash economy and possibly regional and international trade. A number of policies could be pursued with donor and government support to assist in the expansion of the crop; these include:

- efforts to increase yields through better seed selection and breeding leading to the availability and better distribution of higher yielding varieties
- improved agronomic and management practices
- improved extension services and training programmes
- the development of contract farming opportunities
- improved processing techniques
- efforts to expand in the market in urban areas; a factor having a dramatic impact on food consumption in Africa is the rapid increase in migration and urbanization; as a result "street foods" are now a major sector of food processing in many Africa countries supplying a wide spectrum of workers and students; associated with this is the growth of demand for relatively easy food preparation techniques and the associated demand for "fast foods"
- improved market awareness and access; this applies to domestic, regional and international markets
- promotion of existing and new bambara products at consumer, retailer and trader level; nutritional values, compilation and exchange of recipes and cooking methods;
- development in the niche organic and fair traded markets
- possibility of developing bambara as a constituent of weaning foods for babies
- research effort to overcome the digestibility problems

However, while several sources have argued that "demand exceed supply", there is a danger in encouraging production too much in case there is no viable market in the short term for the increased output. There are several examples where this has happened and, as a result, farmers have produced a surplus which they have found difficult to market and have been discouraged from future production. Nevertheless, it is vital to remember that identifying and developing successful further opportunities for the production, processing and marketing of bambara will have direct benefits mainly for many women producers who currently represent some of the most impoverished groups of people in sub-Sahara Africa.

Output 4

Studies on the effect of kawe treatment on water absorption and cooking characteristics of bambara groundnut varieties.

The need for simple methods that could be applied to overcome the hard-to-cook effect of bambara in order to promote its consumption makes the results of this study quite significant. Understanding the tenderising effect of the common rock salt, *kawe*, and the minimum levels necessary to achieve the needed results for bambara, were the main outputs sought in the present studies.

Effect of kawe treatment on water absorption properties of local bambara varieties: Values of water absorption over a 12-hour period in different concentrations of *kawe* solution are presented in Fig. 4.1 for five bambara varieties. In the absence of *kawe*, the cream pinkeye bambara achieved the highest water absorption value (62.8%) within 12 hours of soaking while the dark brown bambara had the lowest water absorption (37.5%) over the same period. The disparity in the rate of water absorption relates to the differences in grain sizes and conforms to earlier findings with sorghum grains where smaller seed sizes were found to absorb water at a faster rate than large-sized grains. The cream pinkeye had the smallest seed size while the dark brown variety was the largest in size. At low concentrations of *kawe* in the soak solution (0.1%) significant increases in the rate of water absorption were observed in four varieties of bambara. These increases ranged from 5.2% in the cream blackeye variety to 23.2% in the dark brown one. One variety, the maroon white-eye, recorded a decrease in the rate of water absorption at all concentrations of kawe in the soak water.

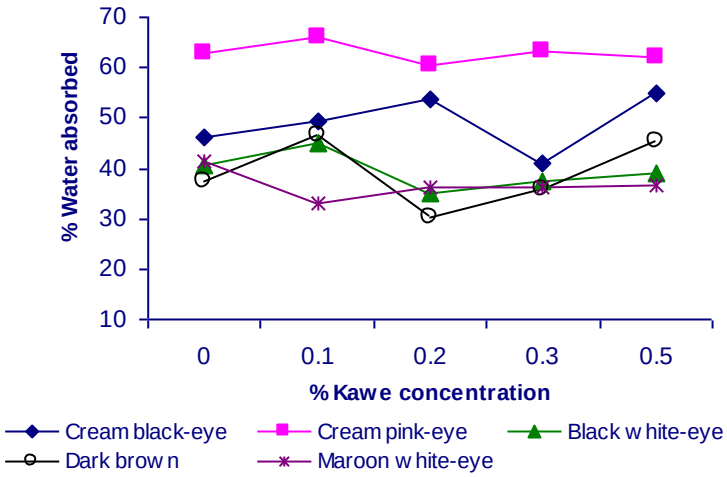


Fig 4.1. *Effect of pre-soaking (12 h) in kawe on water absorption characteristics of local bambara varieties*

Effect of pre-soaking and boiling on water absorption: The effects of pre-soaking and boiling in *kawe* solutions on the water absorption properties of two varieties of bambara are shown in Table 4.1. Based on their water absorption properties the cream pinkeye was described as a relatively easy-to-cook variety while the maroon white-eye was described as being hard-to-cook. For both varieties of bambara, significant increases in water absorption were achieved with increasing soaking and boiling times in the absence of *kawe*. In *kawe* solutions however, water absorption was enhanced by the combined effects of the shorter soaking time (3h), lower *kawe* concentration (0.3%) and boiling. Prolonged soaking and boiling in higher concentrations of *kawe* tended to cause leaching resulting in apparently low water absorption values. In a similar study on the micro-structural changes of cowpeas cooked in *kawe*, extensive cell swelling and deformation of cells occurred and some cells were observed to have burst (Uzogara et al., 1990). Such microstructural changes may explain leaching observed in cooked bambara seeds.

Table 4.1. Effects of pre-soaking and boiling in kawe solutions on the water absorption characteristics of two bambara varieties[1]

Bambara variety	Soaking time (h)	% water absorption after boiling for 0.5 h and 1.0 h					
		0.0 % *kawe* soln.		0.3 % *kawe* soln.		0.5 % *kawe* soln.	
		0.5 h	1.0 h	0.5 h	1.0 h	0.5 h	1.0 h
Cream pink-eye	0.0	68.9 ±2.4	87.1 ±2.2	81.6 ±1.6	91.3 ±1.8	88.8 ±2.1	97.8 ±1.8
	3.0	79.9 ±1.8	88.2 ±1.5	87.2 ±1.2	89.7 ±0.9	72.0 ±1.3	87.2 ±2.1
	6.0	84.4 ±2.7	92.8 ±2.1	77.2 ±1.0	84.4 ±1.1	67.0 ±1.0	70.2 ±1.4
Maroon white-eye	0.0	53.2 ±1.0	76.8 ±1.2	58.7 ±0.9	80.9 ±2.1	54.0 ±0.8	76.0 ±1.1
	3.0	58.9 ±2.2	79.3 ±1.7	65.2 ±1.0	83.8 ±1.4	66.2 ±1.4	79.3 ±0.8
	6.0	58.6 ±1.6	81.6 ±1.4	69.8 ±1.2	86.6 ±1.3	63.2 ±1.2	65.7 ±1.5

[1]Values are means ± standard deviation of triplicate determinations

Effects of pre-soaking and boiling in kawe solution on cooking times and texture of bambara:

Based on findings from field surveys the five bambara varieties were grouped into the two categories of relatively easy-to-cook and hard-to-cook. The cream blackeye and the cream pinkeye were said to cook relatively faster than the black white-eye, the dark brown and the maroon white-eye varieties. Previous studies under a DFID-funded project also showed similarities in the physical and water absorption characteristics of the varieties within each of these two categories. Significant differences ($p<0.05$) were observed in the cooking times and relative softness of the two bambara varieties when pre-soaked and boiled in pure water at 0% *kawe* concentration (Table 4.2). For each duration of pre-soaking, the cream pinkeye variety cooked faster and recorded texturometer readings that indicated softer texture than the maroon white-eye variety. Pre-soaking was also found to facilitate faster cooking and softer texture after boiling for 1h. In the hard to cook maroon variety,

Table 4. 2. Effects of pre-soaking and boiling in kawe solutions on the cooking times and texturometer readings of two local varieties of bambara[1]

Kawe **solution (%)**	**Soaking time (h)**	**Time to cook (min)**		**Texturometer reading/ softness (Kg force)**[2]	
		Cream pink-eye	Maroon white-eye	Cream pink-eye	Maroon white-eye
0.0	0.0	88.0 ± 4.0	118.0 ± 4.0	8.52 ± 0.47	11.76 ± 0.07
	3.0	78.0 ± 4.0	90.0 ± 3.0	8.00 ± 0.07	8.60 ± 0.02
	6.0	67.0 ± 3.0	60.0 ± 3.0	6.12 ± 0.08	7.57 ± 0.08
0.3	0.0	80.0 ± 4.0	99.0 ± 4.0	6.78 ± 0.23	8.78 ± 0.02
	3.0	65.0 ± 5.0	75.0 ± 3.0	6.23 ± 0.09	6.90 ± 0.19
	6.0	50.0 ± 1.0	54.0 ± 3.0	5.59 ± 0.07	5.80 ± 0.01
0.5	0.0	72.0 ± 1.0	82.0 ± 1.0	6.58 ± 0.06	6.90 ± 0.03
	3.0	50.0 ± 2.0	58.0 ± 2.0	6.00 ± 0.11	4.94 ± 0.04
	6.0	44.0 ± 4.0	50.0 ± 1.0	3.11 ± 0.03	4.82 ± 0.14

[1]Values are means ± standard deviation of triplicate determinations. [2]Texturometer readings were taken after boiling for one hour

pre-soaking in 0.5% *kawe* for 6h reduced cooking time by over 50% when compared to cooking time of bambara that were not pre-soaked in *kawe.* A similar observation was made in the soft-to-cook cream pinkeye variety. Texturometer readings showed harder textures in bambara that did not receive any *kawe* treatment indicating the ability of *kawe* to soften bambara during pre-soaking and cooking. The softening effect of *kawe* increased with increased levels of *kawe* concentration in the soaking or boiling water and with soaking time.

