Nutritional composition of five new Nigerian *Musa* hybrid cultivars: implications for adoption in human nutrition

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Abstract — Introduction. A study was carried out to investigate the proximate and mineral composition of plantain and banana fruits of new hybrids selected in Nigeria, compared with those of a local cultivar, Agbagba. Our aim was to assess their nutritional value and to enhance the adoption and utilization potential of these new selected hybrids. **Materials and methods**. Five new *Musa* hybrids developed at the IITA, Nigeria, were investigated. Proximate values of fat, carbohydrate and protein of the samples were determined and the energy content of each sample was calculated. Fruit mineral analysis was performed for each cultivar studied. The data were statistically analyzed. **Results and discussion**. All the new hybrids were higher than the local cultivar Agbagba in protein and crude fiber content. Conversely, Agbagba fruit had the highest level of carbohydrate. A significant difference was observed between the PITA 14 hybrid and the rest of the cultivars in total energy and fat content. Both the BITA 3 and PITA 26 hybrids contained the highest levels of ash. The PITA 17 hybrid contained the highest moisture. The PITA 14 and PITA 24 hybrids were different from all other cultivars in phosphorus and copper contents. The calcium concentration in the PITA 14 and PITA 17 hybrids differed regarding the rest of the cultivars assessed. Also, the levels of potassium and manganese found in all the hybrids were different from those obtained in Agbagba, while the latter differed from all the hybrids in magnesium and sodium levels. **Conclusion**. The new *Musa* hybrids assessed are superior to the Agbagba plantain in nutritional value, which could enhance the adoption and utilization potential of these new hybrids by the local population.

Nigeria / *Musa* (plantains) / *Musa* (bananas) / fruits / hybrids / proximate composition / chemical composition / mineral content / nutritive value / energy value

Composition alimentaire de cinq nouveaux cultivars hybrides nigérians de *Musa* : implications pour leur adoption dans la nutrition humaine.

Résumé — Introduction. La composition globale et minérale de nouveaux hybrides de bananes et plantains sélectionnés au Nigéria a été étudiée et comparée à celle des fruits d'un cultivar local, Agbagba. Notre but a été d'évaluer leur valeur nutritive et de mettre en valeur le potentiel d'adoption et d'utilisation de ces nouveaux hybrides sélectionnés. **Matériel et méthodes**. Cinq nouveaux hybrides de *Musa* développés par l'IITA, Nigéria, ont été étudiés. Des teneurs globales en matières grasses, hydrates de carbone et protéines des échantillons ont été déterminées et la valeur énergétique de chaque échantillon a été calculée. L'analyse minérale des fruits a été effectuée pour chaque cultivar étudié. Les données ont été analysées statistiquement. **Résultats et discussion.** Tous les nouveaux hybrides se sont révélés supérieurs au cultivar local Agbagba quant au contenu en protéines et en fibres brutes. Réciproquement, le fruit d'Agbagba a eu la plus haute teneur en hydrates de carbone. Une différence significative est apparue entre l'hybride PITA 14 et le reste des cultivars pour ce qui est de la valeur énergétique totale et de la teneur en matières grasses. Les hybrides BITA 3 et PITA 26 ont présenté les teneurs les plus élevées en cendres. L'hybride PITA 17 a présenté la teneur en humidité la plus élevée. Les hybrides PITA 4 et PITA 24 ont été différents de tous les autres cultivars quant à leurs teneurs en phosphore et en cuivre. La concentration en calcium de PITA 14 et PITA 17 a différé de celle des autres cultivars. En outre, les teneurs en potassium et en manganèse trouvés pour tous les hybrides ont été différents de celles obtenues pour Agbagba, alors que ce dernier s'est démarqué par ses taux en magnésium et en sodium. **Conclusion**. La valeur nutritive des nouveaux hybrides de *Musa* évalués se révèle supérieure à celle du plantain Agbagba, ce qui met en évidence un potentiel d'adoption et d'utilisation de ces nouveaux hybrides par les agriculteurs nigérians.

