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Proximate Composition, Mineral Elements and Starch Characteristics: Study of Eight (8) Unripe Plantain Cultivars in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AOO designed the study, performed the statistical analysis, and wrote the protocol. Author JON carried out the sample analyses. Author ACF wrote the first draft of the manuscript and managed literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: Composition of foods eaten routinely in quantities that constitute and supply macro and micronutrients is relevant in the overall assessment of public health status. Analysis of such foods will provide evidence on nutritional quality, guide to healthy choice and promote intake of varieties with superior qualities during ill-health and prevention of diet-associated disorders.
Aims: To evaluate the proximate composition, mineral elements, glycemic index, amylose content and gelatinization temperature of eight (8) cultivars of unripe plantains (*Musa paradisiaca*) commonly consumed in Nigeria.
Methodology: Mature unripe varieties purchased from a public local market were identified by a crop scientist. Flour samples obtained from the fresh plantain pulps were analysed in triplicates by standard methods, including AOAC official methods.
Results: Moisture content ranged from 10.00-18.30% with statistical significant differences (*P<.05*) within the mean values. The ranges of ash, fibre, fat, protein and carbohydrate were 0.55-2.53,

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0.19-0.61, 2.05-4.07, 1.12-7.24 and 69.96-81.18%, on dry weight basis, respectively. The ranges of mineral elements were Na 18.47-27.78, K 264.75-452.50, Ca 102.15-162.04, Mg 86.72-150.05, P 152.69-260.21, and Fe 11.92-21.46 mg/kg weight of sample. Amylose contents showed significant differences (*P<.05*) across the means and ranged from 40.25-70.75%. The cultivar, Efol had the least for amylose content (40.25%) and gelatinization temperature (68.50^{0}C). Glycemic index ranged from 39.04 to 51.05%.

Conclusion: Plantain cultivars in this study contain variable nutritional compositions. The proximate and mineral nutrients were moderately low except carbohydrate with high content. The plantain cultivars had high amylose contents and low glycemic indices. Consumption of these plantains may have important non-pharmacological health benefits in the dietary management of type 2 diabetis mellitus, especially Nblpaul and Agbagba cultivars.

Keywords: Proximate composition; unripe plantain; glycemic index; amylose content.

1. INTRODUCTION

Globally, plantain (AAB), cooking banana (ABB) and dessert banana (*Musa* spp., AA, AB and AAA genome), constitute fourth most important commodity after rice, wheat and maize [1]. Over 130 countries grow the staple food in an area of 4.8 million ha producing 93.39 million tones of banana and plantain, with Brazil the fourth largest world producer after India, the Philippines, and China [1,2]. Plantain and cooking banana are major staples with nutritious appeal in the West and Central Africa, Central Asia, the Caribbean Islands and coastal parts of South America. In the West and Central Africa, plantains are rich source of energy and at least 116 plantain cultivars have been reported in these regions, with about 20 cultivars in Nigeria [3]. However, only a few are relevant for commercial and economic sustainability. Bananas belong to *Musa* species with considerable morphological diversity ranging from plant size, bunch orientation to bunch type but with poor genetic differentiation as revealed by molecular markers [4]. They include plantain (*Musa paradisiaca,* AAB), cooking-banana (*Musa acuminate,* ABB) and dessert bananas (*Musa Cavendish,* AAA). It is believed that they are hybrid products of two wild diploid species, *Musa acuminata* and *Musa balbisiana* with genome AA and BB respectively [5,6]. Plantain and cooking-banana are similar in physical appearance to unripe regular dessert banana. But the former is larger in size, requires cooking to soften the starchy pulp before consumption. Studies have reported processing methods for unripe and mildly ripe plantain and cooking-bananas before consumption. They are roasted, boiled with beans or tomatoes, cooked, steamed, baked, sliced and fried into chips, dehydrated for consumption, preservation and to serve as composite ingredients in industries for making baby foods [7,8,9]. Dip-frying of plantain pulp has been reported to cause reduction in beneficial micronutrients [10]. However, the chemical compositions of plantains vary and literature has implicated a number of responsible factors, including maturity, degree of ripeness, soil type, variety and climate [4,7]. Starch is the main component of unripe plantain which undergoes important changes during ripening [2]. Comparative analysis reported higher carbohydrate in unripe plantain than in ripe with higher sugars, glucose, sucrose and fructose [4,11,]. In similar studies, carbohydrate (above 80%) was found as a major component in unripe plantain [7,12]. Baiyeri et al. [13] found significantly high levels of Nitrogen, Phosphorus, Potassium, Magnesium, and Calcium in fully ripe plantain pulp, but low levels of Fe, Cu, Zn, Na. Plantains are also reported to be a great source of vitamins A, B_1, B_2, B_3, B_6 and C [14]. Increased amylose or resistant starch in diet decreases postprandial glucose level and insulin responses in people with either normal glucose tolerance or impaired glucose tolerance [15]. In the traditional management of diabetes mellitus, consumption of local staples is important, and evidence is accumulating for hypoglycemic effect of unripe plantain intake in human and experimental studies [16]. Currently, dietary modification remains the mainstay for achieving glycemic control among the diabetics to cripple diabetic vascular complications for extended life expectancy. The American Dietetic Association (ADA) reviewed the evidence for low GI foods, acknowledged that low GI foods may reduce postprandial glucose levels and asserted that there is sufficient evidence of long term benefits to recommend using low GI diets as a primary strategy in meal planning [17]. Therefore, identification and consumption of low GI foods with slow postprandial glycemic response is relevant to form the basis for dietary change and

