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Full Length Research Paper

Production and characterization of flour produced from ripe "apem" plantain (*Musa sapientum* L. var. *paradisiacal;* French horn) grown in Ghana

H. D. Zakpaa, E. E. Mak-Mensah and J. Adubofour

Department of Biochemistry and Biotechnology, Faculty of Biosciences, College of Science, Kwame Nkrumah University of Science and Technology, Private Mail Bag, Kumasi, Ghana.

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The importation and processing of wheat grain into flour by economies like Ghana does constitute an enormous economic drain. To remedy this situation, FAO of the United Nations launched its Compost Flour Programme, which aimed to formulate flour mixtures consisting mainly of indigenous raw materials and raw wheat to a lesser extent. The production of plantain baked products, instant breakfast meals and baby food formulation have been proven to be technically feasible with powder from both ripe and unripe fruit. Further, the production of plantain powder and processing of the flour into baked goods could reduce the cost of the plantain baked products and would also reduce dependence on imported wheat and increase self-sufficiency in food. In this investigation, proximate and mineral analyses and some functional properties of ripe *Musa sapientum* L. powder were analyzed. The powder contained 3.14% moisture, 2.68% protein, 2.68% ash, 0.334% fat, 91.16% carbohydrate and 1603.09 KJ of energy. Bulk density was 0.76 gmL^{-1}, water-binding capacity of 71.0 g/100g, solubility of 18.87% and swelling power of 5.237 gg^{-1}. Mineral content per 100 g was analyzed to be 1.125 g sodium, 0.297 mg phosphorus, 2.900 g iron, 0.419 g calcium and 435.200 g potassium.

Key words: Plantain, *Musa sapientum*, French horn, food product development, flour, proximate analysis, functional properties, Ghana.

INTRODUCTION

This investigation aimed at processing a local cultivar of plantain into a stable flour as a way of extending the shelf life of ripe plantain fruits, to add value to plantain for both the local markets and for export, thereby ensuring food security. Low cost processing methods, such as solar drying etc., suitable for use in local Ghanaian homes, were employed to obtain a product that was then subjected to various analyses to determine the quality of the resulting product.

In Ghana, two main cultivars of plantain, the "apem" (a triploid French plantain called French horn) and "apantu" (gaint horned) are grown. Plantain belongs to the genus *Musa* in the family *Musaceae*. Plantain (*Musa* sp. AAB group) is a giant perennial herb. It is a natural inter-specific cross between the two wild species *Musa auminata* colla which contributes genome A and *Musa balbisiana* colla, which contributes genome B (Simmonds and Shepherd, 1955). Morphological description has proven very useful for the identification of the large diversity of plantain cultivars that exist in the tropics (Tezenas du Montcel, 1987; Swennen, 1990a; Jarret and Gawel, 1995). In addition to the use of morphological description in identifying specific plantain cultivars, various DNA-based marker techniques have also been employed. These techniques can supply additional information not available from the examination of morphological characteristics alone (Jarret and Gawel, 1995; Shaibu et al., 2003).

Plantain requires about two and a half to four months after shooting before the fruit becomes ready for harvesting or a total of about eight to twelve months after planting (Simmonds, 1948; Swennen, 1990a). At maturity, a constant weight is maintained for two to four days, and then the weight starts to decrease with changes in the

*Corresponding author. E-mail: hzakpaa@hotmail.com. Tel: 233-24-4840766, 233-52-63065, 233-51-60298.

peel colour from green to yellow and then to black. The maturity of the fruit may be determined by the weight of the pulp to peel ratio, brittleness of floral ends and disappearance of angularity of the fingers.

The chemical composition of plantain varies with the variety, maturity, degree of ripeness and where it is grown (soil type). The water content in the green plant is about 61% and increases on ripening to about 68%. The increase in water is presumably due to the break down of carbohydrates during respiration. Green plantain contains starch which is in the range of 21 to 26%. The starch in the unripe plantain is mainly amylose and amylopectin and this is replaced by sucrose, fructose, and glucose during the ripening stage due to the hydrolysis of the starch (Marriott et al., 1981). The carbohydrate content reduces to between 5 and 10% when ripe. The sugar content is between 0.9 to 2.0% in the green fruit but becomes more prominent in the ripe state. The titrable acidity of plantain is about twice that of sweet potato (Aurand et al., 1987).

