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

A. O. Oko¹, A. C. Famurewa²* and J. O. Nwaza¹

¹Department of Biotechnology, Ebonyi State University, P.M.B. 053 Abakaliki, Ebonyi State, Nigeria.
²Department of Medical Biochemistry, Faculty of Basic Medical Sciences, Federal University, Ndufu-Alike Ikwo, P.M.B. 1010, Abakaliki, Nigeria.

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.

Article Information

DOI: 10.9734/BJAST/2015/14096

Editor(s): (1) Ming-Chih Shih, Department of Health and Nutrition Science, Chinese Culture University, Taiwan.

Reviewers: (1) Anonymous, Federal University of Santa Maria, Brazil. (2) Anonymous, Instituto Politecnico Nacional, Unidad Michoacán, Mexico. (3) Anonymous, University of Nigeria, Nsukka, Nigeria.

Complete Peer review History: http://www.sciencedomain.org/review-history.php?id=766&id=5&aid=7346

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.

*Corresponding author: E-mail: clementademola@yahoo.com;
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 tons 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 acuminate 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, B1, B2, B3, B6 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 Orchard 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 HNO₃ and H₂SO₄, 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.
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 Efok 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, Shodehinnde 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 Nibror 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...
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 150.05 mg/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 diabetes 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\textsuperscript a | 2.53±0.04\textsuperscript a | 0.22±0.03\textsuperscript d | 2.05±0.07\textsuperscript d | 7.22±0.31\textsuperscript b | 69.69±0.03\textsuperscript a |
| Nblpaul    | 14.90±0.14\textsuperscript b | 2.03±0.04\textsuperscript b | 0.61±0.01\textsuperscript b | 2.50±0.14\textsuperscript b | 5.23±0.09\textsuperscript b | 74.74±0.11\textsuperscript b |
| Agbagba    | 15.30±0.14\textsuperscript d | 2.53±0.04\textsuperscript d | 0.32±0.00\textsuperscript d | 2.90±0.14\textsuperscript d | 3.22±0.22\textsuperscript d | 75.74±0.18\textsuperscript d |
| Atagafong  | 16.10±0.14\textsuperscript c | 0.55±0.07\textsuperscript d | 0.19±0.01\textsuperscript d | 4.07±0.10\textsuperscript d | 1.51±0.21\textsuperscript d | 77.58±0.54\textsuperscript d |
| Pita 14    | 16.18±0.14\textsuperscript c | 1.20±0.28\textsuperscript c | 0.44±0.03\textsuperscript c | 3.44±0.06\textsuperscript c | 7.24±0.21\textsuperscript c | 70.88±0.58\textsuperscript c |
| Nibrator   | 16.10±0.14\textsuperscript c | 1.00±0.00\textsuperscript c | 0.36±0.03\textsuperscript c | 2.66±0.08\textsuperscript c | 1.12±0.22\textsuperscript c | 78.77±0.04\textsuperscript c |
| Aging      | 11.90±0.14\textsuperscript c | 1.45±0.07\textsuperscript c | 0.51±0.01\textsuperscript d | 3.60±0.00\textsuperscript d | 7.11±0.16\textsuperscript d | 75.43±0.07\textsuperscript d |
| Calcutta 4 | 10.00±0.00\textsuperscript g | 1.55±0.07\textsuperscript c | 0.48±0.00\textsuperscript c | 3.65±0.07\textsuperscript c | 3.17±0.16\textsuperscript c | 81.18±0.11\textsuperscript c |

*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.*
the GI range obtained in this study. The dietary GIs for unripe plantains [16] which were within

respectively. A recent study assessing the effect of foods having obtained 37 and 39 GIs (Calrose and Pelde, 20% amylose). In line with index than did the no amylose) gave a significantly lower GI and insulin

with higher amylose content (Doongara, 28% amylose). In support, studies by Brand

hyperglycemia and therefore have

amylose may have responsible for high

appearance of glucose in blood stream. The high

content was found, it may contribute to the

blood glucose levels compared with insoluble

fiber is more effective in lowering postprandial

inhibition of carbohydrate absorption. Riccardi

amylose 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

fibers have been associated with reduced risk for

metabolic and degenerative disorders. Taken

together, health problems associated with diet,

lifestyle and in particular with the control of blood

glucose levels. The consumption of unripe plantain.

comparable proximate compositions to what is

reported in the literature except the fiber content.

