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Bio accessibility of minerals in some plantain and banana hybrids grown in Nigeria

*** Kiin-Kabari DB, Agoha A**
Department of Food Science and Technology, Rivers State University of Science and Technology, Port Harcourt, Nigeria

Abstract
The mineral compositions, digested mineral and percentage soluble minerals were investigated in three banana hybrids (FHIA 34, FHIA 21 and FHIA 17) and three plantain cultivars grown in Nigeria (Ogoni red, Two-fingers and Agbagba). The total mineral composition of the three plantain and banana hybrids evaluated showed that iron, potassium, zinc and sodium contents of FHIA 17 differed significantly (P<0.05) from the local agbagba and all other hybrids. All the hybrids differed significantly (P<0.05) in calcium composition from each other, with Ogoni red given the highest calcium content of 448.19mg/g. FHIA 17 and Two-fingers with iron and sodium content of 29.19mg/g; 27.31mg/g and 496.34mg/g; 363.57mg/g, respectively, were significantly (P<0.05) higher than the rest of the hybrids. The percentage soluble minerals in the hybrids showed that all minerals differed significantly (P<0.05) in solubility, with calcium (95.17%) in agbagba and magnesium (32.57%) in Two-fingers as the highest and least soluble minerals, respectively. The results showed that the local plantain and banana hybrids could serve as better replacement for other high calorie foods in terms of their nutritional composition. The use of local hybrids in food product development as supplements or even full meals may help consumers to select foods that will moderate the overall dietary impact.

Keywords: minerals, bio accessibility, plantain, banana, hybrids

1. Introduction

Banana (*Musa acuminata*) and plantain (*Musa paradisiaca*) are the world's biggest herbs, grown abundantly in many developing countries. The plant family Musaceae, composed of banana, plantain, and ornamental bananas, originally evolved in south-east Asia and surrounding tropical and subtropical regions including New Guinea (Scot *et al.,* 2006) [22]. The plants are stenothermic, cultivated in hot and wet regions, and bear fruits all year round, though, the major harvest comes in the dry season (November to February) when most other starchy staples are unavailable or difficult to harvest, thus playing a key role in providing food security in food-scarce months (Akinyemi *et al.,* 2010) [3]. In Nigeria, plantain and banana production is concentrated in the southern regions, the highest production levels are in the states of Akwa-Ibom, Anambra, Abia, Benue, cross Rivers, Imo, Enugu, Rivers, Edo, Delta, plateau, Lagos, Kogi, Osun, Ogun, and Oyo (Ekunwe and Ajayi, 2010) [9]. Plantain and cooking banana (*Musa spp*.) is cultivated mainly as a carbohydrate staple in many developing countries, especially in Africa (IITA, 2010). The distinction between banana and plantain is a source of some confusion, both in agricultural research and in the popular imagination. All bananas and plantains belong to the same genus, *Musa*, which contains 30-40 species (Stover and Simmonds, 1987) [23]. The FAO and the International Institute of Tropical Agriculture (IITA), among other research centres, use the word "banana" to refer to Musa species that are sweeter and eaten raw, such as FHIA 34, FHIA 21 and FHIA 17 and "plantain" to denote *Musa* species that are starchier and cooked before eating, such as Agbagba, Ogoni red and two fingers (IITA, 2012) [15]. Banana and plantain are rich in minerals such as calcium, iron, copper, magnesium, phosphorus, zinc, potassium, and sodium (Baiyeri and Ajayi, 2000; Adeniji *et al.,* 2006) [5, 2]. However, information on the bio availability of these minerals is scarce. This study was therefore aimed at determining the mineral content of three banana hybrids and three plantain hybrids and to ascertain the bio-accessibility of these minerals using the in-vitro digestion method, so as to provide information on the percentage soluble fraction available for absorption.

2. Materials and Methods

Fresh plantain (Agbagba, Ogoni red, two fingers) and banana hybrids fruits (FHIA 34, FHIA 17, FHIA 21) used in this work were obtained from the Rivers State Agricultural Development Programme (RS ADP) research farm, Rumuokoro, Port Harcourt, Nigeria. The collected fruits were thoroughly washed and wet peeled, then sliced and oven dried at 65±10^{0}C for 24h. The dried chips were milled into powder using NAKAI (MXJ210PN) electric grinder, then packaged in a clean and air tight container. Mineral analysis was done by dry ashing according to procedure 14.013 of AOAC (2012). Muffle furnace (Model SKL, China) at temperature of 550^{0}C was used for ashing. After sample preparation, total mineral determination was done using Atomic Absorption spectrophotometer (AAS) (Hitachi Z-5300, polarized Zeaman, Hitachi Ltd, Japan). The light source was Hollow cathode lamp of each element, using acetylene and air combinations, with air pressure of 0.3Mpa, and air flow rate of 6.5L/min, acetylene pressure of 0.09Mpa and a flow rate of 1.7 L/min was used.