The results of this study showed that pre-soaking and boiling in *kawe* did not produce significant changes in the water absorption characteristics of bambara when compared with seeds that were not pre-soaked before boiling. However, pre-soaking and boiling in increasing concentrations of *kawe* significantly softened bambara seeds. This indicates that the presence of *kawe* results in modifications of the microstructural characteristics of the bambara seeds making them softer. These

modifications, apparently, cause leaching during prolonged soaking or boiling thus producing inconsistent trends in the water absorption characteristics.

It was concluded from the studies that the enhanced cooking and texture softening effect of *kawe*, was due to modifications in the microstructure of the seeds, which also resulted in extensive cell swelling. Consequently, the cells burst with subsequent leaching that brought about an apparent reduction in water absorption.

Output 5

Development of Improved Legume Flour Production Technology for Enhanced Bambara Utilization In Ghana

The need for an appropriate technology for bambara processing to help enhance utilization and potentiate production is one of the main expected outputs of this project. Studies undertaken on this aspect of the project sought to establish varietal and processing effects on the quality of bambara flour as an acceptable shelf-stable intermediate product for various food uses. Based on this, the most appropriate techniques were applied to develop the product.

Varietal and processing effects on bambara flour quality: The effects of bambara cultivars, heat treatment and dehulling on the proximate composition, mineral content and concentration of tannin are shown in Tables 5.1 and 5.2. The most significant effect of processing on the proximate composition was found in the protein content of the bambara. For all the varieties studied, dehulling, with or without heat treatment, caused significant increases in the protein content of the samples. The protein content of the different raw un-processed varieties of bambara ranged between16.8 and 18.4% with three varieties having similar content. When dehulled, the samples had protein values ranging from 20.8 to 25.5%. Roasting did not change the protein content significantly. With regards to the minerals, there was no specific trend applicable to all the varieties, on the effect of processing. For example, boiling and dehulling did not have much effect on iron content but significant increases in the phosphorus content were observed. In some cases, boiling and dehulling increased the content of some of the minerals, while decreases or no changes were observed in others. In all cases however, iron content remained fairly the same.

Tannin, more than any other component, was most affected by both variety and processing. Tannin content of raw bambara ranged between 3.6 and 13.9 mg CE/g sample, increasing with increased pigmentation. The cream pink-eye variety contained the lowest concentration of tannins and the greatest concentration was observed in the black white-eye variety (Table 5.2). Dehulling of the raw bambara resulted in significant ($p<0.05$) decreases in the tannin concentrations. Tannin losses due to dehulling ranged between 57% for the light-coloured cream type to 92% for the highly pigmented black cultivar. Plahar *et al*., (1997) reported as much as 98% losses in tannin concentration of highly pigmented high-tannin cowpea cultivars after dehulling.

Table 5.1. Varietal and processing effects on the proximate composition of bambara flours[1]

Variety and processing treatment	% Component				
	Moisture	Protein	Fat	Ash	CHOs
Cream Pink-eye					
Raw un-dehulled	10.58±0.20	16.76±0.42	9.47±0.06	3.05±0.06	60.14±0.51
Raw dehulled	5.55±0.18	20.76±0.71	8.82±0.07	3.21±0.01	61.66±0.81
Roasted un-dehulled	6.45±0.01	17.53±0.33	7.72±0.01	3.27±0.02	65.05±0.33
Boiled & dehulled	6.59±0.21	21.60±0.57	7.99±0.23	3.17±0.04	60.67±0.52
Dark brown					
Raw un-dehulled	11.08±0.02	18.43±0.04	7.47±0.10	3.36±0.04	59.67±0.08
Raw dehulled	7.26±0.09	25.07±0.75	8.18±0.01	3.43±0.01	56.07±0.87
Roasted un-dehulled	5.77±0.06	18.60±0.19	7.96±0.08	3.42±0.10	64.26±0.31
Boiled & dehulled	7.25±0.10	25.48±0.59	8.75±0.07	3.48±0.04	55.05±0.45
Maroon					
Raw un-dehulled	10.65±0.11	16.94±0.16	6.97±0.13	3.06±0.02	62.40±0.42
Raw dehulled	5.89±0.01	18.88±0.25	8.89±0.13	3.26±0.03	63.23±0.04
Roasted un-dehulled	7.03±0.11	17.07±0.35	7.44±0.04	3.27±0.05	65.20±0.25
Boiled & dehulled	6.04±0.10	19.41±0.44	8.93±0.20	3.36±0.07	62.26±0.81
Black white-eye					
Raw un-dehulled	10.52±0.11	16.75±0.07	7.27±0.02	3.24±0.03	62.23±0.04
Raw dehulled	6.24±0.16	18.08±0.26	10.29±0.07	3.21±0.04	62.20±0.46
Roasted un-dehulled	6.60±0.25	16.93±0.13	7.46±0.04	3.39±0.02	65.63±0.10
Boiled & dehulled	6.70±0.20	18.62±0.51	10.04±0.08	3.30±0.04	61.35±0.59

[1]Values are means of three replicates ± standard deviation.

Table 5.2. Varietal and processing effects on selected minerals and tannin content of bambara flours.[1]

Variety and processing treatment	Component			
	Calcium (mg/100g)	**Phosphorus (mg/100g)**	**Iron (mg/100g)**	**Tannins mgCE/100g**
Cream Pink-eye				
Raw un-dehulled	85.80±1.27	73.95±0.07	1.29±0.01	3.63±0.12
Raw dehulled	61.25±2.33	123.50±0.85	1.08±0.01	1.54±0.49
Roasted un-dehulled	89.35±3.04	136.50±0.42	1.59±0.01	2.47±0.31
Boiled & dehulled	61.12±1.25	127.33±1.46	1.16±0.03	0.79±0.51
Dark brown				
Raw un-dehulled	74.85±0.21	98.85±0.07	1.09±0.01	5.08±0.41
Raw dehulled	65.05±4.03	124.20±0.99	1.10±0.01	0.13±0.03
Roasted un-dehulled	86.85±0.78	111.60±0.14	1.29±0.01	3.97±0.34
Boiled & dehulled	63.81±1.28	123.92±0.23	1.10±0.04	0.09±0.02
Maroon				
Raw un-dehulled	76.10±1.41	123.70±1.27	1.59±0.02	5.92±1.00
Raw dehulled	110.75±0.07	123.65±0.07	1.58±0.01	0.10±0.02
Roasted un-dehulled	83.05±0.49	123.55±0.78	1.09±0.01	5.62±0.84
Boiled & dehulled	110.92±0.19	123.99±0.01	1.68±0.09	0.07±0.01
Black white-eye				
Raw un-dehulled	74.85±0.21	98.45±0.21	1.08±0.01	13.93±1.46
Raw dehulled	121.05±2.19	111.60±0.57	1.10±0.01	1.06±0.12
Roasted un-dehulled	115.10±0.71	109.15±0.78	1.10±0.01	13.06±1.22
Boiled & dehulled	121.39±0.81	111.54±2.40	1.15±0.18	0.08±0.02

[1]Values are means of three replicates ± standard deviation.