Plantains therefore have a high carbohydrate content (31 g/100 g) and low fat content (0.4 g/100 g). They are good sources of vitamins and minerals (Adeniji, et al., 2006), particularly iron (24 mg/kg), potassium (9.5 mg/ kg), calcium (715 mg/kg), vitamin A, ascorbic acid, thiamin, riboflavin and niacin. The sodium content (351 mg/kg) is low in dietary terms hence recommended for low sodium diets (Izonfuo and Omuaru, 1988; Stover and Simmonds, 1987; Welford et al., 1988). The amino acid components include β-alanine, aminobutyric acid, glutamine, asparagine, histidine, serine, arginine and leucine. The ascorbic acid is high compared to that of banana. As a starchy staple food, plantain supply about 1 g protein/100 g edible portion (USDA, 2009). As a healthy adult requires about 0.75 g protein kg^{-1} day^{-1} (Burton and Willis, 1976), plantain alone cannot meet adult protein needs.

The fat content of plantains and bananas is very low, less than 0.5%, and so fats do not contribute much to the energy content. Although the total lipid content remains essentially unchanged during ripening, the composition of fatty acids, especially within the phospholipids fraction has been observed to change, with a decrease in their saturation (Ogazi, 1996).

The energy value of a food derives from the sum of its carbohydrates, fat and protein content. In the case of plantain, the carbohydrate fraction is by far the most important. The sugars and starches that make up this fraction are present in varying concentrations according to the state of the ripeness of the fruit. The two main components of this starch are amylose and amylopectin, present in a ratio of about 1:5. Sugars comprise only about 1.3% of total dry matter in unripe plantains, but rises to around 17% in the ripe fruit (Ogazi, 1985). Plantains are considered palatable at lower water content than maize, thus boiled and mashed plantain may prove to be a higher energy staple than maize porridge (Chandler, 1995). For example the energy value/100 g plantain is as follows: raw fresh fruit, 112 kcal; boiled fruit, 122 kcal; ripe fried fruit, 267 kcal (Chandler, 1995).

Plantains and bananas are a good source of vitamin A (carotene), vitamin B complex (thiamin, niacin riboflavin and B_6) and vitamin C (ascorbic acid). Processing and cooking will affect the vitamin content. In comparison with other starchy staples; vitamin C content is similar to those of sweet potato, cassava and potato. Plantains provide a better source of vitamin A than most other staples (Aurand, 1987; Kirk and Sawyer, 1991; USDA, 2009). Although plantains do not provide a particularly good source of several important minerals in human nutrition, such as calcium, iron and iodine, they are notably high in potassium and low in sodium (Marriott et al., 1983; Stover and Simmonds, 1987; USDA, 2009).

Non starch polysaccharides (collectively known as fibers) include crude fiber, cellulose, pectic substances, hemicelluloses and other polysaccharides. Unripe plantain pulp has a total of 3.5% dry matter as cellulose and hemicellulose and therefore constitutes a good source of dietary fiber (Kirk and Sawyer, 1991).

Plantain is grown in 52 countries with world production of 33 million metric tonnes (FAO, 2005). Locally, plantain constitutes about 13% of the county's agricultural gross domestic product of Ghana (SRID-MOFA, 2006), and ranks third in volume of production among starchy staples in Ghana. In the agricultural sector, plantain is ranked fourth in Ghana (FAO, 2005). Total annual national production is 2.00 million tonnes (SRID-MOFA, 2006) with per capita consumption of 101.8 kg (SRID-MOFA, 2006; FAO, 2005; Lescot, 2000). Plantain for local consumption undoubtfully, plays a role in food and income security and has the potential to contribute to national food security and reduce rural poverty. This crucial role is still largely ignored by policy makers and therefore special public awareness effort is required to sensitize policy makers in both producing and donor countries. Despite the importance of plantain, major constraints threaten its cultivation in terms of pest and disease infestations, soil fertility, planting materials, post-harvest losses, marketing constraints, particularly poor road system and lack of infrastructure and storage facilities and much of the fruits harvested go waste.

