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The Functional Properties and Nutritional Profile of Flour made from Two Selected Plantain Varieties (*Musa balbisiana* and *Musa accuminata*)

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Abstract Africa is rich in variety of staple foods. The need to improve the available nutrient information on staple foods according to the specific variety cannot be overlooked to improve the existing food composition tables. Plantain is an economically viable agricultural produce. Its potential to be made into different food products and food forms increases this characteristic. The functional properties and nutritional profile of flours made from two selected plantain varieties (*musa balbisiana* and *musa accuminata*) were determined. Unripe plantains were purchased, washed, peeled, chopped into smaller chips, and sundried until a crispy form was observed. The chips were ground into powder and used for analysis. Functional properties and nutritional profile of the plantain varieties were determined. For functional properties, *Musa balbisiana* flour had higher ($p<0.050$) water absorption (78.00±0.00), oil absorption (69.00±0.00) and swelling capacity (10.42±0.00) than *Musa accuminata.* In contrary, *Musa accuminata* flour had higher solubility index (13.67±0.58) and bulk density (0.74±0.02). Also, *Musa accuminata* had higher ($p<0.05$) dry matter, ash, fibre, and protein (5.54±0.51%, 3.31±0.31%, 3.77±0.12 and 5.84±0.51, respectively) while *Musa balbisiana* had higher ($p<0.05$) fat and carbohydrate contents (2.33±0.58 and 83.14±0.36, respectively). Similarly, *Musa balbisiana* had higher macro-mineral contents ($p<0.05$) while chromium, copper, and vitamins B2, B3, and B6 contents were similar for both samples ($p>0.05$). In general, this study showed that flour made from the two varieties of plantain, although with varying nutritional profiles, are both nutrient-rich and can be used to ensure food and nutrition security.

Keywords Plantain flour, Proximate composition, Functional properties, Food security, Unripe plantain

1. Introduction

Plantains *(Musa paradisiaca)* are an inexpensive source of calories, and essential minerals such as potassium [1]. Plantain ranks third in production among starchy staples after cassava and yam and Nigeria is the world's top plantain producer, producing 2.5 million metric tons [2,3]. The diversity in the plantain crop results from a variety of cultivars. Many are hybrids derived from the cross of two wild species, *Musa acuminata* and *Musa balbisiana*. The currently accepted scientific name for all such crosses is *Musa paradisiaca* [4]. Plantains in their ripe and unripe forms are consumed in many various ways in Nigeria. They can be boiled, roasted, fried and ground into powder for the preparation of several delicacies. Consumption of unripe plantain is of particular interest due to its perceived nutritional and health associated benefits. Earlier studies [5,6,7] had reported the health benefits of plantains. Despite the high patronage and usage of plantain as staple food, very few information are available on the nutritional composition and functional properties in literature [8].

The nutrient and chemical properties of a food product are a major determinant of the food product's health benefit [9]. The functional properties are characteristics that determine the response of nutrients in food samples during storage, processing, and preparation. Their responses determine the quality and acceptability of the food samples [10]. The water and oil absorption capacity, swelling capacity, bulk density, and solubility index are important properties that influence the use of starchy staples such as plantain [11].

An understanding of the nutritional and functional profile of plantain flour may be of benefit to the food industry especially in the formulation of new food products and may also find wider usage in the bakery and nutraceutical industries. This will address the gaps in existing food composition tables, improve available nutrient information

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on staple foods according to the specific food varieties and improve clinical nutrition practice and diet therapy.

Hence this study was designed to add to existing literature on the proximate composition of flours from two varieties of plantain and also provide further knowledge on their functional properties.

2. Materials and Methods

2.1. Raw Material Procurement and Sample Preparation

Two varieties of unripe plantain (*Musa balbisiana* and *Musa accuminata*) which are staples in the West and Central African diet, especially Nigeria, were purchased from Oluode market in Osogbo, Osun State. The unripe plantain fruits were washed in clean water and dried with paper towels before peeling and slicing. The peels were discarded and the pulps were sliced, arranged on porous trays and sundried until they were crispy. Dried samples were milled using Silver crest multifunction blender (SC-1589_Germany) into powder and stored in air tight containers for analysis.

2.2. Functional Properties Determination

The swelling index, water/oil absorption capacity, solubility index, and bulk density (BD), were determined.

Swelling index was determined according to Okaka and Potter [12]. 100 ml graduated cylinder was filled with the sample to 10 ml mark. The distilled water was added to give a total volume of 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and left to stand for a further 8 min and the volume occupied by the sample was taken after the 8th min.