Varietal and processing effects on sensory characteristics: Mean sensory scores for porridges of weaning foods formulated with bambara flours prepared by different processing techniques with different types of bambara showed that the processing technique used had a more profound effect on the sensory characteristics than the influence of variety (Table 5.3). For most of the sensory attributes of the products, lowest mean scores were obtained for weaning foods prepared with raw undehulled bambara flour. Undehulled, highly pigmented varieties also exhibited their poor sensory characteristics in the colour and overall acceptability of the weaning foods. Irrespective of variety, dehulling produced high scores for colour. In general dehulling was found to improve the

consistency of the product while heat treatment, whether boiling or roasting, improved the taste, aroma and overall acceptability. Mean sensory scores for samples containing flours prepared with boiled and dehulled bambara indicated very much to extreme liking for the product. On the other hand, weaning food samples from flours that were not heat-treated or dehulled gave sensory scores that indicated only slight preference for the product. Promotion of such formulated products based on their nutritional advantage alone will not succeed. Sensory and functional attributes, rather than nutrition, play a major role in the acceptance of new food products in Ghana. When used in the preparation of traditional bambara foods such as akla/koose and tubani, the main effects of variety and processing were observed in the appearance, colour and texture (Tables 5.4 and 5.5). In highly pigmented varieties of bambara, dehulling was found necessary to enhance the appearance and colour of the traditional foods. For all the varieties tested, dehulling also improved the textural characteristics of the products. Significance of heat treatment was found in the improvement of the aroma.

Technology developed for high quality bambara flour (HQBF): Based on the results of varietal and processing effects on bambara flour quality, dehulling and heat treatment (specifically, boiling) were identified as critical unit operations in the technology development process, necessary to achieve the desired quality attributes. Applying all the techniques involved in the development of a new product, the final process for the production of the high quality bambara flour was established. The flow diagram shown in figure 5.1 describes the process. Samples of flour produced were prepared using this standard technique and evaluated to establish its chemical, functional and sensory attributes.

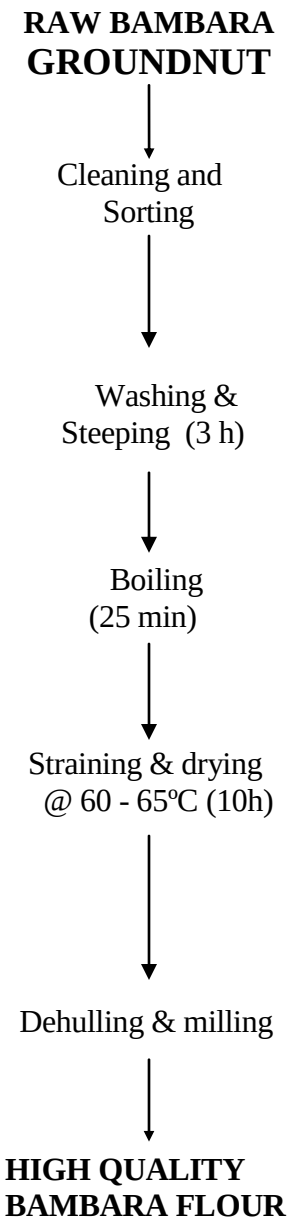


Fig. 1. Flow diagram for the preparation of high quality bambara flour samples

Table 5.3. Varietal and processing effects on the sensory characteristics of bambara-based weaning food[1]

Variety and processing treatment	Mean sensory scores[2]				
	Colour	**Consistency**	**Taste**	**Aroma**	**Overall acceptability**
Cream Pink-eye					
Raw un-dehulled	7.20 ± 0.41^{a}	6.52 ± 0.55^{b}	6.20 ± 0.56^{b}	5.87 ± 0.52^{b}	6.20 ± 0.41^{c}
Raw dehulled	7.63 ± 0.36^{a}	7.64 ± 0.45^{a}	6.18 ± 0.34^{b}	6.12 ± 0.38^{b}	6.44 ± 0.36^{c}
Roasted un-dehulled	7.13 ± 0.35^{a}	6.47 ± 0.52^{b}	8.33 ± 0.49^{a}	8.40 ± 0.51^{a}	7.23 ± 0.24^{b}
Boiled & dehulled	7.53 ± 0.49^{a}	7.93 ± 0.46^{a}	8.27 ± 0.46^{a}	8.20 ± 0.41^{a}	8.27 ± 0.32^{a}
Dark brown					
Raw un-dehulled	6.47 ± 0.52^{b}	6.32 ± 0.50^{b}	6.32 ± 0.28^{b}	6.05 ± 0.30^{b}	6.24 ± 0.41^{c}
Raw dehulled	6.52 ± 0.34^{b}	7.65 ± 0.48^{a}	5.97 ± 0.34^{b}	6.00 ± 0.47^{b}	6.42 ± 0.32^{c}
Roasted un-dehulled	6.27 ± 0.46^{b}	6.55 ± 0.45^{b}	7.88 ± 0.25^{a}	7.22 ± 0.35^{a}	7.00 ± 0.24^{b}
Boiled & dehulled	7.67 ± 0.46^{a}	8.04 ± 0.46^{a}	8.23 ± 0.40^{a}	7.52 ± 0.25^{a}	8.12 ± 0.34^{a}
Maroon					
Raw un-dehulled	6.47 ± 0.64^{b}	6.43 ± 0.32^{b}	6.26 ± 0.26^{b}	6.44 ± 0.43^{b}	6.35 ± 0.23^{c}
Raw dehulled	6.55 ± 0.48^{b}	7.86 ± 0.26^{a}	6.05 ± 0.36^{b}	6.93 ± 0.46^{b}	6.20 ± 0.30^{c}
Roasted un-dehulled	6.53 ± 0.64^{b}	6.02 ± 0.45^{b}	7.97 ± 0.50^{a}	7.63 ± 0.33^{a}	7.45 ± 0.21^{b}
Boiled & dehulled	7.93 ± 0.46^{a}	8.12 ± 0.36^{a}	8.17 ± 0.32^{a}	8.00 ± 0.40^{a}	8.40 ± 0.33^{a}
Black white-eye					
Raw un-dehulled	5.80 ± 0.41^{c}	6.04 ± 0.30^{b}	6.44 ± 0.44^{b}	6.37 ± 0.57^{c}	6.31 ± 0.28^{c}
Raw dehulled	6.66 ± 0.43^{b}	7.90 ± 0.38^{a}	6.45 ± 0.45^{b}	6.84 ± 0.43^{b}	6.12 ± 0.42^{c}
Roasted un-dehulled	5.67 ± 0.49^{c}	6.13 ± 0.36^{b}	8.05 ± 0.20^{a}	7.82 ± 0.30^{a}	7.27 ± 0.37^{b}
Boiled & dehulled	7.70 ± 0.53^{a}	8.12 ± 0.44^{a}	8.00 ± 0.31^{a}	8.45 ± 0.32^{a}	7.98 ± 0.23^{a}

[1]Means in a column not followed by the same superscript letter are significantly different ($p<0.05$)
[2]Based on a 9-point hedonic scale with 9= like extremely, 5= neither like nor dislike, and 1 = dislike extremely.

Table5.4. Varietal and processing effects on the sensory characteristics of bambara-based traditional 'Tubani'