Nigéria / *Musa* (plantains) / *Musa* (bananes) / fruits / hybride / composition globale / composition chimique / teneur en éléments minéraux / valeur nutritive / valeur énergétique

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1. Introduction

Plantain and banana (*Musa* spp.) are major food crops in the humid and sub-humid parts of Africa and a major source of energy for millions of people in these regions [1]. They provide not only a rich source of dietary energy [2], but also contribute to providing a good quality diet and rural income [3]. Their adaptation to the food and farming systems and multiplicity of uses make them indispensable to food security. The International Institute of Tropical Agriculture (IITA) has developed several cultivars of plantain and banana, which are disease- and pest-resistant, and high-yielding combined with good post-harvest qualities. Promising *Musa* hybrids are currently being disseminated to the farmers in Nigeria, and many parts of West and Central Africa (WCA) and East and Southern Africa (ESA), aimed at improving the livelihood of farmers and generating raw materials for industries.

Plantain is traditionally grown for cooking as part of a staple diet, or for processing into more durable products such as flour that can be stored for later use [4, 5]. Dessert banana is usually eaten raw when ripe and it is the most popular fruit worldwide in terms of export [6]. The physico-chemical and proximate composition of plantain and banana has been widely documented [7–10]. Baiyeri and Unadike [10–12] have also investigated the mineral concentration in plantain and banana, including micronutrients. Earlier, Ketiku [13] investigated the chemical composition of unripe plantain, including carbohydrate constituents and amino acid profile, while Samuel *et al.* [14] examined the effect of soil amendment practices on the post-harvest quality of a cooking banana hybrid, BITA 3.

Composite flours from plantain, cassava, soybeans and other indigenous crops have been exploited in baking [15–18], as well as snacks and complementary food formulations [19, 20]. Plantain flour is an essential traditional food in the Western part of Nigeria, where it is usually mixed with an appropriate quantity of boiling water to make thick dough and eaten with vegetable soup [21]. The introgression of genes of bananas used in obtaining the new hybrids may alter fruit quality characteristics, which may in turn affect their nutritional composition. Our study was therefore carried out to investigate the proximate and mineral composition of new plantain and banana hybrid fruits to enhance adoption and explore their processing and utilization potential.

2. Materials and methods

2.1. Collection of samples

Five new *Musa* hybrids developed at the IITA, Nigeria, named either PITA (Plantain International Institute of Tropical Agriculture) or BITA (Banana International Institute of Tropical Agriculture) were investigated. The cultivars included four plantain hybrids (PITA 14, PITA 17, PITA 24 and PITA 26) and one cooking banana hybrid (BITA 3), with an African plantain landrace, Agbagba, as reference. Plantain and banana samples were obtained from the experimental station of the IITA, High Rainfall Station, Onne agroecology, located at lat. 04° 43' N, long. 07° 01' E and 10 m alt., near Port Harcourt, Nigeria. Representative fruit samples were obtained from hand number 2 from the proximal end of the bunch, as recommended by Baiyeri and Ortiz [22].

2.2. Preparation of samples

The samples were peeled manually with the aid of a stainless steel kitchen knife and pulps were sliced and placed in Petri dishes and covered with filter paper to avoid contamination. Samples were dried in a Forced-Air Sanyo Gallenkamp Moisture Extraction Oven at 65 °C for about 48 h and milled with the aid of a stainless steel Kenwood Chef Warring Blender, Model KM001 series.

2.3. Analytical procedures

Proximate chemical composition was determined using AOAC [23] procedures. The energy content of the sample (kJ·100 g^{-1}) was computed from the proximate data

using the Atwater formula [24]. The sources of energy are fat, carbohydrate and protein, which supplied (9, 4, and 4) kcal·g^{-1}, respectively. For each sample, the values of fat, carbohydrate and protein were multiplied by the appropriate factor. These values were then added together, which represents the energy content of each sample. Mineral analysis was performed using the procedure described by Allen *et al.* [25]. All mineral elements investigated were determined spectrophotometrically on the Buck Scientific Atomic Absorption/Emission Spectrophotometer 205 in the Plant Anatomy and Physiology Research Laboratory, Faculty of Science, University of Port Harcourt Herbarium, Port Harcourt, Nigeria.

2.4. Data analyses

The data generated were analyzed using the Statistical Analysis Systems [26] software package. Significance of treatment means was tested at the 5% probability level using Duncan's New Multiple Range Test (DNMRT).