In Ghana during the glut season from late August to late April, before the "Easter storms" set in, markets are filled with vehicles laden with loads of the fruits from the remote production areas.

The production of food powders is on the increase as a result of gradual urbanization and globalization. For example, in Ghana the production and export of powder from local tuber crops and cereals is gradually gaining market status. Apart from extending the storage life of these staples (due to the low moisture of the dried product), powder products are easy to handle in terms of transport and space. In Ghana a company such as Rosafrik Co. Ltd., produces and exports powdered starchy stables such as "fufu", "tuozaafi", "kokonte" (cassava meal), "banku"

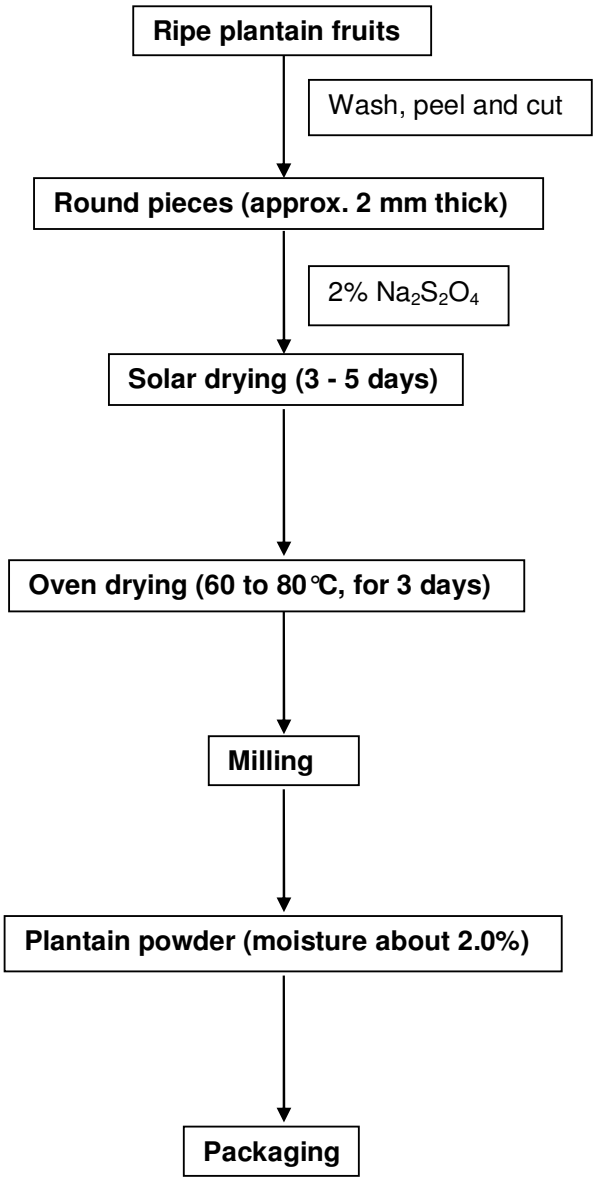

Figure 1. Flow chart of plantain flour preparation

etc. to countries such as the USA and UK.

In the manufacture of plantain powder, fully ripe plantain pulp is converted into a paste by passing through a chopper followed by a colloid mill. 1.0 to 2.0 sodium metabisulphite solution is added to improve the colour of the final product. Spray- or drum-drying may by used, with drum-drying being favoured as all the solids are recovered. A typical spray dryer can produce 70 kg powder per hour to give yields of 8 to 11% of the fresh fruit, while drum-drying gives a final yield of about 13% of the fresh fruit. In the latter method, the moisture content is reduced to 8 to 12% and further decreased to 2% by drying or cabinet dryer at 60°C (Ogazi, 1996).

There are different ways of preserving plantain fruits. However, the type of method employed should make economic sense. An enquiry from a food processing company in Kumasi, Ghana revealed that, plantain processed into "fufu" flour can store for up to a maximum of two years.

Although much work or research has been done in the areas of disease and pests (MUSACO research team: Musa network for West and Central Africa) that is, integrated strategies to reverse plantain losses in Ghana (IITA, 1997) through Sigatoka-resistant hybrid production, not much has been done in the area of post harvest losses in terms of long term keeping quality of the matured fruits.