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 | 381.25±0.3 | 128.50±0.71 | 124.06±0.08 | 249.32±0.02 | 19.10±0.00 |
| Nblpaul  | 27.78±0.04 | 452.50±0.09 | 162.04±0.06 | 150.05±0.06 | 260.21±0.29 | 21.46±0.06 |
| Aqbagba  | 21.73±0.03 | 367.44±0.62 | 122.26±0.3 | 122.34±0.06 | 234.16±0.06 | 17.02±0.03 |
| Atagafon | 20.71±0.06 | 340.25±0.35 | 116.02±0.02 | 123.91±1.14 | 152.69±0.04 | 15.38±0.05 |
| Pita 14  | 21.55±0.07 | 356.25±0.3 | 123.04±0.09 | 119.63±0.55 | 193.40±0.02 | 13.41±0.42 |
| Nibrator | 22.00±0.00 | 342.00±0.00 | 121.51±0.03 | 116.62±0.02 | 184.66±0.06 | 11.92±0.02 |
| Aging    | 18.47±0.04 | 264.75±0.3 | 102.15±0.05 | 86.72±0.04  | 209.42±0.01 | 16.18±0.03 |
| Calcutta 4 | 25.06±0.08 | 332.20±0.17 | 130.16±1.2 | 104.11±0.16 | 191.38±1.03 | 14.55±0.50 |

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         | 40.25±0.35          | 68.50±0.71               |
| Nblpaul  | 44.03±0.04         | 49.85±0.21          | 72.0±0.00                |
| Aqbagba  | 39.04±0.02         | 69.80±0.14          | 73.50±0.71               |
| Atagafon | 41.10±0.00         | 69.10±0.14          | 76.0±1.41                |
| Pita 14  | 45.22±0.05         | 70.75±0.35          | 69.50±0.71               |
| Nibrator | 39.12±0.02         | 45.35±0.35          | 75.50±0.71               |
| Aging    | 41.26±0.01         | 66.80±0.28          | 72.0±0.00                |
| Calcutta 4 | 50.45±0.04        | 55.95±0.21          | 76.50±0.71               |

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 hypoglycemic 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 foods. 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.