3. Results and discussion

3.1. Proximate composition

The results for the proximate composition of the new plantain and banana hybrids showed that the moisture content of the flour ranged from 1.5–6.75% (*table I*), which was much less than the 8% [27] obtained in some black Sigatoka-resistant plantain and banana hybrids. PITA 17 was significantly different ($p < 0.05$) from all other cultivars in moisture content. The keeping quality of plantain and banana flour is greatly influenced by its moisture content. Edelmiro *et al.* [28] and Ogazi and Jones [29] reported that 10% moisture content in flour is ideal for good keeping quality. The moisture content obtained in our research suggests that flour produced from new plantain and banana hybrids may keep longer. Carbohydrate was highest in the plantain landrace, Agbagba (82.9%), which differed significantly ($p < 0.05$) from all other cultivars. Healthy, moderately active adult males and females require at least 100 g of carbohydrate·day^{-1} [30] to sustain normal brain metabolism and muscle function [31], and the carbohydrate should represent at least 50% of energy intake. Our data shows that *Musa* hybrids satisfy this requirement.

The rate at which carbohydrate is digested and released into the bloodstream is influenced by many factors, such as the food's physical form, its fat, protein and fiber content, and the chemical structure of its carbohydrate [32]. This suggests that different carbohydrates do not have the same effects on blood glucose (sugar) levels after consumption. Consequently, the glycaemic index method was developed in order to rank equal carbohydrate portions of different foods according to the extent to which they increase glucose levels after being eaten [33]. The glycaemic index (GI) is an important parameter of food quality, which compares the hyperglycaemic effect of a tested meal with pure glucose [34]. Carbohydrates that break down quickly during digestion have a high GI because their B-glucose response is fast and high. Such foods have a large rise and fall in the level of blood glucose. Carbohydrates that break down slowly have a low GI, which produces a gradual, relatively low rise in the level of blood glucose [35]. Glycaemic index values are also used in scientific research to examine the relationship between the glycaemic impact of diets and the risk of certain diseases. Epidemiological studies have shown that the long-term consumption of a diet with a high glycaemic impact, which induces high and recurrent surges in blood glucose levels, increases the risk of diabetes, heart disease and certain cancers [36, 37]. In contrast, both epidemiological and experimental studies revealed that diets based on low-GI foods reduce the risk of these diseases, improve blood glucose control in diabetic patients, reduce high blood fat levels, and can be useful for weight control [36]. The glycaemic index of banana is 55, which suggests that banana fruit is a low-GI food [38, 39]. Tsai *et al.* [40] reported that diets with a high glycaemic response exacerbate

Table I.
Chemical composition and energy content assessed in fruits of five improved plantain and banana IITA hybrids (BITA 3, PITA 14, PITA 17, PITA 24 and PITA 26) compared with those of a local cultivar, Agbagba, in Nigeria.

Cultivar	Moisture content	Protein	Carbohydrate	Fat	Crude fiber	Ash	Total energy content
			(%)				kJ·100 g^{-1}
BITA 3	1.50 e	3.94 a	80.6 b	2.80 b	7.05 b	4.15 a	363.4 c
PITA 14	4.45 d	3.94 a	79.9 b	4.20 a	5.92 c	1.50 c	373.2 a
PITA 17	6.75 a	3.94 a	75.8 c	2.43 c	7.81 a	3.25 b	340.8 e
PITA 24	5.00 c	3.94 a	76.5 c	1.47 d	5.28 d	1.47 c	335.0 f
PITA 26	5.90 b	3.94 a	76.5 c	2.90 b	6.99 b	3.80 a	347.9 d
Agbagba	6.00 b	3.06 b	82.9 a	2.80 b	2.26 e	2.95 b	369.0 b
Mean	4.93	3.79	78.7	2.77	5.89	2.85	354.9

Values in the same column with different letters are significantly different at $p < 0.05$.

the metabolic consequences of the insulin resistance syndrome, and suggest that a high intake of carbohydrate, glycaemic load and glycaemic index increases the risk of symptomatic gall stone disease in men. It is anticipated that increased consumption of new plantain and banana hybrids may help to circumvent these health problems associated with high-GI foods.