Variety and processing treatment	Mean sensory scores[2]				
	Colour & Appearance	**Texture**	**Taste**	**Aroma**	**Overall acceptability**
Cream Pink-eye					
Raw un-dehulled	7.80 ± 0.21^{a}	5.50 ± 0.25^{b}	7.22 ± 0.35^{b}	6.78 ± 0.25^{c}	6.85 ± 0.48^{c}
Raw dehulled	7.73 ± 0.32^{a}	7.44 ± 0.24^{a}	7.18 ± 0.43^{b}	6.52 ± 0.38^{c}	7.24 ± 0.52^{b}
Roasted un-dehulled	6.11 ± 0.30^{b}	5.64 ± 0.32^{b}	7.30 ± 0.34^{b}	7.80 ± 0.56^{a}	6.63 ± 0.21^{c}
Boiled & dehulled	8.15 ± 0.43^{a}	7.79 ± 0.34^{a}	8.12 ± 0.14^{a}	8.40 ± 0.45^{a}	8.17 ± 0.25^{a}
Dark brown					
Raw un-dehulled	5.14 ± 0.22^{c}	5.25 ± 0.35^{b}	7.23 ± 0.23^{b}	6.02 ± 0.20^{c}	5.94 ± 0.46^{d}
Raw dehulled	6.35 ± 0.23^{b}	7.85 ± 0.48^{a}	7.49 ± 0.24^{b}	6.30 ± 0.45^{c}	7.02 ± 0.39^{b}
Roasted un-dehulled	5.47 ± 0.34^{c}	5.35 ± 0.45^{b}	7.18 ± 0.25^{b}	7.27 ± 0.35^{b}	6.22 ± 0.25^{d}
Boiled & dehulled	7.66 ± 0.41^{a}	8.01 ± 0.46^{a}	8.28 ± 0.34^{a}	8.25 ± 0.15^{a}	8.05 ± 0.24^{a}
Maroon					
Raw un-dehulled	5.27 ± 0.64^{c}	5.34 ± 0.23^{b}	7.26 ± 0.26^{b}	6.32 ± 0.31^{c}	6.05 ± 0.24^{d}
Raw dehulled	6.74 ± 0.48^{b}	7.78 ± 0.28^{a}	7.15 ± 0.33^{b}	6.43 ± 0.36^{c}	7.02 ± 0.38^{b}
Roasted un-dehulled	6.45 ± 0.36^{b}	5.02 ± 0.25^{b}	7.17 ± 0.45^{b}	7.43 ± 0.33^{b}	6.54 ± 0.28^{c}
Boiled & dehulled	7.69 ± 0.40^{a}	7.81 ± 0.36^{a}	7.93 ± 0.23^{a}	8.30 ± 0.20^{a}	7.94 ± 0.26^{a}
Black white-eye					
Raw un-dehulled	4.95 ± 0.24^{d}	5.10 ± 0.32^{b}	7.42 ± 0.38^{b}	6.43 ± 0.57^{c}	5.98 ± 0.27^{d}
Raw dehulled	6.56 ± 0.33^{b}	7.90 ± 0.28^{a}	7.35 ± 0.25^{b}	6.28 ± 0.43^{c}	7.02 ± 0.44^{b}
Roasted un-dehulled	3.62 ± 0.42^{e}	5.13 ± 0.35^{b}	7.25 ± 0.21^{a}	7.87 ± 0.30^{a}	6.02 ± 0.34^{c}
Boiled & dehulled	7.78 ± 0.35^{a}	8.10 ± 0.24^{a}	8.00 ± 0.34^{a}	8.25 ± 0.32^{a}	8.08 ± 0.20^{a}

[1]Means in a column not followed by the same superscript letter are significantly different ($p<0.05$)
[2]Based on a 9-point hedonic scale with 9= like extremely, 5= neither like nor dislike, and 1 = dislike extremely.

Table 5.5. Varietal and processing effects on the sensory characteristics of bambara-based traditional 'Akla/Koose'[1]

Variety and processing treatment	Mean sensory scores[2]				
	Colour & Appearance	**Texture/ Sponginess**	**Taste**	**Aroma**	**Overall acceptability**
Cream Pink-eye					
Raw un-dehulled	7.81 ± 0.22^{a}	5.62 ± 0.32^{b}	7.37 ± 0.28^{b}	6.86 ± 0.35^{c}	6.55 ± 0.46^{c}
Raw dehulled	7.83 ± 0.30^{a}	7.54 ± 0.34^{a}	7.29 ± 0.33^{b}	6.65 ± 0.38^{c}	7.32 ± 0.34^{b}
Roasted un-dehulled	6.14 ± 0.10^{b}	5.71 ± 0.24^{b}	7.41 ± 0.13^{b}	7.91 ± 0.36^{a}	6.43 ± 0.41^{c}
Boiled & dehulled	8.02 ± 0.34^{a}	7.81 ± 0.23^{a}	8.20 ± 0.23^{a}	8.32 ± 0.34^{a}	8.09 ± 0.35^{a}
Dark brown					
Raw un-dehulled	5.43 ± 0.24^{c}	5.16 ± 0.38^{b}	7.18 ± 0.26^{b}	6.11 ± 0.20^{c}	5.83 ± 0.26^{d}
Raw dehulled	6.25 ± 0.26^{b}	7.88 ± 0.41^{a}	7.24 ± 0.23^{b}	6.38 ± 0.45^{c}	7.12 ± 0.37^{b}
Roasted un-dehulled	5.38 ± 0.32^{c}	5.41 ± 0.46^{b}	7.09 ± 0.28^{b}	7.31 ± 0.35^{b}	6.17 ± 0.28^{d}
Boiled & dehulled	7.86 ± 0.38^{a}	8.12 ± 0.36^{a}	8.18 ± 0.31^{a}	8.17 ± 0.15^{a}	8.00 ± 0.20^{a}
Maroon					
Raw un-dehulled	5.12 ± 0.42^{c}	5.44 ± 0.30^{b}	7.16 ± 0.28^{b}	6.28 ± 0.31^{c}	6.25 ± 0.27^{d}
Raw dehulled	6.85 ± 0.44^{b}	7.86 ± 0.32^{a}	7.24 ± 0.37^{b}	6.23 ± 0.36^{c}	7.12 ± 0.24^{b}
Roasted un-dehulled	6.70 ± 0.32^{b}	5.12 ± 0.28^{b}	7.19 ± 0.33^{b}	7.45 ± 0.33^{b}	6.50 ± 0.28^{c}
Boiled & dehulled	7.96 ± 0.34^{a}	7.88 ± 0.38^{a}	7.90 ± 0.21^{a}	8.20 ± 0.20^{a}	8.12 ± 0.18^{a}
Black white-eye					
Raw un-dehulled	5.05 ± 0.26^{d}	5.21 ± 0.37^{b}	7.22 ± 0.32^{b}	6.27 ± 0.57^{c}	6.08 ± 0.38^{d}
Raw dehulled	6.65 ± 0.43^{b}	8.16 ± 0.32^{a}	7.38 ± 0.27^{b}	6.26 ± 0.43^{c}	7.00 ± 0.40^{b}
Roasted un-dehulled	4.02 ± 0.47^{e}	5.24 ± 0.38^{b}	7.35 ± 0.23^{a}	7.79 ± 0.30^{a}	6.00 ± 0.38^{c}
Boiled & dehulled	7.94 ± 0.38^{a}	8.22 ± 0.26^{a}	8.10 ± 0.36^{a}	8.15 ± 0.32^{a}	7.90 ± 0.20^{a}

[1]Means in a column not followed by the same superscript letter are significantly different ($p<0.05$)
[2]Based on a 9-point hedonic scale with 9= like extremely, 5= neither like nor dislike, and 1 = dislike extremely.

Chemical composition of HQBF samples: The proximate composition, selected minerals and tannin content of the high quality bambara flour samples produced from mixed varieties of bambara, are given in Table 5.6. There were no significant differences in the proximate composition of the flours from the two mixed bambara samples. Both the 'white' and the 'red' bambara produced flour samples with low enough moisture content (about 6%) to ensure good storage stability. The HQBF samples had high protein content of about 21%, fat content of about 8% and a relatively high carbohydrate content of about 61% to make the product rank highly as an almost complete food, nutritionally. As a source of protein base for weaning food formulation, the

protein content of about 21% could be considered high enough to give a final product with a protein content of about 16%. This is almost double that of the traditional weaning food, and more than satisfies the requirements for weaning foods stipulated by the Protein Advisory Group of the United Nations (PAG 1971). Phosphorus, calcium and iron contents of the HQBF were also very high.

The most significant effect of the processing technique used in the production of the HQBF was the drastic reduction in tannin content of the final product. Tannin content of the flour samples was about 0.8mg CE/g sample, which is low enough to prevent any potential adverse effects on bioavailability of minerals and protein digestibility. In earlier studies with cowpea, Plahar *et al*., (1997) reported that tannin concentrations of up to 4.2 mg CE/g sample did not impose significant anti-nutritional effects compared to the effects of other factors in the raw cowpea seeds.

Hot paste viscosity characteristics of HQBF samples***:*** The amylograms of the two HQBF flours were re-plotted on rectangular co-ordinates and superimposed for comparison (Fig 5.1). Individual values for pasting temperature, pasting time, peak viscosity, viscosity at 95°C, 15 min height, paste stability, viscosity at 50°C, set back viscosity and cooking time are also shown in Table 5.7. Although the two flour samples had a similar gelatinization temperature, the pasting characteristics were significantly different. The 'white' sample showed a much higher pasting viscosities in terms of the peak viscosity, viscosity at 95ºC, viscosity at 50ºC, as well as setback value. Prolonged cooking at 95°C for 15 min. did not result in reduced viscosity for the two samples. Both samples showed some resistance of the starch granules to prolonged heating, while they continued to increase in viscosity. Negative values for paste stability were therefore obtained for both samples because of the continued increase in viscosity during holding. Low cooking times of 11.5 and 12.0 min were recorded for the 'white' and 'red' samples, respectively.