risk reduction for obesity, diabetes and other chronic degenerative diseases. Anti-ulcerogenic, ulcer healing and anti-diabetic activities of unripe plantain fruit pulp were found in experimental models, and more effective when compared with some conventional agents with known anti-ulcerogenic activity [18]. Recently, the flavonoid leucocyanidin has been identified as the active ingredient in plantain for its anti-ulcerogenic properties [14]. It appears the health benefits of unripe plantain further justify the report of increased consumption pattern of unripe plantain in adult individuals in Nigeria [7]. Further study may help identify cultivars with superior qualities for consumption especially among the ulcer and diabetic patients. This study therefore aimed at providing data on proximate composition, mineral elements, amylose content and glycemic index of eight (8) cultivars of plantain with a view to know better cultivar/cultivars with nutritional qualities for better dietary advice and consumption.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Eight (8) mature, unripe and recently harvested plantain fruits were purchased from the public market, Abakaliki, Ebonyi State, Nigeria. The fruits were taken to the Central Orchad of National Root Crop Research Institute, Umudike, Abia State where they were identified and authenticated by Dr F.N. Kalu as Efol, Nblpual, Agbagba, Atagafong, Pita 14, Nibrator, Aging and Calcutta 4 Fig. 1. The plantain fruits were washed to remove dirts and other contaminants. The skin of the fruits was peeled off and pulps cut into small pieces and sun-dried to reduce moisture content and then placed in drying oven at 105°C to constant weight. The samples were ground and sieved to obtain flour, stored in polythene bags before analysis at the Biochemistry Laboratory of Kogi State University, Anyigba. All determinations were done in triplicates.

2.2 Chemicals and Reagents

Chemicals and reagents used in this study were of analytical grade and were products of BDH Chemical Ltd, England.

2.3 Proximate Composition

The proximate composition of each plantain sample was determined using the standard methods of analysis of Association of Official Analytical Chemists, AOAC 1995 [19]. Air-oven method was used to determine the moisture content of the samples. The protein was determined by micro-Kjeldahl method with conversion factor of 6.25. The ash content was determined using a muffle furnace at 550°C for 4 hours until constant weight is obtained for the ash. Soxhlet extraction method using petroleum ether was used to extract the fat content. The crude fibre was determined by Kirk and Sawyer method, 1991 [20]. The carbohydrate content was obtained by difference. The analyses were done in triplicates and the average taken as the candidate value.

2.4 Mineral Element Analysis

Sodium, potassium, calcium, magnesium and iron were analysed, after digestion with concentrated HNO_3 and H_2SO_4, with Atomic Absorption Spectrophotometer, AAS (Model Buck 2006, Buck Scientific, USA). Phosphorus was estimated by vanado-molybdate colorimetric method [21].