The water absorption capacity of the flours was determined by the method of Sosulski *et al*. [13]. One gram of sample was mixed with 10 mL distilled water and allowed to stand at ambient temperature (30 ± 2℃) for 30 min, then centrifuged for 30 min at 3000 rpm or 2000 × g. Water absorption was examined as percentage water bound per gram of flour.

Solubility was determined by dissolving one (1) g of flour in 10 ml of distilled water contained in a centrifuge tube. This mixture was stirred for 30 minutes with a stirrer and then kept in a water bath at 37℃ for 30 minutes. It was then centrifuged at 5000 rpm for 15 minutes and dried at 105℃ to a constant mass and weighed [14].

The oil absorption capacity was determined [13]. One gram of sample was mixed with 10 ml soybean oil (Sp. Gravity 0.9092) and allowed to stand at ambient temperature (30 ± 2℃) for 30 min, then centrifuged for 30 min at 300 rpm or 2000 × g. Oil absorption was examined as percentage oil bound per gram of flour.

The volume of 100g of the flour was measured in a measuring cylinder (250 ml) after tapping the cylinder on a wooden plank until no visible decrease in volume was noticed, and based on the weight and volume, the apparent (bulk) density was calculated [15].

2.3. Proximate Composition Determination

The moisture, ash, protein, fat, and crude fibre were determined by the methods of AOAC [16]. Carbohydrate was determined by difference as 100 – (% moisture + % ash + % lipid + % crude protein).

2.4. Mineral and Vitamin Composition Determination

Micronutrient contents such as potassium and sodium were assayed by flame spectrophotometry [17] while calcium, magnesium, and phosphorus were analyzed using atomic absorption spectrophotometry (Hot lab AA320N automatic flame graphite furnace double beam).

Ascorbic acid assay was determined as described by Ndayambaje et al [18] and Beta-carotene was determined using the methods by James [19].

2.5. Statistical Analysis

All data obtained were statistically analyzed using analysis of variance (ANOVA) to determine significant differences at5% level of significance using SPSS v24.0. The means were separated using the Duncan Multiple Range test. All data were expressed as mean± standard deviation of triplicate values.

3. Results and Discussion

3.1. Functional Properties of the Samples

The functional properties of the both plantain flour samples are shown in Table 1. *Musa balbisiana* had asignificantly ($p<0.05$) higher water absorption capacity (78.00± 0.00%), oil absorption capacity (69.00± 0.00%), and swelling capacity (10.42± 0.00%) than found in M*usa accuminata* (71.67± 0.58%, 67.67± 0.5%, 9.94± 0.00% respectively). Water absorption capacity is the property that determines how much water a flour can absorb in order to rise and improve yield and consistency during food processing [20]. It also gives the organoleptic properties that determine the uniqueness and consumer acceptability of the food product [21]. The water absorption capacity is usually dependent on the starch and non-starchy component of the flour and indicates the suitability of flour in baking [20]. The water absorption capacity from this study is lower compared to 130.00±1.00 and 196 ml/100g reported for unripe plantain flour sun-dried [20] and oven dried respectively [22]. Oil is important in the flavour retention and mouth feel of a food sample. The oil absorption of plantain flour samples is 3 times lower compared to results from Arinola et al. [20] and Osundahunsi [22] but similar to the values for the six cultivars studied by Honfo et al. in Benin [23].

The bulk density is an important factor in packaging and handling requirements in the food industry. It is a desirable quality because it gives packaging advantages and flexibility in processing [24,25]. Flours with low bulk density are more suitable in complementary food formulation while flours with high bulk density are more suitable in food preparations [26]. The bulk density was significantly different ($P<0.05$)

with 0.74± 0.02% and 0.71±0.00% recorded in *Musa balbisiana and Musa accuminata* respectively. This result is similar to the results recorded for the six cultivars studied in Benin [23]. Similar values have also been reported in wheat-plantain flour [27], wheat-brown rice flour [28], and breadfruit flour [29]. The solubility recorded in *Musa accuminata and Musa balbisana* were significantly different at 13.67± 0.58 % and 12.67± 1.16% respectively.

Table 1. Functional Properties of Selected Plantain Flours

Functional Properties	*Musa acuminata*	*Musa balbisiana*
Water absorption (%)	71.67± 0.58^b	78.00±0.00^a
Oil absorption (%)	67.67± 0.50^b	69.00±0.00^a
Swelling capacity (%)	9.94± 0.00^b	10.42± 0.00^a
Solubility (%)	13.67± 0.58^a	12.67± 1.16^b
Bulk density (g/ml)	0.74± 0.02^a	0.71± 0.00^b

Results are presented as mean± standard deviation of triplicate determination. superscripts represent significance when parameters are compared across rows.