MATERIALS AND METHODS

Mature plantain fruits (maturity age of 3.5 months) were obtained from the CSIR (Centre for Scientific Research and Industrial Research), Crop Research Institute, Fumesua-Kumasi.

Methodology of ripe plantain flour production

1. Washed plantain fruits were ripened by covering in jute sack for four days (ripening was induced by addition of ripe orange peels to fruits in the sack).
2. Washed ripe plantain fruits were sorted from damaged or rotten fruits and then weighed.
3. Fruits were hand peeled and chopped into pieces (approx. 2 mm thick) using a stainless steel knife.
4. 2.0% of sodium metabisulfite ($Na_2S_2O_4$) was prepared by dissolving 2 g of the salt in approximately 100 ml of distilled water.
5. 25 ml of the prepared 2.0% $Na_2S_2O_4$ was added to each 500 g weighed chopped pulp.
6. The round chopped pieces were initially subjected to solar drying (3 - 5 days).
7. The sulphited pulp was then dried in a Gallenkamp oven dryer maintained between 60 to 80°C for 72 h to obtain dry chips which were milled with a ball mill to get the dry powder.
8. Proximate and mineral analyses, as well as functional properties determinations were carried out on the dried powder.

The procedure for dry powder preparation is shown in Figure 1. The yield of powder was calculated from the weight measurement of the powder obtained after drying (P_w)/g, the total weight of fresh whole plantain fingers taken (PT)/g. The weight of the pulp and peels were also measured. The yield was calculated as:

$$\frac{(P_w)/g \times 100\%}{(P_T)/g}$$

Proximate analysis: Moisture determination

About 2.0 g of powder was weighed and transferred into a previously weighed crucible. The crucible was then placed into the drying oven at 105°C for 5 h. After this, they were removed and placed in a desiccator to cool. The cooled crucibles were reweighed. This was done in triplicate. The loss in weight after drying was then calculated as the percentage moisture (AOAC, 1990).

Proximate analysis: Ash determination

About 20 g of sample was weighed into a previously weighed crucible

and placed in the muffle furnace (600°C) for 2 h. The crucibles were cooled and reweighed. The loss in weight was then calculated as percentage as or mineral content of the sample (AOAC, 1990).

Proximate analysis: Crude fat determination

The dry sample from moisture determination was transferred to a 22 x 80 mm paper thimble. A small ball of cotton wool or glass wool was put into the thimble to prevent loss of sample. Anti-bumping granules were added to a previously dried 250 ml round bottom flask and weighed. 150 ml of petroleum spirit was added to the flask and the apparatus was assembled. A quick fit condenser was connected to the Soxlet extractor and refluxed for six hours on low heat. The flask was removed and evaporated on a steam bath. The flask with the fat was heated for 30 min in an oven at 103°C. The flask and its contents were cooled to room temperature in a desiccator after which it was weighed and percentage fat calculated (AOAC, 1990).

Proximate analysis: Crude fiber determination

A defatted sample of about 2.0 g was transferred into a 750 ml Erlenmeyer flask and approximately 0.5 g of asbestos was added. 200 ml of boiling 1.255% H_2SO_4 was added and the flask was immediately placed on a hot plate and a condenser was connected. The sample came to a boil within a minute. The flask was removed at the end of 40 min and the contents immediately filtered through cheese cloth and washed with large volume of boiling water. The washing was continued until the filtrates were no longer acidic. The charge and asbestos were scrapped with a spatula back into the flask with 1.25% NaOH solution using a wash bottle calibrated to deliver 200 ml. The flask again was connected to the condenser and boiling was undertaken for exactly 30 min. The content of the flask was filtered through fine linen with large volumes of boiling water as before. The residue was transferred to a crucible and washed with 15 ml alcohol. The crucible and contents were dried for 1 h at 100°C, cooled and then weighed. The crucible was ignited in the muffle furnace for 30 min, cooled and reweighed. The loss in weight was then determined (AOAC, 1990).