REFERENCES

1. Ravi I, Mustaffa MM. Starch and amylose variability in banana cultivars. Ind. J. Plant Physiol; 2013. DOI:10.1007/S40502-013-0014-2.
2. Pelissari FM, Andrade-Mahecha MM, Sobral PA, Menegalli FC. Isolation and characterization of flour and starch of plantain banana (Musa paradisiaca). Starch/Stärke. 2012;64:382-391. DOI: 10.1002/star.201100133.
3. Swennen R. Plantain cultivation under West African conditions. A reference manual, IITA, Ibadan, Nigeria. 1990:1-18.
4. Zakpaa HD, Al-Hassan A, Adubofour J. An investigation into the feasibility of production and characterization of starch from “Apantu” plantain (giant horn) grown in Ghana. African J of Food Sci. 2010;4(9):571-577.
5. Pacheco-Dalahaye E, Maldonado R, Perez E, Schroeder M. Production and characterization of unripe plantain (Musa paradisiaca L.) flours. INTERSCIENCIA. 2008;33(4):290-296.
6. Makanjuola OM, Ajayi AB, Mathew K, Makanjuola JO. The proximate composition and mineral contents of three plantain cultivars harvested at matured green level. International J of Innovation in Biosciences. 2013;3(2):23-26.
7. Odenigbo MA, Asumgha VU, Ubbor S, Nwauzor C, Otuonye AC, Offia-Olua BI, et al. Proximate composition and consumption pattern of plantain and cooking-banana. British Journal of Applied Science and Technology. 2013;3(4):1035-1043.
8. Adeolu AT, Enesi DO. Assessment of proximate, minerals, vitamin and phytochemical compositions of plantain (Musa paradisiaca) bract- an agricultural waste. Int Res J Plant Sci. 2013;4(7):192-197.
9. Falana IB. Effect of low irradiation doses and some physical treatment on the keeping quality of plantain (Musa AAB). Ph.D Thesis, Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Nigeria; 1997.
10. Ahenkora K, Kyei MA, Marfo EK, Banful B. Nutritional composition of false horn apantupa plantain during ripening and processing. Afr. Crop Sci. J. 1996;4:243-247.
11. Egbebi AO, Bademosi TA. Chemical composition of ripe and unripe banana and plantain. Int J Trop Med and Public Health. 2011;1(1):1-5.
12. Juarez-Garcia L, Agama-Acero E, Sayago-Ayerdi SG, Rodriguez-Ambriz SL, Bello-Perez LA. Composition, digestability and application in bread-making of banana flours. Plant Foods Human Nutr. 2006;61(3):131-137.
13. Baiyeri KP, Aba SC, Otitoju GT, Mbah OB. The effects of ripening and cooking methods on mineral and proximate composition of plantain (Musa sp. AAB cv. ‘Agbagba’) fruit pulp. African Journal of Biotechnol. 2011;10(36):6979-6984.
14. Shodehinde SA, Oboh G. Antioxidant properties of aqueous extract of unripe Musa paradisiaca on sodium nitroprusside-induced lipid peroxidation in rat pancreas in vitro. Asian Pac. J Trop Biomed. 2013;3(6):449-457.
15. Beha KM, Scholfield DF, Hallfrisch JG, Liljeberg-Elmstahl HG. Consumption of both resistant starch and β-Glucan improves postprandial plasma glucose and insulin in women. Diab. Care. 2006;29:976-981.
16. Ogbugu CA, Odom TC, Ndulaka JC, Ogbodo MO. Effect of various processing methods of ripe and unripe plantain diets on blood glucose level. European Journal of Biology and Medical Science Research. 2013;1(3):49-54.
17. Kouassi NK, Tiahou GG, Abodo JR, Camara-Cisse M, Amani GN. Influence of
the variety and cooking methods on glycemic index of yam. Pak J Nutr. 2009;8(7):993-999.

18. Kumar M, Gautam MK, Singh A, Goel RK. Healing effect of Musa sapientum var. paradisiaca in diabetic and co-occurring gastric ulcer: Cytokines and growth factors by PCR amplification. BMC Complementary and Alternative Medicine. 2013;13:305.

19. AOAC. Official Methods of Analysis (16th edn). Association of Official Analytical Chemists, Arlington, V.A, USA; 1995.

20. Kirk PS, Sawyer R. Fats and Oils. In: Pearson’s composition and analysis of foods. 9th edn. Longman Group Limited, UK. 1991:641.

21. Ologhobo AD, Fetuga BL. Investigation of the trypsin inhibitor, hemagglutinin, phytic and tannic acid contents of cowpea Vigna unguiculata. Food Chemistry. 1983;12(4):249-254.

22. Williams PC, Kuzina PD, Hlynka I. A rapid colorimetric procedure for estimating the amyllose content of starches and flours. Cereal Chem. 1970;47:411-421.

23. Hettiwaratchi UPK, Ekanayake S, Welihinda J. Prediction of glycemic index (GI) of meals by starch hydrolysis indices. Int. Food Research Journal. 2012;19(3):1153-1159.

24. Arisa NU, Adelekan AO, Alamu AE, Oggunfowora EJ. The effect of pretreatment of plantain (Musa paradisiaca) flour on the pasting and sensory characteristics of biscuits. Pak J Food Sci. 2013;23(1):43-51.