Hot paste viscosity characteristics of a product, as determined from such amylograms, give an indication of the starch behaviour and the rheological characteristics of the cooked product. Viscosity plays a very important role in the acceptability of the product, especially if these products are major components in foods that require some degree of binding to maintain structural integrity. An acceptable weaning food for example, is supposed to develop into a paste-like

Table 5.6. Chemical composition of bambara nuts and HQBF samples

	Light coloured mixture ('White')		Dark coloured mixture ('Red')	
Component	Bambara nuts	Flour sample	Bambara nuts	Flour sample
Moisture (%)	10.3± 0.4[a]	6.1±0.7[b]	10.6±0.1[a]	6.7±0.6[b]
Protein (%)	17.2± 0.6[b]	21.2±0.5[a]	17.9±0.3[b]	21.2±0.8[a]
Fat (%)	9.2±0.5[a]	8.4±0.6[a]	7.1±0.2[b]	9.2±0.7[a]
Ash (%)	3.1±0.1[a]	3.2±0.1[a]	3.10.1[a]	3.4±0.3[a]
Carbohydrate (%)	60.2±0.6[b]	61.2±0.5[a]	61.2±0.9[a]	59.6±0.9[b]
Calcium (mg/100g)	87.6± 2.5[a]	61.2±0.1[d]	75.5±0.9[b]	73.9±0.7[c]
Phosphorus (mg/100g)	136.2±1.4[a]	125.4±2.7[b]	117.6±4.6[c]	119.8±3.2[c]
Iron (mg/100g)	1.2±0.1[a]	1.1±0.1[a]	1.3.0±0.3[a]	1.3±0.1[a]
Tannin (mg CE/g sample	3.05±0.82[b]	0.10±0.01[c]	12.43±2.13[a]	0.08±0.01[c]

[1]Values are means ± standard deviations of measurements from three replicates. Means in a row not followed by same superscript letter are significantly different ($p \leq 0.05$).

porridge when cooked, and become moderately viscous. A watery, non-viscous slurry is not acceptable traditionally. In weaning food formulations with bambara flour therefore, it is quite an important requirement to ensure that an acceptable degree of viscosity is attained in the cooked product. The results of the study show that the two types of mixed grains found on the market are quite suitable for the production of a high quality bambara flour with the desirable hot paste viscosity characteristics.

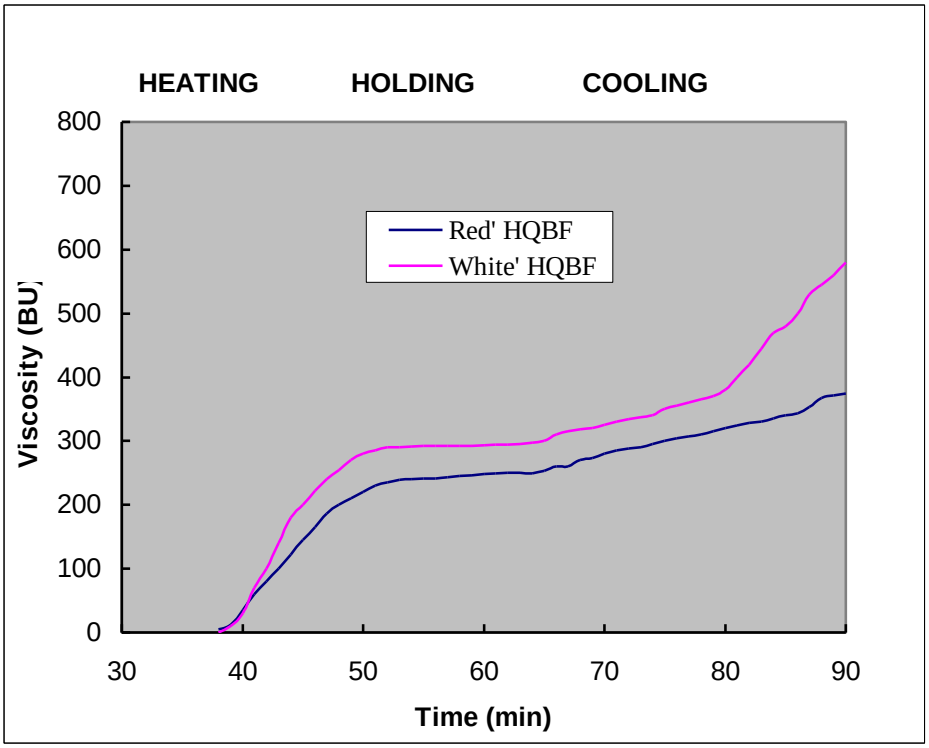


Fig.5.1. Amylograph pasting characteristics of high quality bambara flour samples

Table 5.7. Pasting viscosities of HQBF samples.[1]

Characteristic	'White' sample[2]	'Red' sample[3]
Pasting temp. (^{o}C)	82.7 ± 1.0	82.0 ± 0.8
Pasting time (min)	38.5 ± 0.6	38.0 ± 0.4
Peak viscosity (BU)	280 ± 5.0	240 ± 8.0
Peak visc. time (min)	50.0 ± 1.5	54.0 ± 1.0
Viscosity @ 95^{o}C (BU)	240 ± 8.0	186 ± 5.0
15-minute ht. (BU)	294 ± 9.0	250 ± 3.0
Paste stability (BU)[4]	-14.0 ± 3.0	-10.0 ± 2.0
Viscosity @ 50^{o}C (BU)	580 ± 8.0	374 ± 11.0
Set-back value (BU)	300 ± 10.0	304 ± 13.0
Ease of Cooking (min)[5]	9.5 ± 1.0	12.5 ± 1.0

[1]Values are means ± standard deviation of triplicate determinations. [2]Prepared from a mixture of light-cloured grains. [3]Prepared from a mixture of dark-coloured grains [4]Paste stability = difference between the peak viscosity and that obtained at the end of holding period. [5]Ease of cooking = difference between time to reach gelatinization temperature and time to obtain maximum viscosity during heating.

Sensory characteristics of HQBF samples**.** Mean sensory scores for selected foods based on the high quality bambara flour (HQBF) are shown in Table 5.8. In general, comparable degrees of liking for the sensory attributes of general appearance, colour, and aroma were obtained for all the food products. For all the sensory attributes, the weaning food and tubani were rated similarly. Owing to relatively wide variations in the scores, apparently lower mean sensory scores were not found to be significantly different. Also, there were no significant differences in the acceptability of the 'red' and 'white' types of bambara flours for the selected foods tested. The HQBF weaning food and the HQBF *tubani* had mean scores for all sensory attributes indicating very much liking whether the red or white varieties of beans were used in the preparation of the flour. When used for the other traditional food, *akla/koose,* however, significantly lower scores for texture/consistency, mouthfeel and taste were obtained. The mean scores obtained for these sensory characteristics indicated moderate liking.

Table 5.8. Mean sensory scores for selected foods prepared with HQBF samples

Sensory characteristics	Weaning food		Akla/Koose		Tubani	
	'White'	'Red'	'White'	'Red'	'White'	'Red'
General appearance	8.00±0.54[a]	7.70±0.50[a]	7.55±0.64[a]	7.50±0.60[a]	7.74±0.54[a]	7.56±0.72[a]
Colour	8.00±0.63[a]	7.80±0.36[a]	8.00±0.34[a]	7.60±0.44[a]	8.20±0.43[a]	7.90±0.50[a]
Aroma	7.90±0.34[a]	8.00±0.40[a]	8.00±0.54[a]	7.85±0.64[a]	8.16±0.53[a]	7.80±0.54[a]
Texture/consistency	8.27±0.64[a]	8.20±0.34[a]	7.20±0.45[b]	7.32±0.40[b]	8.00±0.50[a]	8.00±0.36[a]
Mouthfeel	8.10±0.56[a]	7.81±0.76[a]	7.30±0.56[b]	7.38±0.76[b]	7.96±0.70[a]	7.70±0.64[a]
Taste	8.10±0.55[a]	7.90±0.65[a]	7.10±0.55[b]	7.33±0.50[b]	7.95±0.45[a]	7.80±0.50[a]
Overall acceptability	8.16±0.24[a]	7.80±0.34[a]	7.35±0.34[b]	7.25±0.40[b]	7.90±0.64[a]	7.85±0.54[a]

[1]Means in a row not followed by the same superscript letter are significantly different ($p<0.05$). Scores are based on a 9-point hedonic scale with 9= like extremely, 5= neither like nor dislike, and 1 = dislike extremely.