Digestion: 2.0 g of sample was weighed and transferred into a digestion flask with 0.5 g selenium- based catalyst crystal and a few anti-bumping agents. 25.0 ml of concentrated H_2SO_4 was added and the flask was shaken to wet the entire sample.

The flask was placed on a digestion burner and heated slowly until bubbling ceased and the resulting solution was clear. The solution was cooled to room temperature. The digested sample was transferred into a 100 ml volumetric flask and made up to the mark (AOAC, 1990).

Protein determination: Distillation

25 ml of 2% boric acid was pipetted into a 250 ml conical flask and 2 drops of mixed indicator was added. The conical flask with its content was placed under a condenser such that the tip of the condenser was completely immersed in the solution. 10 ml of the digested sample was transferred through the stop cork of the funnel on the steam jacket into the chamber. 15 ml of 40% NaOH was added to the decomposition flask. The funnel stop cork was then closed. The stop cork on the steam trap outlet was closed which forced steam through the decomposition chamber and in the process drove the librated ammonia into the collection flask. The boric acid changed to yellow as soon as it came into contact with the ammonia liberated and the distillation continued for 5 min. At the end of 5 min, the receiving flask was lowered such that the condenser tip was just above the liquid and washed with a little distilled water. Distillation was continued for another 30 min after which the burner was removed from the steam generator (flask). The apparatus was flashed as was done in the digestion step above.

Protein determination: Titration

The distillate was titrated with 0.1 M HCl solution. The same procedure was followed for the blank except that the sample was omitted. The titre values of the duplicate samples were recorded and the percentage protein calculated (%Protein = % Nitrogen x 6.25).

Functional properties: Water-binding capacity (WBC) determination

The water-absorption capacity of the flours was evaluated by placing 2 g samples in a centrifuge tube. 40.0 ml of distilled water was added and the resultant slurry was shaken for one hour before centrifugation at 2,200 rpm for 15 min. The supernatant was decanted and the amount of water in grams gained by a 100 g sample was determined (Yamazaki, 1953; Medcalf and Gilles, 1965).

Bulk density determination

The bulk density of the flour was determined by placing10 g of sample in a 50 ml graduated cylinder with gentle uniform tapping during filling. The cylinder was filled to the mark and the weight of the flour was measured. The bulk density was calculated as mass by volume in grams per milliliter (gmL^{-1}). The average of two determinations is reported (Medcalf and Gilles, 1965).

Solubility and swelling power determination

1.0 g of powder was placed into a pre-weighed centrifuge tube. 40.0 ml of distilled water was then added and stirred. The mixture was placed on a water bath thermostatically controlled at 85°C with continuous stirring for 30 min. It was cooled to room temperature and then centrifuged at 2,200 rpm for 15 min.

The supernatant was poured into a pre-weighed crucible and then placed in the oven to evaporate. The solid residue in the crucible was weighed again and the difference in weight calculated as percentage solubility. The paste in the tube was then weighed and the swelling power determined by the following equation:

$$\% \text{ Solubility} = \frac{\text{Weight of soluble starch x } 100\%}{\text{Weight of original sample}} \quad (1)$$

$$\% \text{ Swelling power} = \frac{\text{Weight of sedimented paste}}{\text{Weight of original sample x (100 - percentage solids)}} \times 100\% \quad (2)$$

(Leach et al., 1959)

Mineral analysis

Phosphorus (P)

Analytical grade KH_2PO_4 was used to prepare serial standards. To 20.0 ml each of the serial standards was added 1.0 ml CDR (50 ml of 2.5 M H_2SO_4; 15 ml of 4.0% ammonium molybdate; and 10.0 ml

of ascorbic acid) colour-developing reagent. This was repeated for the sample. A blank was also prepared using distilled water. The tubes were incubated at room temperature for 1 to 1½ h and the absorbance read from the spectrophotometer (LKB Biochrom Ultrospec II, Model 4050, Cambridge, England) at 770 nm.