3.2. Proximate Composition of Plantain Samples

Table 2. Proximate Composition of Selected Plantain Samples

Proximate	*Musa acuminata*	*Musa balbisiana*
Dry matter (%)	5.54±0.51^a	4.38± 0.00^b
Ash (%)	3.31± 0.31^a	2.53± 0.12^b
Crude Fibre (%)	3.77± 0.12^a	3.23± 0.15^b
Crude Protein (%)	5.84± 0.51^a	4.84± 0.00^b
Crude Fat (%)	1.33± 0.58^b	2.33± 0.58^a
Carbohydrate (%)	80.38± 1.14^b	83.14± 0.36^a
Energy (Kcal)	356.88± 2.67^b	371.09± 3.83^a

Results are presented as mean± standard deviation of triplicate determination. superscripts represent significance when parameters are compared across rows.

Table 2 shows the proximate composition of the plantain flour samples. There were variations in the proximate composition of the plantain varieties. *Musa accuminata* contained a dry matter of 5.54±0.51% which was higher (P<0.05) than 4.38± 0.00 found in *Musa balbisiana.* The ash content for *Musa accuminata* was 3.31±0.31% compared with a lower (P<0.05) 2.53± 0.12 found in *Musa balbisiana.* This is higher than was found in the six cultivars from Benin [23], and in soy-plantain composite [28], but lower compared to oven-dried and sun-dried unripe plantain flour from Benue State, Nigeria [24]. The crude fiber of 3.77± 0.12% found in *Musa accuminata* was higher (P<0.05) than 3.23± 0.15% found in *Musa balbisiana*. However, these results were lower compared to the oven-dried and sun-dried plantain flours from Benue, Nigeria [29]. The protein content was significantly different (P<0.05) with 5.84± 0.51% and 4.38±0.00% recorded in *Musa accuminata*. and *Musa balbisiana* respectively. These results were higher compared to findings from Benue State [29] and fermented unripe and ripe plantain [30] but lower in soy-plantain flour [28]. Crude fat contents that were recorded in both samples were similar with 1.33± 0.58% and 2.33± 0.58% for *Musa accuminata and Musa balbisiana,* respectively. This was similar to the findings of Yarkwan and Uvir [29], and [30] in 72 hours fermented ripe and unripe plantain flour. *Musa balbisiana* contained 83.14±0.36% of carbohydrate which was higher than (P<0.05) 80.38± 1.14% in *Musa accuminata*. The energy content for *Musa balbisiana* 371.09±3.83% was significantly higher (P<0.05) than 356.88± 2.67 found in *Musa accuminata.*

3.3. Mineral Content of Flour Samples

The mineral contents of the flour samples are shown in table 3. *Musa balbisiana* has a significantly higher manganese (1.54± 0.01mg/100g) and iron (227.31± 0.01 mg/100g) content than *Musa accuminata* (1.45± 0.01 mg/100g and 220.44±0.01 mg/100g respectively) while there was no significant difference between the zinc, chromium, and copper content in both flours. The iron content of assayed samples is significantly higher than found in the 47 accessions studies by Fung et al., [31] while the zinc contents are similar ranging from 0.00mg/100g to 1.219mg/100g. Plantains (*Musa spp.*) are expected to contain 3mg of calcium, 500mg of potassium, 35mg of magnesium, 4 mg of sodium, and 30 mg of phosphorus per 100g [32]. *Musa balbisiana* contains significantly higher (p<0.05) calcium (312.23± 0.02mg/100g), potassium (165.32± 0.01mg/100g), magnesium (163.11± 0.00 mg/100g), sodium (210.11± 0.00 mg/100g) and phosphorus (358.82± 0.01 mg/100g) content compared to *Musa accuminata* respectively. This identifies the possibility of variation in the mineral content of plantain varieties.

Table 3. Mineral Content of Selected Plantain Flour Samples

Minerals (mg/100g)	*Musa acuminate*	*Musa balbisiana*
Manganese	1.45± 0.01^b	1.54± 0.01^a
Zinc	0.10± 0.00^a	1.02± 0.00^a
Chromium	0.10± 0.00^a	0.10± 0.00^a
Iron	220.44± 0.01^b	227.31± 0.01^a
Copper	0.70± 0.00^a	0.70± 0.00^a
Calcium	310.08± 0.06^b	312.23± 0.02^a
Potassium	162.00± 0.00^b	165.32± 0.01^a
Magnesium	160.23± 0.01^b	163.11± 0.00^a
Sodium	208.01± 0.01^b	210.11± 0.00^a
Phosphorus	352.52± 0.01^b	358.82± 0.01^a

Results are presented as mean± standard deviation of triplicate determination. superscripts represent significance when parameters are compared across rows.