The study concluded that the technology developed for the preparation of the high quality bambara flour gives a product that can effectively improve bambara utilization in Ghana because of its suitability for existing traditional foods, as well as its versatility in application and potential for diversified food uses. This situation can contribute significantly to increased production and utilization of bambara for enhanced food and nutrition security in the sub-region.

Output 6

Participatory field-testing of high quality bambara flour (HQBF) in Northern Ghana

In the field test for the suitability of the HQBF for traditional food uses among food processors/ cooked food vendors in Northern Ghana, the results showed good acceptance of the product for akla and tubani. In comparison with the traditional bambara flour that the respondents were familiar with, the following comments were made:

- The HQBF has good flavour and does not possess the typical raw beany odour associated with the traditional flour
- The HQBF does not produce the flatulence or stomach bloating effect typical of the traditional bambara flour.
- The HQBF has a high degree of versatility in application. This means that the typical quality characteristics of the HQBF, makes it suitable for diversified food uses.
- The cooking time for foods prepared with the HQBF is drastically reduced
- There are no varietal differences in the suitability of the flour for traditional food uses
- The HQBF gives more yield for traditional foods. It has high whipping properties.
- However, the HQBF still has the low binding properties and cassava flour has to be added to avoid disintegration of solid foods such as *tubani*.

A high level of acceptability of the flour for traditional commercial food preparations was established.

Output 7

Recipe development based on high quality bambara flour (HQBF)

Seven acceptable recipes developed and tested for the high quality bambara flour are given in the Tables 7.1 – 7.7 below. An extension brochure was prepared on these recipes and disseminated at the stakeholders' workshop held in Northern Ghana as part of project activities.

7.1. BAMBARA KOOSE/AKLA

INGREDIENTS	QUANTITY	INGREDIENTS	QUANTITY
1. Bambara flour	500 grams	4. Salt	10 grams
2. Ground onions	200 grams	5. Water	400 ml.
3. Ground ginger	100 grams		

Method

1. Pour 100mls of water in a clean bowl before adding bambara flour (to avoid lumps)
2. Beat vigorously as you add the rest of the water in bits.
3. Beat until mixture becomes fluffy and have a dropping consistency.
4. Add ground onions and ginger; stir well and season with smooth salt.
5. Heat oil and drop koose mixture in spoonfuls.
6. Fry to a golden brown colour, and serve hot.

7.2. BAMBARA TUBAANI

INGREDIENTS	QUANTITY	INGREDIENTS	QUANTITY
Bambara flour	500 grams	Ground fresh pepper	20 grams
Ground onions	200 grams	Smooth salt	20 grams
Ground shrimps	200 grams	Water	500 mls
Ground ginger	50 grams	Vegetable oil	100 mls

Method

1. Gradually add water to the flour and beat vigorously until mixture becomes fluffy.
2. Add all the ground ingredients salt being the last.
3. Add vegetable oil and stir well
4. Grease moulds or cake tins with some of the vegetable oil.
5. Fill ¾ way full and cover with greaseproof paper or kitchen foil secure with strings.
6. Steam for 2 hrs and until a skewer comes out clean when inserted. Serve hot.

7.3. BAMBARA KOKO

INGREDIENTS	QUANTITY	INGREDIENTS	QUANTITY
Fermented maize dough Bambara flour	200 grams 25 grams	Sugar Salt	To taste To taste

Method

1. Mix corn dough and **bambara flour** with water and strain.
2. Add salt to taste and bring to boil while stirring continuously to avoid formation of lumps.
3. Allow to boil at low heat for additional 20 minutes.
4. Serve with sugar added to taste.

7.4. BAMBARA TOM BROWN

INGREDIENTS	QUANTITY		
Roasted maize flour	120 grams	Sugar	To taste
Bambara flour	25 grams	Salt	To taste

Method

1. Mix roasted maize flour and bambara flour with water to form a smooth slurry.
2. Add salt to taste and bring to boil while stirring continuously to avoid formation of lumps.
3. Allow to boil at low heat for additional 20 minutes.
4. Serve with sugar added to taste.

7.5. BAMBARA/WHEAT BREAD

INGREDIENTS	QUANTITY	INGREDIENTS	QUANTITY
Bambara flour	180 grams	Milk	150 mls.
Strong wheat flour	420 grams	Grated nutmeg	2 teaspoon
Granulated sugar	100 grams	Smooth salt	1 teaspoon
Baker's yeast	10 grams	Vanilla essence	2 teaspoons
Margarine	150 grams	Water	175 mls.

Method

1. Sift the two flours together.
2. Rub in margarine, salt, nutmeg and sugar.
3. Add instant yeast
4. Add milk to tepid water and vanilla essence
5. Gradually incorporate the milk and water into the dry ingredients
6. Knead to a smooth dough
7. Leave for about 45 mins.
8. Knock back and mould into desired shapes and sizes.
9. Leave to proof or double its size
10. Bake in a previously heated oven till golden brown.

7.6. BAMBARA COOKIES

INGREDIENTS	QUANTITY	INGREDIENTS	QUANTITY
Bambara flour	300 grams	Essence	2 teaspoons
Soft wheat flour	300 grams	Bicarbonate of soda	1 teaspoon
Granulated sugar	300 grams		
Margarine/ butter	450 grams	Eggs	4 medium

Method

1. Cream fat and sugar till fluffy
2. Add eggs gradually
3. Add essence and cream well
4. Sift the two flours together with bicarbonate of soda
5. Fold flour into creamed mixture
6. Feed a biscuit maker with mixture and pipe unto a greased baking sheet.
7. Bake in a cool oven for 25 mins or till golden brown (150^0 F)
8. Remove, cool and store or serve.

7.7. BAMBARA QUEEN CAKES

INGREDIENTS	QUANTITY	INGREDIENTS	QUANTITY
Bambara flour	180 grams	Eggs	10 medium
Soft wheat flour	320 grams	Baking powder	14 grams
Granulated sugar	400 grams	Essence	2 teaspoons
Margarine or butter	450 grams	Grated nutmeg	2 teaspoons

Method

1. Cream sugar and fat together till white and fluffy
2. Add eggs gradually, beating one or two at a time
3. Mix the two flours together and sift.
4. Add baking powder and grated nutmeg to the flour
5. Add essence to the creamed mixture and mix well
6. With a metal spoon, fold the flour into the creamed mixture well
7. Grease patty tins or arrange cake cup and half fill them,
8. Bake in a preheated oven for 20-25 mins or till golden brown.

Output 8

Stakeholders' workshop

Participation: In all, 40 participants were registered at the workshop. This number was made up of researchers from both the CSIR of Ghana (FRI and CRI) and the NRI, farmers, food processors/cooked food vendors, policy makers, opinion leaders, NGOs, Agricultural extension staff of MoFA, matrons from educational institutions and caterers.

Technical Presentations: Five technical papers, based on the results of various research activities undertaken, were presented by the respective researchers. Details of the research activities and outputs have already been provided elsewhere in this report.

Plenary Session: This session was on the prospects and constraints for the production and utilisation of high quality bambara flour in the traditional food delivery system in Ghana. A rapid participatory evaluation and review analysis showed a high objectives achievement level indicating that the project was implemented as planned within the budget constraints and highly successful. Invariably, the review process also brought to the fore more problems associated with processing and utilization.