Calcium (Ca^{2+})

Analytical grade calcium chloride was used to prepare serial dilutions. 3.5 M 2-amino-2-methyl-1-propanol was also prepared. In this case the colour-developing reagent (CDR) was made from 15 ml of 3.5 M 2-amino-2-methyl-1-propanol; 40 ml ethanediol as buffer; 0.002 g 0f *O*-cresol phthalein complexone; 0.1 g of 8-hydroxylquinolin and made up to 500 ml). 5 ml of each serial standard was added to 3.0 ml CDR and their absorbance taken. This was repeated for the sample in duplicate. The samples were incubated at room temperature for 20 to 30 min and their absorbance read at 570 nm.

Iron (Fe^{2+})

An analytical grade iron (II) compound was used to prepare serial standards. 10% of ascorbic acid was also prepared. The function of the ascorbic acid was to reduce any iron (III) in the sample to iron (II).To 1.0 ml of each sample in a test tube was added 1 ml of 10% ascorbic acid. This was followed by the addition of 0.5 ml of 0.5% phenanthroline. This was repeated for the sample in duplicate. The tubes were incubated at room temperature for 30 min and their absorbance read at 520 nm.

Sodium and potassium (Na+ and K+)

These minerals were determined by flame photometry. Flame photometry works on the principle that when an atom of a metal is energized, its energy level changes, that is, it goes to the excited state. Energy of a specific wavelength and intensity is released when the atom returns to its ground state. The intensity of a characteristic wavelength produced by the atom in the flame is proportional to the number of atom excited in the flame which is proportional to the concentration of the metal that is the mineral. A sodium filter was used to filter out the intensity of the light given off by the sodium in the mixture. A detector detects the intensity of the light which then sends signals to a galvanometer. The same principle was used for potassium. Sodium gives off a yellow colour and potassium gives off a red-violet colour. In determining the mineral content (P, Na, Fe, K, and Ca) of a food or feed, the residue left after ashing is dissolved in a known volume of concentrated HCl, usually 2.0 ml. This is filtered and made up to 100 ml with distilled water. The solution is then used for mineral analysis. All determinations were done in triplicates.

RESULTS AND DISCUSSION

Analysis of proximate composition provides information on the basic chemical composition of foods/ feeds. The compositions are moisture, ash, crude fat, protein, crude fiber, and carbohydrate (Table 1). These components are fundamental to the assessment of the nutritive quality of the food being analysed. Proximate analysis is usually sufficient to establish the general category of foodstuff to which a particular food sample belongs and the similarity of a particular food sample to materials previously reported in literature. Careful sampling is required to obtain accurate and reproducible values or results. The chemical and physical properties of foodstuffs exhibit a certain inherent variability among different samples; variability within a given sample, however, can be minimized by proper sampling. Analyses are usually performed on small discrete samples rather than the entire amount of food stuff (a so-called perfect sample). Various techniques (grinding, mixing, etc.) are used to insure that such small samples are representative of the entire material and provide a true measure of its overall content.

The moisture content for the plantain flour was determined to be 3.14% (± 0.22%) as compared to a value 5.43% quoted in literature (USDA, 2009) Moisture content of food or processed product gives an indication of its shelf life and nutritive values. Low moisture content is a requirement for long storage life. The moisture content of a fresh fruit is related to its dry matter content and therefore to the yield obtained from a particular crop or cultivar. The yield obtained using the “apem” cultivar was 25.86%

Crude fat determines the free fatty lipids (neutral fats-triglycerides) of a product. This property can be used as the basis in determining processing temperatures as well as auto-oxidation which can lead to rancidity (can affect flavour of food). Crude fat is always determined on defatted samples. A value of 0.336% (± 0.054) was obtained for crude fat. Work carried out by Fagbemi (1999) in Nigeria on unripe plantain fruit (powder) gave a value of 3.00%. However, the range in literature was given to be between 0.2 to 0.5% (Jaffe et al., 1963; Ketiku, 1973; Ogazi, 1996; USDA, 2009). The low content of fat will enhance the storage life of the flour due to the lowered chance of rancid flavour development (Table 1).