2.5 Determination of Amylose Content

The amylose content of starch was determined according to the Rapid Iodine Colorimetric Method described by Williams et al. [22]. Standard control was used in the determination of amylose content in samples.

2.6 Determination of Glycemic Index

Glycemic Index was calculated from the hydrolysis index (area under the curve procedure) expressed in percentage described by Hettiaratchi et al. [23].

2.7 Determination of Gelatinization Temperature

10% suspension of the flour sample was prepared in a test tube. The aqueous suspension was heated in a boiling water bath, with continuous stirring. Gelatinization was observed after 30s and measured accurately as the gelatinization temperature.

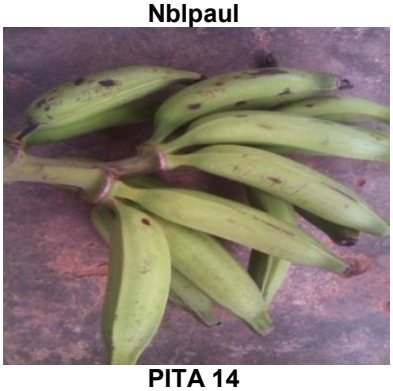

Calcutta 4


Efol


Aging


Nblpaul


Agbagba


PITA 14


Nibrator


Atagafong

Fig. 1. Eight (8) plantain cultivars analysed in the study (*Musa* spp)

2.8 Statistical Analysis

All measurements were carried out in triplicates. The triplicate mean values of the samples from the eight cultivars were subjected to one way ANOVA using SPSS version 18 statistical software. Differences considered significant at 5% (*P<.05*). Results were expressed as mean ± standard deviation.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

Determination of proximate composition of food is an important index in assessing nutritional potential of crops. Table 1 depicts the nutrient compositions present in each of the eight plantain cultivars considered in this study. The moisture content varied significantly and ranged between 10.00 to 18.30%. Calcutta 4 had the least while Efol had the highest moisture content. Moisture content is an important component in relation to food quality, shelf life and application in food industry. Plantains have been reported to contain mainly water and carbohydrate [6]. In previous studies, moisture contents ranging from 5.0 to 61.0% have been reported for unripe plantains [24,25]. Higher values of 52.93, 59.57 and 57.87% were found in three unripe plantain cultivars by Makanjuola et al. [6]. However, our result for moisture content is comparable to previous reports of studies which conclude that <20% moisture content is suitable for a stable shelf life of plantain [2,5,24,26]. The plantain flours analysed in this study may be good as binders and composite flour in food and baking industries due to low moisture content. As shown in Table 1, the ash content did not show significant differences among the cultivars except Nblpaul and Atagafong cultivars with 2.03 and 0.55% (*P<.05*) respectively. It varied from 0.55 to 2.53%. Ash contents obtained in this study are similar to the reported values by Pelissari et al. [2], Odenigbo et al. [7], Pacheco-Delahaye et al. [5], and Luzia and Jorge for non-conventional Brazilian fruits [27]. However, Shodehinde and Oboh have reported significantly different higher values in roasted and boiled plantain flours [14]. The fibre content varied from 0.19 to 0.61%. Research evidence highlights the linkage of dietary and functional fibres to positive health outcomes. The known health benefits of dietary fibre intake have been related to reduce blood cholesterol level, slow absorption of glucose, improved insulin sensitivity. Available data from studies indicate that significantly lower risk for obesity, type 2 diabetes, constipation, coronary heart disease and some cancers could be expected with increased dietary fibre consumption [28]. Plantain and banana fruits have high fibre and resistant starch content and their flours are a high dietary fibre source [5]. However, it is noteworthy to point out that we have reported lower fibre content (0.19 to 0.61%) in comparison to higher values, 4.44% [24], 1.18% [2], 1.30% [26] in previous studies. The low fibre content may be due to varieties considered in this study. Several adverse physiological responses may develop in individuals who consume low levels of dietary fibre over time, particularly an increased risk of coronary heart disease [28]. Fat content ranged from 2.05 to 4.07% with Atagafong having the highest value significantly different (*P<.05*) from others. Similar results were reported by Arisa et al. [24] and Osundahunsi [26], although very low level of 0.21% was found by Eleazu et al. [29]. The protein content ranged from 1.12% for Nibrator to 7.24% for Pita 14. Many studies have reported lower protein content than 7.11%, 7.22% and 7.24% reported in this study. Comparatively, the cultivars are good source of protein. However, plantain alone cannot supply protein need to human, as a healthy adult requires about 0.75 g/kg per day [24]. Carbohydrate content ranged from 69.69 to 81.18% with significant differences within the triplicate mean values (*P<.05*). These results reinforce other existing previous studies showing a large percentage of carbohydrate in plantains. It is the principal component of unripe plantain flour. High amounts of carbohydrates are an alternative source of fibre in food and may constitute important energy source once included in diet [27]. The ratio of amylose to amylopectin in carbohydrate has important implication on food quality, industrial application and health. The beneficial effect of unripe plantain is associated with component of carbohydrate, resistant starch (RS) which is related to amylose content much more than amylopectin [1]. The proximate compositions in the plantain cultivars generally showed variations within the triplicate mean values and with earlier reported values. According to Yu et al. [27], the proximate composition of fruits can be influenced by several factors, including variety, cultivar, maturity, climate and geographical condition of production, handling during and post-harvest, processing and storage. Furthermore, the species genotype, growing conditions, and the interaction between