Discussions on whether the High Quality Bambara Flour developed should be considered a solution to the drudgery involved with the use of bambara or whether there is a lot to be done, generated varied views from participants. However, consensus reached by participants indicated that research work conducted under the current project partly answers the question posed. Participants expressed the need to adopt a holistic approach to increasing the utilization and for that matter market base for bambara. This as proposed should cover a wider range of integrated issues spanning from production to marketing. It was suggested that further activities should focus on:

- On farm trials and seed development
- Educational campaign and awareness creation on utilization of HQBF
- Exploiting the existing and potential domestic market
- Gender issues
- Use of women groups and NGOs for dissemination of research results

- Private sector participation. Small to medium scale bambara flour production by entrepreneurs should be promoted
- Competitive and comparative advantage of Bambara over other legumes should be assessed
- NRI should consider intervention in dissemination and impact assessment with emphasis on socio-economic aspects.
- Widening the geographical focus on bambara processing and utilization. This could be achieved by subcontracting research areas to University students (for their thesis) as a means of reducing cost and increasing scope of work.
- The Women In Agricultural Development (WIAD) of MoFA should be involved and tasked to work on expansion of the utilization base.
- More workshops to be organized and local women tasked to prepare Bambara based traditional dishes and also to use their innovative ideas to develop new recipes
- Packaging bambara and bambara products in convenient forms for super markets in the urban areas should be looked at
- Use bambara in complementary foods in adult diets.

<u>The way forward / Action points:</u>

- Effective promotion of the HQBF should be actively pursued as this will increase demand
- Presently, issues pertaining to bambara production and utilization are confined predominantly to women. More men should be made to get involved
- Dissemination of information on the research output should be actively pursued to attract funding from DFID
- Developing the local market should be given priority. Export should be put on hold for now
- Concentrate on small-scale private entrepreneurs because of limited current raw material supply
- Exploit link-ups with research institutions in Nigeria for collaborative work. This will enhance fund-sourcing capabilities.
- Identify areas that can have maximum impact and sustainability for extension

Contribution of Outputs

Contribution to DFID's developmental goals: DFID's developmental goal focuses on improved livelihood of poor people through sustainably enhanced production and productivity, with the purpose of having poor people benefit from new knowledge applied to food commodity systems. This project sought to contribute effectively to the achievement of this goal by developing and effectively promoting strategies which improve food security of poor households through increased availability and improved quality of cereals and pulse foods and better access to markets. The outputs are that improved methods for cooking and processing bambara, which significantly reduces both time and resources required, are developed for small-scale farm families, and production and market potential for bambara assessed. The technologies developed in this project to facilitate processing and utilization of bambara will potentiate improvement in production levels, which will lead to enhanced income, thus contributing to alleviating the livelihood constraints. Promotion of the developments will stimulate resurgence in the popularity of the crop and provide women with confidence to enable them to increase its cultivation. Additional cash from sales will improve food security of households in rural Northern Ghana and in other bambara producing areas. The output on the comprehensive assessment and identification of the market potential, both in Ghana and elsewhere, will strengthen the opportunity for achieving sales.

List of publications

i. LARWEH, P.M. and PLAHAR, W.A. (2000). Production, storage, processing and Utilization of bambara in Ghana. Food Research Institute (FRI), Accra, Ghana. 35 pp.

ii. GRENNHALGH, P. (2000). The market potential for bambara groundnut. Natural Resources Institute (NRI), Chatham, Kent, UK. 27 pp.

iii. OBENG-ASIEDU, P., LARWEH P.M. and PLAHAR, W.A. (2000). Marketing of Bambara in Ghana. Food Research Institute (FRI), Accra, Ghana. 43 pp.

iv. ANNAN, N.T., PLAHAR, W.A. and SWETMAN, T. (2001). Effect of Kawe treatment on the water absorption and cooking characteristics of bambara groundnut varieties. Food Research Institute (FRI), Accra, Ghana. 15 pp.

v. ANNAN, N.T., PLAHAR, W.A. and TAMAKLOE, I.A. (2001). Development of improved legume flour production technology for enhanced bambara utilization in Ghana. Food Research Institute, Accra (FRI), Ghana. 20 pp.

vi. FOOD RESEARCH INSTITUTE (2002) Marketing and processing of bambara groundnuts (W. Africa), Final Technical Report, Project R7581. Food Research Institute (FRI), Accra, Ghana. 83pp.

vii. PLAHAR, W.A., ANNAN, N.T., LARWEH, P.M., COOTE, C. and STEVENSON, S. (2002) Making Better Use of Bambara to help Address Livelihood Constraints of Farmers. Volta River Authority Conference Room, Tamale, Ghana, 26 February 2002. [One-Day Stakeholders' Workshop for 40 Participants]

viii. FOOD RESEARCH INSTITUTE (2001). High quality bambara flour: Method of preparation, quality characteristics and uses. 100 copies. Food Research Institute, Accra, Ghana. 2 pp. [Extension Leaflet]

ix. FOOD RESEARCH INSTITUTE (2001). Reducing Cooking Time for Bambara. 100 copies. Food Research Institute, Accra, Ghana. 2 pp. [Extension Leaflet]

x. FOOD RESEARCH INSTITUTE (2001). Tasty Tricks with Bambara Flour: Useful recipes based on bambara flour. 100 copies. Food Research Institute, Accra, Ghana. 4 pp. [Extension booklet]

Follow up action necessary

Extensive dissemination of the bambara flour technology has been identified at the stakeholders' workshop as the most effective means of making the project achieve the necessary impact through widespread adoption, if funding could be secured for such activity. Effective promotion of the High Quality Bambara Flour technology developed is to be actively pursued, as this will increase demand. Priority is to be given to developing the local market first through training of extension staff and entrepreneurs, awareness creation through workshops, and active involvement of all stakeholders. The main target for commercial production of the flour will be the small-scale private entrepreneurs because of limited current supply of raw material. To enhance fund-sourcing capabilities, link-ups with research institutions in Nigeria will be exploited for collaborative work. Activities to be pursued will therefore follow these lines:

- Market studies on the development high quality bambara flour to be undertaken
- Extension of the technology will be done through training of small scale private entrepreneurs and extensionists
- Participatory development of more end-uses of the flour involving all partners to expand utilization base
- Further promotion of the flour for traditional and commercial catering
- Exploit link-ups with research organizations in the sub-region

APPENDIX 1

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APPENDIX 2

QUESTIONNAIRES FOR FIELD STUDIES

1. Survey on production, processing, storage and utilization of bambara in Ghana

A. SOCIO-ECONOMIC BACKGROUND AND GENERAL INFORMATION

i. Respondent Code Number ……
ii. Date of interview ……
iii. Name of respondent ……
iv. Name of town/village ……
v. District …… Region ……
vi. Ecological zone ……

1. Sex: ☐
Male = 1 Female =2

2. Age ☐

3. Educational Level ☐
No formal education = 1 Primary/JSS/Middle = 2
Secondary/SSS = 3 Others (specify) = 4 …….

4. Religion ☐
Christian = 1 Moslem = 2
Traditionalist = 3 Others (specify) = 4 …….

5. Marital Status ☐
Married = 1 Single = 2
Divorced = 3 Separated = 4
Widowed = 5

6. Main occupation ☐
Farming = 1 Hunting and gathering = 2
Fixed salary based job = 3 Trading = 4 Others (specify) = 5 …….

7. Secondary occupation ☐

B. PRODUCTION

8. Production levels of bambara and other cereal legumes grown by the farmer

Type of legume	Acreage under cultivation	Yield/planting season or year	Proportion consumed	Proportion sold

Bambara = 1 Soybean = 3 Other (specify) = 5……..
Groundnut = 2 Cowpea = 4

9. What are your reasons for growing bambara? ☐

Subsistence	= 1	For both	= 3
For cash	= 2	Other (specify)	= 4 ……

10. Does bambara give you more income than other legumes grown? ☐
Yes = 1 No = 2

11. If no to question 10, which legume(s) give you a higher income? ☐
Groundnut = 1 Soybean = 2 Cowpea = 3 Other (specify) = 4

12. In which months of the year is bambara in high supply……..

13. In which months of the year is bambara in low supply…….

14. Has your production of bambara increased or decreased over the past 3 years? ☐
Increased = 1 Decreased = 2

15. What accounted for the increase in production? ☐
Good weather = 1 Increased capital = 2 Higher income = 3
Acquisition of bigger land = 4 Other (specify) = 5……..
NA = 6

16. What accounted for the decrease in production? ☐
Poor weather = 1 Lack of capital = 2 Reduced income = 3
Lack of land = 4 Other (specify) = 5 NA = 6…….