25. Eleazu CO, Okafor PN, Akpomari J, Awa E, Ikpeama AI, Eleazu CO. Chemical composition, antioxidant activity, functional properties and inhibitory action of unripe plantain (Musa paradisiaca) flour. African Journal of Biotechnol. 2011;10(74):16948-16952

26. Osundahunsi OF. Scanning electron microscope study and pasting properties of unripe plantain. Journal of Food, Agriculture and Environment. 2009;7(3 and 4):182-186.

27. Luzia DM, and Jorge N. Study of antioxidant activity of non-conventional Brazilian fruits. J Food Sci Technol. 2014;51(6):1167-1172.

28. Kranz S, Brauchle M, Slavin JL, Miller KB. What do we know about dietary fibre intake in children and health? The effects of fibre intake on constipation, obesity and diabetes in children. Adv. Nutr. 2012;3:47-53.

29. Eleazu CO, Okafor PN, Ikpeama A. Total antioxidant capacity, nutritional composition and inhibitory activity of unripe plantain (Musa paradisiaca) on oxidative stress in alloxan-induced diabetic rabbits. Pak. J. Nutr. 2010;9(11):1052-1057.

30. O’Donnell M, Mente A, Rangarajan S, McQueen MJ, Wang X, Liu L, et al. Urinary sodium and potassium excretion mortality, and cardiovascular events. N Engl J Med. 2014;371:612-23. DOI:10.1056/NEJMoa1311889.

31. Department of agriculture, department of health and human services. Report of the dietary guidelines advisory committee on the dietary guideline for Americans, 2010, to the secretary of agriculture and secretary of health and human services, Washington DC: Department of Agriculture, Agricultural Research Service; 2010. Available: http://www.cnpp.usda.gov/publication/dietaryguidelines/2010/dgac/report/2010dgacreport-camera-ready-ian11-11pdf

32. Adeniyi TA, Sanni LU, Barimalaa LS, Hart AD. Determination of micronutrients and colour variability among new plantain and banana hybrids flour. World J Chem. 2006;1(1):23-27.

33. Wolever TM, Brand-Miller JC, Abernethy J, Astrup A, Atkinson F, Axelsen M, et al. Measuring the glycemic index of foods: Interlaboratory study. Am J Clin Nutr. 2008;87(suppl):247S-57S.

34. Brand-Miller J, Wolever TMS, Foster-Powell K, Colagiuri S. The new glucose revolution: The authoritative guide to the GI. Marlowe and Company, New York; 2003.

35. Heath R, Gilbertson GDD, Miller JB, Thorburn AW, Evans S, Chodros P, Werther GA. The effect of flexible low glycemic index dietary advice versus measured carbohydrate exchange diets on glycemic control in children with type 1 diabetes. Diab. Care. 2001;24:1137-1143.

36. Brand-Miller JB, Fang E, Bramall L. Rice: A high or low glycemic index food? Am J Clin Nutr. 1992;56:1034-1036.

37. Widowati S, Santosa BAS, Budyanto D. Karakterisasi mutu dan indeks glikemik beras bera milosa rendah dan tinggi. Hlm. Prosiding seminar apresiasi hasil penelitian padi menunjang P2BN. Balai
38. Bahado-Singh PS, Wheatley AO, Ahmad MH, Morrison EY, Asemota HN. Food processing methods influence the glycemic indices of some commonly eaten West Indian carbohydrate-rich foods. Br J Nutr. 2006;96(3):476-481. DOI:10.1079/BJN20061792.

39. Widowati S, Susila Santosa BA, Astawan M, Akhyar. Reducing glycemic index of some rice varieties using parboiling process. Indones J. Agric. 2010;3(2):104-111.

40. Foster-Powell KF, Holt SHA, Brand-Miller JC. International table of glycemic index and been worth glycemic load. Am J Clin Nutr. 2002;76:5-56.

41. Riccardi G, Rivellese AA. Effect of dietary fibre and carbohydrate on glucose and lipoprotein metabolism in diabetic patients. Diab. Care. 1991;14(12):1115-1125.