genotype and environmental characteristics may also influence directly in the composition of fruits.

3.2 Mineral Element Composition

The mineral compositions of the studied cultivars are shown in Table 2. There were significant differences within the cultivars for sodium level (*P<.05*). It ranged from 18.47 for Aging to 27.78 mg/kg for Nblpaul. Potassium level ranged from 264.75 to 453.50 mg/kg with significant differences within the cultivars (*P<.05*). Nblpaul had the highest potassium level. Sodium and potassium perform important biochemical functions as in acid-base balance, nerve impulse mediation and cell membrane Na/K channels and pumps. However, compelling evidence have implicated high dietary sodium intake in the development of cardiovascular disease, importantly hypertension and that increased intake of dietary potassium is beneficial in relation to blood pressure control [30]. Currently, results are inconclusive as to whether potential adverse effects are associated with low intake of sodium [30]. Meanwhile, sodium intake of <1.5 g or <2.3 g per day is recommended in dietary guidelines [31]. Plantains are reputed to be low in sodium and high in potassium and calcium and this was confirmed by our results. Potassium was present in about 15 times as sodium. The highest value, 27.78 mg/kg reported in our study is very low in dietary terms. Therefore, consumption of plantain may not predispose general population or salt-sensitive hypertensives to hypernatremia or high blood pressure respectively. No significant differences among the Agbagba, Pita 14 and Nibrator calcium content. The magnesium content ranged from 86.72 to 150.05mg/kg for Aging and Nblpaul respectively. Phosphorus content of the plantain varieties showed significant differences (*P<.05*). Nblpaul had the highest and Atagafong had the lowest phosphorus content, 260.21 mg/kg and 152.69 mg/kg respectively. The cultivars differed significantly in their iron content. Iron content was highest in Nblpaul and lowest in Nibrator. Similar results for iron, calcium and phosphorus content have been reported for different cultivars, including Agbagba cultivar [6,13,32].