The protein content of foodstuffs is commonly done by analysis of total nitrogen according to the method of Kjeldahl. Total nitrogen is the sum of that derived from amino acids, which generally represent the vast majority, and that from non-protein nitrogen (NPN) sources, generally minor in quantity, existing in the foodstuff. Total nitrogen derived from the analysis is converted into protein by multiplying by a factor (6.25), that takes into account the nitrogen content of a known or average amino acid composition. The total nitrogen (protein) content of the flour was determined to be 2.68%. Ketiku (1973) in his work determined the protein level in plantain to be between 3.0 to 3.5%, as-is, or 1.3 to 1.8%, on dry-matter basis. The level of protein in unripe plantain powder was determined by Fagbemi (1999), to be 3.6%. Protein content in plantain flour is low compared to other widely eaten stable roots, tubers and fruits (Aurand, 1987; USDA, 2009). Although the protein content is lower, the nutritive quality of food is not only scored by its protein content. The underlying factor is the overall energy value it can supply to the consumer. The carbo-hydrate and energy contents (91.162% and 1603.091 kJ,

Table 1. Proximate composition, mineral composition and functional properties of plantain flour.

Proximate composition value standard deviation		
Moisture (%)	3.14	± 0.220
Ash (%)	2.68	± 0.050
Protein [N x 6.25 (%)]	2.682	± 0.050
Crude fat (%)	0.336	± 0.054
Fiber (%)	0.979	± 0.167
Carbohydrate (%)	91.162	± 2.010
Energy (kJ)	1603.09	-
Yield (%)	25.86	-
Mineral composition		
Sodium (mg/100 g)	1.125	± 0.030
Phosphorus (mg/100 g)	0.297	± 0.005
Iron (mg/100 g)	2.900	± 0.050
Calcium (mg/100 g)	0.419	± 0.011
Potassium (mg/100 g)	435.200	± 2.200
Functional properties		
Solubility (%)	18.870	± 0.004
Swelling power (gg-1)	5.237	± 0.030
Water-binding capacity (g/100 g)	71.003	± 0.004
Bulk density (gml^{-1})	0.755	± 0.020

respectively) are comparable with those of the common stables (Irvine, 1982; Sampson, 1986; Aurand, 1987; Kirk and Sawyer, 1991).

Crude fiber measures the cellulose, hemicellulose and lignin content of food. Lignin comprises polymers of phenolic acids and hemicellulose is made up of hetero-polymers of polysaccharides. Crude fiber is reported as the loss in weight on ignition of dry residue remaining after digesting material with 1.25% H_2SO_4 and 1.25% NaOH under specified conditions (This removes proteins and carbohydrates). This was determined to be 0.98%, a value very close to 0.9% stated in the works of Izonfou and Omuaru (1988) and 1.1% by Ketiku (1973).

The ash content was determined to be 2.68% ± 0.055 (Table 1), comparable to 1.66 to 2.00% for unripe plantain analysed by other researchers (Ketiku, 1973; Irvine, 1982; Sampson, 1986; Aurand, 1987; Kirk and Saywyer, 1991). The ash of foodstuff is the inorganic content residue remaining after the organic matter has been burnt away. The ash content can provide an estimate of the quality of the product, since high levels may indicate contamination. The slight increase in the value could be attributed to the differences in soil or growth conditions (Wilson, 1987). Of the 104 natural elements, only few serve as nutrient in living system and only few are essential (Burton and Willis, 1976). In determining the mineral content of a foodstuff or feed, first the total inorganic content is determined, that is, either by dry ashing at 600°C or wet ashing. From a nutritional stand point the ash content is not important as contaminations do occur. Analysis of minerals therefore had to be carried out to ascertain the actual mineral value of the food sample. The minerals usually determined are Ca, Fe, I, Na, Zn and P. Phosphorus (P) is widely present in foods and other sources so deficiency is rare (Burton and Willis. 1976).

The mineral content of the powder was generally low. Sodium, potassium, iron and phosphorus levels were determined as 1.125 mg/100 g, 435.20 mg/100 g, 2.9 mg/100 g and 0.297 mg/g, respectively (Table 1); compared with 4, 499 and 0.6 mg/100 g, for sodium, potassium and iron respectively stated in other works (USDA, 2009). The iron and potassium levels were higher in the flour produced from the “apem” cultivar of plantain than for most of the others cultivars used in other projects, and this could be attributed to differences in soil conditions (soil type and mineral content) as well as different conditions of experimental analysis (Wilson, 1987; Swennen, 1990b).