The protein contents of the hybrids were generally low, with the hybrids having 3.94% each (*table I*), and this value was significantly different ($p < 0.05$) from the 3.06% obtained in Agbagba. These lower levels may be due to precipitation of proteins by complexing with polyphenols and tannins [41]. The fat (4.2%) and crude fiber (7.81%) found in PITA 14 and PITA 17, respectively (*table I*), were significantly ($p < 0.05$) higher than those in other cultivars. The high level of crude fiber obtained in our study suggests that plantain hybrids could provide a considerable amount of roughage in the human diet. The cooking banana hybrid BITA 3 and a plantain hybrid, PITA 26, differed significantly ($p < 0.05$) from other cultivars in ash. Similar reports on proximate chemical composition in green plantain have been documented [8, 10, 11]. This new data demonstrates that improved *Musa* hybrids could provide a substitute for plantain landraces. Interestingly, one of the plantain hybrids, PITA 14, topped the table of total energy value with 373.2 kJ·100 g^{-1} (*table I*), which was significantly different from other cultivars and suggests that the new varieties may constitute important raw materials in high-energy food formulation. Platt [42] reported that, at the ripe or unripe stage, the total energy content of plantain is about 128 kcal·100 g^{-1} edible portion. Adeniji and Empere [16] reported 360.4 kJ·100 g^{-1} in cakes developed from 100% flour of Cardaba, a variety of cooking banana.

3.2. Mineral concentration

The data of the mineral profile of the new plantain and banana hybrids showed that potassium and manganese contents of all the hybrids evaluated differed significantly ($p < 0.05$) from the local control (Agbagba), while Agbagba differed significantly ($p < 0.05$) from all the hybrids in magnesium and sodium (*table II*). The results also showed that PITA 14 and PITA 24 are significantly different ($p < 0.05$) from the rest of the cultivars in phosphorus content. PITA 14 and PITA 17 differed significantly ($p < 0.05$) from all other cultivars in calcium concentration. The physiological role of minerals is well documented [43–45]. PITA 14 and PITA 17 had 600 µg Ca·g^{-1} each; this is consistent with the 661 µg Ca·g^{-1} obtained in green plantain [12]. PITA 14 and PITA 24 had

Table II.
Mineral composition of fruits for five improved plantain and banana IITA hybrids (PITA 3, PITA 14, PITA 17, PITA 24 and PITA 26) compared with that of a local cultivar, Agbagba, in Nigeria.

Cultivar	Ca	Mg	K	P	Na	Mn	Cu
				($\mu g \cdot g^{-1}$)			
BITA 3	300 b	600 d	10.300 b	1000 b	46.71 e	16.3 b	2.3 b
PITA 14	600 a	700 c	10.600 a	1100 a	50.47 c	16.2 b	2.7 b
PITA 17	600 a	800 b	10.700 a	1000 b	46.88 d	16.1 b	2.3 b
PITA 24	300 b	800 b	10.400 b	1100 a	46.61 e	18.0 a	3.4 a
PITA 26	300 b	600 d	8.500 c	900 c	54.21 b	14.6 c	2.27 c
Agbagba	200 c	1000 a	8.100 d	1000 b	90.19 a	9.6 d	2.2 c
Mean	383.3	750	9766.7	1016.7	55.8	15.1	2.5

Values in the same column with different letters are significantly different at $p < 0.05$.

1,100 µg $P \cdot g^{-1}$ each, which is higher than the 505.21 µg $P \cdot g^{-1}$ earlier reported in plantain [46]. The daily requirement of phosphorus for an adult male (67–70 kg body weight) and female (58 kg body weight) is 800 mg [47]. Two of the new hybrids investigated, PITA 14 and PITA 24, can provide approximately 70% of this requirement, if 500 g of flour is consumed. The magnesium content of Agbagba (1000 $\mu g \cdot g^{-1}$) is higher than the 845 $\mu g \cdot g^{-1}$ reported in False Horn *Apantu pa* plantain [11] in Ghana. Two of the plantain hybrids, PITA 17 and PITA 24, are also high (800 $\mu g \cdot g^{-1}$) in magnesium. The Food and Nutrition Board of the National Research Council (NRC) [47] reported that an adult male and female require 350 mg and 300 mg of Mg daily, respectively. Our data suggests that 350 g of flour from PITA 17 and PITA 24 can provide at least 100% of the daily requirement of magnesium for these categories of people. As expected, the new hybrids had very high levels of potassium, with PITA 14 having the highest value of 10,600 µg $K \cdot g^{-1}$. Conversely, the new hybrids are low in sodium, ranging from 46.61 µg $Na \cdot g^{-1}$ in PITA 24 to 90.19 µg $Na \cdot g^{-1}$ in Agbagba. The potassium and sodium contents obtained are good features for the hybrids in dietary terms. The new hybrids are low in sodium when compared with the 340 µg $Na \cdot g^{-1}$ and 112.52 µg $Na \cdot g^{-1}$ reported in green unripe plantain pulp by Omuaru and Izonfuo [12] and Baiyeri [45], respectively. Omuaru and Izonfuo [12] and Baiyeri [45] reported 8,400 µg $K \cdot g^{-1}$ and 6500 µg $K \cdot g^{-1}$ in plantain pulp at the unripe stage. The new hybrids may be recommended for low sodium diets, while the protective effect of high potassium against excessive sodium intake may be advantageous [48]. Manganese was highest (18 µg $Mn \cdot g^{-1}$) in PITA 24, while Agbagba contained the lowest (9.6 µg $Mn \cdot g^{-1}$). PITA 14 had the highest level (2.7 µg $Cu \cdot g^{-1}$) of copper, while the lowest (2.2 µg $Cu \cdot g^{-1}$) was found in Agbagba. The new hybrid copper contents are low compared with the 30 µg $Cu \cdot g^{-1}$ and 10 µg $Cu \cdot g^{-1}$ reported in unripe plantain pulps by Ahenkora *et al.* [11] and Omuaru and Izonfuo [12], respectively. Interestingly, PITA 14 was adjudged the best hybrid, based on farmers' perception from 11 states where the new hybrids and their post-harvest components are currently being disseminated. Our data revealed that PITA 14 could contribute a higher level of nutrients in the human diet. New hybrids may therefore constitute important raw materials in food product development with improved levels of nutrients (*tables I, II*).