17. What is the first (most important) constraint to bambara production in the area. ☐

Climate	= 1	Storage	= 5
Access to land	= 2	Lack of processing equipment	= 6
Labour	= 3	Other (specify)	= 7 ……
Inputs	= 4	No constraint	= 8

18. What is the second constraint ☐
Other (specify) = 7 ……

19.What type of land do you use? ☐

Family	= 1	Hired	= 2
Leased	= 3	Others (specify)	= 4

20. Indicate the type of labour and people involved in the various activities.

i. Land clearing ……	ix. Harvesting ……
ii. Ploughing …….	x. Shelling …….
iii. Harrowing ……	xi. Winnowing ……
iv. Ridging ……	xii. Storage ……
v. Hoeing …….	xiii. Marketing……
vi. Planting ……	Weeding ……
vii. Application of Agro-chemical ……	

Family	=1	Combination (tick)	=4
Hired	=2	Other (specify)	=5
Pooled	=3		

☐

21. Is labour readily available? Yes = 1 No = 2

22. How do you finance your farming activities? ☐
Own resources =1 Bank loan =2 Money lenders=3 Relatives =4 Combination (tick) =5

23. What are the terms of payment if money is borrowed? ……

24. Do you have any problems obtaining agricultural credit? Yes = 1 No = 2 ☐

25. Are the following easily accessible? Yes = 1 No = 2
i. Extension services ☐
ii. Irrigation infrastructure ☐
iii. Mechanized services ☐
iv. Transfer of improved technologies ☐

26. What agricultural inputs do you own ☐
Cutlass = 1 Hoe = 2 Others (specify) = 3……

Gender issues and responsibilities related to bambara production in the household.

27. Who takes responsibility for the following :

	Person responsible	Reasons
i. Preparation of land for bambara cultivation	……	……
ii. Cultivation of bambara	……	……...
iii. Harvesting of bambara	……	……
iv. Shelling of bambara	…….	……
v. Storage of bambara	……	……...
vi. Marketing of bambara	……	……...

Husband = 1 Wife = 2 Both = 3 Children (male) = 4 Children (female) =5 Children (both) = 6
Every household member =7

C. STORAGE, PROCESSING AND UTILIZATION

28. For how long do you dry your bambara after shelling before storage? …….

29. How do you shell your bambara after harvesting? ☐
Manually (specify) = 1…….. Mechanised = 2

30. How do you package the bambara before storage?…….

31. Do you treat the bambara with agro-chemicals before storage? Yes = 1 No = 2 ☐

32. If no to 31, do you treat the bambara by any traditional method before storage? ☐
Yes = 1 No = 2 NA = 3

33. Describe traditional pre storage treatment if applicable …….

34. Where do you store your bambara? ☐
Storage barn = 1 Rooms = 2 Other (specify) = 3……..

35. Do you process bambara into other products? Yes = 1 No = 2 ☐

36. If yes, how do you go about this? ☐
Mill into flour =1 Other (specify) =4
Prepare into paste =2 N/A =5
Combination (tick) =3

37. How often is bambara consumed in the household/week? ☐
Not often = 1 1 - 3x = 2 4 - 6x = 3 daily = 4

38. What traditional meal is bambara used for in the household ☐

Aboboi = 1 Tigbani = 2 Others (specify) = 3…… Combination = 4 (tick)

39. In what form is bambara utilised? ☐
Fresh in pods = 1 Dry & shelled = 2 Others (specify) = 3…… Combination = 4 (tick)

40. What problems do you encounter with bambara processing and utilization ……
……

41. How do you overcome these problems? ……..

42. Is bambara hard to cook? ☐
Yes = 1 No = 2

43. If yes, how do you overcome this problem?……..
……

1. Marketing of Bambara in Ghana

A. SOCIO-ECONOMIC BACKGROUND AND GENERAL INFORMATION

i. Respondent Code Number ……
ii. Date of interview ……
iii. Name of respondent ……
iv. Name of town/village ……
v. District …… Region ……
vi. Ecological zone ……

1. Sex: ☐
Male = 1 Female =2

2. Age ☐

3. Educational Level ☐
No formal education = 1 Primary/JSS/Middle = 2
Secondary/SSS = 3 Others (specify) = 4 …….

4. Religion ☐
Christian = 1 Moslem = 2
Traditionalist = 3 Others (specify) = 4 …….

5. Marital Status ☐
Married = 1 Single = 2
Divorced = 3 Separated = 4
Widowed = 5

6. Main occupation ☐
Farming = 1 Hunting and gathering = 2
Fixed salary based job = 3 Trading = 4 Others (specify) = 5 …….

7. Secondary occupation ☐

B. MARKETING

Marketing:

8. Do you sell bambara for cash or consume at home? ☐
Consume = 1 Sell for cash = 2 Both = 3

9. If you sell for cash, what proportion do you sell? ☐
All = 1 75% = 2 50% = 3 25% = 4 None = 5

10. On the average, how many bowls/bags of bambara can you sell in
i. a day ……. ii. a week…….

11. How much do you realize on a bowl/bag? …….

12. What is the farm-gate price for a bowl/bag of bambara? ……

13. What is the highest selling price? ……..
14. What is the lowest selling price? ……

15. What is the market price for a bowl/bag of bambara? ……

16. Are there lean seasons? ☐
Yes = 1 No = 2

17. In which months of the year are bambara prices high? …….

Transportation:

17. What mode of transportation do you use in moving the produce?

Stage of movement	Mode of transportation
Farm-gate to assembly point Market to urban market Market to assembly point Assembly point to urban market	

head load =1 Road = 2 River/lake =3 Draught animal = 4 Rail = 5 Others(specify) = 6 ……

18. What type of vehicle do you use in road transport? ☐
Articulated truck = 1 Tractor = 2 Minibuses = 3
Draught = 4 Cargo buses = 5 Wooden mummy truck = 6 Others (specify) = 7

19. Do you own or hire the vehicle? ☐
Own = 1 Hire = 2

20. What is the nature of the road you use in your bambara movement? ☐
Untarred and non-motorable during rainy season = 1
Untarred but motorable during rainy season = 2
Tarred but pot-holed = 3 Tarred in good condition = 4

21. In which town/market is your bambara sold? ……

22. How far is the town/market from your farm? …….

23. How long does it take from the farm-gate to the selling point? ……

24. Do you transport the bambara with other commodities? ☐
Yes = 1 No = 2

25. If yes, specify the type of commodity? …….

Market information

26. What is the type of market information available to you?

Type of information	Yes	No	Source
Market price Government policy Road condition Quality of bambara Supply condition Transport charges Others (specify)			

1. Market place 2. District Assembly 3. Agent 4. Transporters
5. MOFA 6. Farmers 7. Own observation 8. Other traders

27. How would you describe the information you receive?

Information	Adequacy	Regular availability	Relevance
Market price Government policy Road condition Quality of bambara Supply condition Transport charges Others (specify)			

1. Not adequate 2. Adequate 3. Readily available 4. Fairly available
5. Seldom available 6. Relevant 7. Not relevant

Transaction cost:

28. What were the major cost components in your transaction during the last two seasons?

Elements of cost	Type of transport		Condition of road	Distance	Cost/unit volume	
1. Transportation	Vehicle	Road			Peak	Lean
2. Storage	Type of storage		Period of storage		Cost/unit	
			Peak	Lean	Peak	Lean
3. Taxation	Type				Tax/unit	

4. Loading/unloading	Cost/unit				
	Loading		Unloading		
	Peak	Lean	Peak	Lean	
5. Assistants	Type of labour			Sales/Commission/unit		
	Permanent	Temporal	Family	Permanent	Temporal	Family

Prices & price structure:

29. What are the purchasing price and selling price of bambara?

30. What are the lowest and highest price periods within a year?

Use table below for 29 & 30

Product	Purchasing price	Selling price	Highest price/month		Lowest price/month	
			Origin market	Destination market	Origin market	Destination market

31. How are prices determined in the markets you buy your products? ☐

Individual traders = 1 Traders association = 2 Co-operatives = 3

Government = 4 The market = 5 Others = 6

32. How are prices determined in the markets you sell your products? ☐

Individual traders = 1 Traders association = 2 Co-operatives = 3
Government = 4 The market = 5 Others = 6

33. What factors influence the determination of your price? ☐

Road conditions = 1 Transportation mode = 2 Distance = 3
Supply and demand = 4 Traders margin = 5 Others (specify) = 6