Ripe plantain flour is rich in minerals like potassium, sodium and phosphorus and this could be formulated into instant flours for convalescence and in the formulation of baby foods as these categories of humans require high levels of minerals for growth and repair.

Plantain is low in sodium (Chandler, 1995), contains very little fat and no cholesterol, therefore it is useful in managing patients with high blood pressure and heart disease (Dzomeku et al., 2007). Plantain flour is free from

substances that give rise to uric acid and therefore is ideal for patients with gout or arthritis (Ahenkora et al., 1996). Due to the low sodium and protein content, plantain is used in special diets for kidney disease sufferers.

For functional property analysis (Table 1), bulk density of 0.755 ± 0.02 gml^{-1} was indicated for the flour produced, comparable to that obtained by other researchers (Fegbemi, 1999). This value is also comparable to that obtained for sweet potato powder (0.7453gml^{-1}) which is used as a thickener or base in foods like yoghurt (USDA, 2009). Based on this similarity, plantain flour could find use as food thickener in the food industries to give body and mouth-feel to food products.

The water-binding capacity (WBC) of the flour was determined to be 71.003 ± 0.004 g/100 g; a value lower than that obtained by Fegbemi (1999) for unripe plantain (250 - 338%). Unripe fruit has high amylose/ amylopectin content implying high -OH groups to form H-bonding and hence ability to bind more water. The ripe fruit on the other hand, has all the starches broken down to form sugars and as such less water binding ability. This property can however be exploited in the formulation of baby foods since less moisture is absorbed, thus making the food less bulky and hence more palatable and easily digested. Work carried out by Fegbemi (1999), on the effect of blanching on the functional properties of green plantain powder gave higher values for the functional properties. Ripening is said to lower the values obtained for all functional properties with the exception of bulk density and gelation.

Percentage solubility and swelling power were determined to be 18.890 ± 0.004% and 5.237 ± 0.03 g/g^{-1} (Table 1), respectively. Swelling power indicates how much water a product can absorb to swell in the presence of heat. This confirmed by the low water binding capacity of the power (71.003 g/100 g). The “apem” plantain flour in foods or as an instant flour would not absorb much water hence would be less bulky, that is, more palatable. The water-binding capacity and swelling power values obtained suggest that the powder might absorb moisture upon storage, especially in the humid forest belt in Ghana were plantain is cultivated, it would therefore be advisable to store the plantain power in moisture-proof bags to extend the storage life of the product. It has been shown that plantain flour has a good potential for use as a functional agent in bakery products on account of its high water absorption capacity, but evaluation of the functionality of flour in test baking has not been demonstrated (Akubor, 1998). Mepba et al. (2007) investigated the feasibility of partially replacingwheat flour with plantain flour in bread and biscuit making and determined that the addition of plantain flour to wheat flour decreased the resistance of dough to extension, extensibility of dough and mechanical work of dough deformation and recommended that technically, organoleptically acceptable breads and biscuits were formulated from wheat-plantain composite flours using up to 80:20 and 60:40 ratios of wheat: plantain flour as maximum acceptable levels of substitution for breads and biscuits, respectively. Olaoye et al. (2006), investigated the use of soy flour and plantain flour substitution in wheat flour, from 0 to 15% each, for the production of bread and stated that there were no significant differences ($p < 0.05$) between the whole wheat bread and the plantain supplemented breads up to 10% plantain flour substitution in all the sensory attributes tested; crust, taste, aroma, shape, internal texture, appearance and general acceptability.

Hence the plantain supplemented breads had comparable sensory and nutritional qualities to the whole wheat bread, while the soy supplemented breads had higher proteins contents than the latter. However the whole wheat bread had highest hedonic mean scores in all the sensory attributes tested.

Conclusion

Plantains are undoubtfully of cultural, food and socio-economic importance in the Ghanaian society. Due to the low moisture content of the plantain powder produced, it is expected to have a longer shelf-life compared to ripe plantain; hence the product could ensure food security all year round as a result of the long storage life and the plentiful supply of ripe plantain available on the local Ghanaian markets.

Based on the functional characteristics and proximate composition of the plantain flour product, it can be incorporated as a food thickener in foods for people of all ages.

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