4. Conclusion

Our data show that new plantain and banana hybrids could provide a better substitute for the plantain landrace in terms of

their nutritional composition. The application of new *Musa* hybrids in food product development may help consumers to select foods that will reduce the overall glycaemic impact (GI) of their diet [35]. Food manufacturers are therefore encouraged in the use of new plantain and banana in product development, resulting in low-GI products to assist with prevention and treatment of diseases associated with high-GI foods. The implementation of a low-GI diet will require an extended list of low-GI foods to be available on the market, as a shortage of low-GI foods has been reported [49]. Increased utilization of new plantain and banana hybrids is therefore strongly recommended based on their nutritional composition.

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Composición alimenticia de cinco nuevos híbridos nigerianos de *Musa*: implicaciones para su adopción en la nutrición humana.

Resumen — Introducción. Se llevó a cabo un estudio para estudiar la composición global y mineral de nuevos híbridos de bananos y plátanos seleccionados en Nigeria, comparado con el de los frutos de un cultivar local, Agbagba. Nuestro objetivo fue aportar una estimación de su valor nutritivo y valorizar el potencial tanto de adopción como de uso de estos nuevos híbridos seleccionados. **Material y métodos**. Se estudiaron cinco nuevos híbridos de *Musa* desarrollados por IITA, Nigeria. Se determinaron las muestras de los contenidos globales en materias grasas, hidratos de carbono y proteínas; y, se calculó el valor energético de cada muestra. Se efectuó el análisis mineral de los frutos para cada cultivar estudiado. Estos datos se analizaron estadísticamente. **Resultados y discusión**. Cada nuevo híbrido era superior y estadísticamente diferente del Agbagba en cuanto al contenido en proteínas y en fibras brutas. Recíprocamente, el fruto Agbagba tuvo el contenido en hidratos de carbono más elevado. Apareció una diferencia significativa entre el híbrido PITA 14 y el resto de los cultivares en relación al valor energético total y al contenido en materias grasas. Los híbridos BITA 3 y PITA 26 presentaron contenidos más elevados en cenizas. El híbrido PITA 17 presentó un contenido en humedad más elevado que el del resto de los cultivares. Los híbridos PITA 4 y PITA 24 eran diferentes del resto de los cultivares en cuanto a sus contenidos en fósforo y en cobre. La concentración en calcio en los híbridos PITA 14 y PITA 17 difirió de modo significante de la del resto de los cultivares evaluados. Además, los contenidos en potasio y en magnesio encontrados para todos los híbridos fueron diferentes de aquellos obtenidos para Agbagba, mientras que este último difirió de todos los híbridos por su contenido en magnesio y en sodio. **Conclusión**. El valor nutritivo de los nuevos híbridos de *Musa* evaluados resulta ser superior al del plátano Agbagba, lo que pone de manifiesto un potencial tanto de adopción como de uso de estos nuevos híbridos por parte de los agricultores nigerianos.

Nigeria / *Musa* (plátanos) / *Musa* (bananos) / frutas / híbridos / composición aproximada / composición quimica / contenido mineral / valor nutritivo / valor energético