3.3 The Glycemic Indices, Amylose Content and Gelatinization Temperature of the Cultivars

Table 3 shows the glycemic index, amylose content and the gelatinization temperature of the cultivars. The glycemic indices (GI) for the cultivars ranged from 39.04 to 51.05% with Agbagba cultivar having the lowest GI and Efol cultivar with the highest GI. The glycemic indices significantly differ and this may suggest different amount of amylose and amylopectin in the plantain. The GI is a measure of the blood glucose-raising ability of the available carbohydrate in food [33]. According to the official classification [34], high GI foods (>70), intermediate GI foods (55-70) and low GI foods (<55) raise blood glucose level rapidly, moderately and slowly respectively. In the present study, the glycemic indices of the plantains commonly consumed in Nigeria were below 55 and Agbagba cultivar had 39.04% as the lowest GI. This indicates that the plantain cultivars are low GI staple foods. However, glucose metabolic disorders, including diabetes are due to high GI food consumption. Heather et al. [35] stated that low GI food can improve metabolic mechanism in adult patients with type 2 diabetis mellitus, while Brand-Miller et al. [36] reported that consumption of low GI food in medium term can control blood glucose level. Furthermore the health benefits of low GI diets have been associated with increased insulin sensitivity, reduce food intake and body weight, and may reduce serum cholesterol [33].

Table 1. Proximate composition of eight (8) unripe plantain cultivars (% dry weight basis)

Sample	Moisture	Ash	Fibre	Fat	Protein	Carbohydrate
Efol	18.30±0.14^{a}	2.53±0.04^{a}	0.22±0.03^{d}	2.05±0.07^{e}	7.22±0.31^{a}	69.69±0.03^{f}
Nblpaul	14.90±0.14^{e}	2.03±0.04^{b}	0.61±0.01^{a}	2.50±0.14^{d}	5.23±0.09^{b}	74.74±0.11^{d}
Agbagba	15.30±0.14^{d}	2.53±0.04^{a}	0.32±0.00^{c}	2.90±0.14^{c}	3.22±0.22^{c}	75.74±0.18^{d}
Atagafong	16.10±0.14^{c}	0.55±0.07^{d}	0.19±0.01^{d}	4.07±0.10^{a}	1.51±0.21^{d}	77.58±0.54^{c}
Pita 14	16.18±0.14^{b}	1.20±0.28^{c}	0.44±0.03^{b}	3.44±0.06^{b}	7.24±0.21^{a}	70.88±0.58^{e}
Nibrator	16.10±0.14^{c}	1.00±0.00^{c}	0.36±0.03^{c}	2.66±0.08^{d}	1.12±0.22^{d}	78.77±0.04^{b}
Aging	11.90±0.14^{f}	1.45±0.07^{c}	0.51±0.01^{b}	3.60±0.00^{b}	7.11±0.16^{a}	75.43±0.07^{d}
Calcutta 4	10.00±0.00^{g}	1.55±0.07^{c}	0.48±0.00^{b}	3.65±0.07^{b}	3.17±0.16^{c}	81.18±0.11^{a}

The values are mean ± SD of triplicates at 5% level of significance; mean values along a column with the same superscript are not significantly different

Table 2. Mineral element composition of eight (8) unripe plantain cultivars (mg/kg)

Sample	Na	K	Ca	Mg	P	Fe
Efol	23.22±0.04^{c}	381.25±0.3^{b}	128.50±0.71^{c}	124.06±0.08^{b}	249.32±0.02^{b}	19.10±0.00^{b}
Nblpaul	27.78±0.04^{a}	452.50±0.00^{a}	162.04±0.06^{a}	150.05±0.06^{a}	260.21±0.29^{a}	21.46±0.06^{a}
Agbagba	21.73±0.03^{e}	367.44±0.62^{c}	122.26±0.3^{d}	122.34±0.06^{b}	234.16±0.06^{c}	17.02±0.03^{c}
Atagafong	20.71±0.06^{g}	340.25±0.35^{f}	116.02±0.02^{e}	123.91±1.14^{b}	152.69±0.04^{h}	15.38±0.05^{e}
Pita 14	21.55±0.07^{f}	356.25±0.3^{d}	123.04±0.0^{d}	119.63±0.55^{b}	193.40±0.02^{e}	13.41±0.42^{g}
Nibrator	22.00±0.00^{d}	342.00±0.00^{e}	121.51±0.0^{d}	116.62±0.02^{b}	184.66±0.06^{g}	11.92±0.02^{h}
Aging	18.47±0.04^{h}	264.75±0.3^{h}	102.15±0.05^{f}	86.72±0.04^{d}	209.42±0.01^{d}	16.18±0.03^{d}
Calcutta 4	25.06±0.08^{b}	332.20±0.17^{g}	130.16±1.2^{b}	104.11±0.16^{c}	191.38±1.03^{f}	14.55±0.50^{f}