3.4. Vitamin Content of Flour Samples

Table 4 contains the vitamin content of the flour samples. Plantains are a rich source of vitamins [33]. Thiamin was obtained with 0.24± 0.00mg/100g in *Musa accuminata* which was higher (P<0.05) than 0.21± 0.01 mg/100g found in *Musa balbisiana*. The ascorbic acid was significantly different (P<0.05) with 1.07± 0.00 mg/100g and 1.35±0.01 mg/100g recorded in *Musa balbisiana* and *Musa accuminata* respectively. Vitamin C is an important nutrient for humans and is readily found in fruits and vegetables [34,35]. The vitamin C content found in the studied plantain flours is remarkably lower compared to results from previous studies [18,36,37]. This implies that plantain flour is not an excellent source of vitamin C. Riboflavin was recorded in *Musa accuminata* and *Musa balbisana* were not significantly different with a record of 0.12± 0.00 mg/100g respectively. This result is within the range (0.10 to 2.72 mg/100 g) of riboflavin found in eight plantain cultivars studied by Englberger [38]. It is estimated that 100g of plantain flesh will meet three times the estimated requirement (7mg/day) of Niacin per day [38]. Niacin recorded in *Musa accuminata* and *Musa balbisana* was not significantly different with a record of 0.11± 0.00 mg/100g and 0.15± 0.00 mg/100g respectively (P>0.05). Pyridoxine recorded in *musa accuminata* and *Musa balbisana* was not significantly different with a record of 0.08± 0.01 mg/100g and (P>0.05) 0.08± 0.00 mg/100g respectively. Folic acid recorded in *Musa accuminata* and *Musa balbisana* was not significantly different with a record of 0.02± 0.04 mg/100g and (P>0.05) 0.23± 0.01 mg/100g respectively.

There were variations in fat-soluble vitamins. *Musa accuminata* recorded a beta-carotene content of 0.32±0.02mg /100g which was higher (P<0.05) than 0.22± 0.03mg/100g in *Musa balbisiana*. This level is significantly lower when compared to the results obtained by Ndayambaje and Dickson [18]. About 21µg of beta-carotene is expected to be contained in a gram of plantain [30]. However, the level of beta-carotene in plantain is expected to rise as ripening occurs [18]. This is a probable reason the beta-carotene in the assayed flour is low since they were from unripe plantains. The vitamin D content for *Musa accuminata*. recorded 0.26±0.06 mg/100g which is significantly higher (P<0.05) than 0.17± 0.02 mg/100g in *Musa balbisiana*. The highest vitamin E was obtained with 0.29± 0.00 mg/100g in *Musa balbisiana* which is significantly higher than (P<0.05) 0.27± 0.00 found in *Musa accuminata*. A 100g of plantain is estimated to meet almost half the vitamin E requirement (3.75mg/day) of a physiological woman.

Table 4. Vitamin Content of Selected Plantain Flour Samples

Vitamins (mg/100g)	Musa acuminata	Musa balbisiana
Vitamin B1 (Thiamin)	0.24 ± 0.00^{a}	0.21 ± 0.01
Vitamin B2 (Riboflavin)	0.12 ± 0.00	0.12 ± 0.00
Vitamin B3 (Niacin)	0.11 ± 0.00	0.15 ± 0.00
Vitamin B6 (Pyridoxine)	0.08 ± 0.01	0.08 ± 0.00
Vitamin B9 (Folic Acid)	0.02 ± 0.04^{b}	0.23 ± 0.01^{a}
Vitamin C (Ascorbic Acid)	1.35 ± 0.01^{a}	1.07 ± 0.00^{b}
Beta-Carotene	0.32 ± 0.02^{a}	0.22 ± 0.03^{b}
Vitamin D	0.26 ± 0.06^{a}	0.17 ± 0.02^{b}
Vitamin E	0.27 ± 0.00^{b}	0.29 ± 0.00^{a}

Results are presented as mean± standard deviation of triplicate determination. superscripts represent significance when parameters are compared across rows.

4. Conclusions

This study has shown that the two flour samples had different nutritional contents and functional properties. Flour made from the two varieties of plantain are both nutrient-rich and can be used to ensure food and nutrition security. This will provide the information needed by Dieticians for diet therapy and as well increase its use in the food industry.

Efforts should therefore be geared towards ensuring food and nutrition security using plantain as a vehicle in regions where plantain is readily accepted as a staple.

Disclosure

This section is ONLY for those who requested disclosure. The name of the experts that reviewed your paper, in case they accepted selling disclosure to you, will appear here. Each reviewer is allowed to make their own price for that, since that is a public endorsement of your findings and may be used for varied purposes.

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