The values are mean ± SD of triplicates at 5% level of significance; mean values along a column with the same superscript are not significantly different

Table 3. Glycemic index, amylose content and gelatinization temperature of cultivars

Sample	Glycemic index (%)	Amylose content (%)	Gelatinization temp. (ºC)
Efol	51.05±0.06^{a}	40.25±0.35^{g}	68.50±0.71^{c}
Nblpaul	44.03±0.04^{d}	49.85±0.21^{e}	72.00±0.00^{b}
Agbagba	39.04±0.02^{h}	69.80±0.14^{b}	73.50±0.71^{b}
Atagafong	41.10±0.00^{f}	69.10±0.14^{b}	76.00±1.41^{a}
Pita 14	45.22±0.05^{c}	70.75±0.35^{a}	69.50±0.71^{c}
Nibrator	39.12±0.02^{g}	45.35±0.35^{f}	75.50±0.71^{a}
Aging	41.26±0.01^{e}	66.80±0.28^{c}	72.00±0.00^{b}
Calcutta 4	50.45±0.04^{b}	55.95±0.21^{d}	76.50±0.71^{a}

The values are mean ± SD of triplicates at 5% level of significance; mean values along a column with the same superscript are not significantly different

Low GI values obtained in the current study may be attributed to the type or quality of starch in the plantains, expressed by high amylose content as presented in Table 3. In consonance with our result for low GI, earlier studies have reported good food quality for high amylose with low GI [37,38]. Researchers have argued that amylose digests more slowly than amylopectin because amylose is a polymer of simple sugars with straight, unbranched chains [39]. This straight-chain amylose forms a solid bond so that it is not easily gelatinized, whereas amylopectin is highly branched, available for enzymatic digestion with the open structure [36,40] and therefore have hyperglycemic activity than food containing high amylose. In support, studies by Brand-Miller et al. [36] and Widowati et al. [37] showed that rice with higher amylose content (Doongara, 28% amylose) gave a significantly lower GI and insulin index than did the normal amylose rice cultivars (Calrose and Pelde, 20% amylose). In line with our results, Bahado-Singh et al. [38] reported green banana and green plantain as low GI foods having obtained 37 and 39 GIs respectively. A recent study assessing the effect of processing methods on the glycemic index of plantain found glycemic indices of 44, 46 and 46 GIs for unripe plantains [16] which were within the GI range obtained in this study. The dietary fibre in food plays an important role to slow glycemic response for less insulin secretion by inhibition of carbohydrate absorption. Riccardi and Rivellese also reported that soluble dietary fiber is more effective in lowering postprandial blood glucose levels compared with insoluble dietary fibre [41]. Although in this study, low fibre content was found, it may contribute to the overall characteristics of plantain carbohydrate for gradual absorption, assimilation and appearance of glucose in blood stream. The high amylose may have responsible for high gelatinization temperature for the plantain flour Table 3. The solid bond in amylose may require more time and heat to gelatinize. Low GI foods have been associated with reduced risk for metabolic and degenerative disorders. Taken together, health problems associated with dietary lifestyle and in particular with the control of blood glucose level such as type 2 DM may benefit from the consumption of unripe plantain.

4. CONCLUSION

This study have analysed nutritional compositions of eight plantain fruits commonly consumed in Nigeria. The plantains had comparable proximate compositions to what is reported in the literature except the fibre content.

The flour may find application in food industry due to low moisture content as ingredient for foods that require good shelf life. The potassium is comparatively more abundant than sodium. Salt-sensitive hypertensives with diet restrictions may have health benefit through high potassium-sodium ratio. The influence of cultivars on compositions analysed may be responsible for significant differences within the values. Amylose content was high in all, suggesting good quality of starch in the plantain cultivars. The glycemic indices classified the plantains as low GI staple food. Dietary modification for the diabetes patients, individuals with impaired glucose tolerance or people with particular concern for their diets and health may consider unripe plantain intake in meals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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