2.1. Mineral bio-accessibility using *in-vitro* enzyme digestion

The samples were subjected to in-vitro enzymatic digestion with pepsin plus pancreatin according to the method described by Ikeda (1990) [16]. Enzyme solution containing 16 mg pepsin (cat No. P6887) and 3.5ml of 0.06N Hcl, 1.0g sodium chloride made up to 100 ml with deionised water was prepared. Another solution containing 1.6 g of pancreatin, (cat No. P1750) dissolved in phosphate buffer (pH 7.5) and made up to 100ml with same buffer was also prepared. In a test tube, 20ml of pepsin enzyme solution was added to 0.5g of the sample. The closed test-tube was shakened and incubated at 37^0C for 3h. Immediately after peptic digestion, pH was adjusted to 8.0 using phosphate buffer. Toluene was added to the buffer to prevent the growth of microorganisms. Pancreatin solution (25ml) with deoxycholate (1.0%) was then added to the digestion mixtures and samples were subsequently incubated for 20h at 37^0C. After digestion, the suspensions were placed in ice-cold vessel and then clarified by centrifugations at 10,000rpm for 20min. The supernatants obtained were subjected to mineral analysis using atomic absorption spectrophotometer (AAS). The percentage soluble fraction was calculated from the total mineral content and the mineral content after digestion. The data obtained were analysed using analysis of variance (ANOVA) with SPSS 16.0 software version 2007.

3. Results and Discussion

3.1 Total Mineral Composition

The total mineral dry weight composition of the three banana and plantain hybrids are shown in Table 1. The highest total sodium (496.34mg/100g), potassium (1925mg/100g), iron (29.19mg/100g) and zinc (0.93mg/100g) were recorded by FHIA 17 banana hybrid and least total sodium (121.67mg/100g) in FHIA 21 banana hybrid. Ogoni red gave the highest amount of calcium (448.19mg/100g). All the hybrids differed significantly (P<0.05) in calcium composition. FHIA 17 and two fingers showed significant higher iron and sodium composition from the rest of the hybrids. FHIA 21 and two fingers had 1650mg/100g and 1655mg/100g of potassium; this is in line with the result obtained in green plantain by Omaruo and Izonfou (1988) [22]. The physiological role of minerals as essential micronutrients is well documented (Ihekoronye and Ngoddy, 1985; Omigbinde, 2001) [14, 21]. Minerals make up the micronutrients that are very necessary for physiological and biochemical processes by which the human body takes in and utilizes food to maintain health and activity (Mohapatra *et al.*, 2009; Davies and Jamabo, 2016) [19, 8]. Micro minerals play a very vital role in the body such as iron needed for red blood cell production, zinc for healthy skin, reproductive and immune function, magnesium for nervous system health and calcium for strong healthy bones and teeth (Möttönen and Uhari, 1997) [18]. Iron plays an essential role in the respiratory pigments haemoglobin and myoglobin while calcium is firmly linked to many of the roles that vitamin D plays in the body (Bresgen *et al.*, 2010) [6]. Sodium is a vital mineral that act as the main monovalent ion of extracellular fluids constituting 93% of the ions (bases) found in the blood stream (Underwood and Suttle, 1999) [24] and helps prevention of muscular cramp (Foskett and Paskins, 2011) [12].

Table 1: Total Mineral Compositions (mg/100g) of Three Banana Hybrids and Three Plantain Hybrids

Samples	Ca	Na	K	Mg	Fe	Zn
A	257.23^d	496.34^a	1925.89^a	140.89^b	29.19^a	0.93^a
B	165.70^e	121.67^f	1650.28^c	116.65^f	8.13^d	0.71^b
C	285.64^c	309.93^c	1407.89^d	119.55^e	20.88^b	0.36^e
D	448.19^a	143.19^d	741.42^e	150.53^a	7.50^e	0.41^d
E	326.67^b	363.57^b	1655.02^b	138.83^c	27.31^a	0.41^d
F	136.88^f	131.93^e	1163.74^c	129.47^d	9.56^c	0.55^c

$^{a-f}$ Means with the same superscript in the same column are not significantly different (P>0.05)
Key: A=FHIA 17; B=FHIA 21; C=FHIA 34; D=Ogoni red; E=Two fingers; F=Agbagba; Ca=Calcium; Fe=iron; K=Potassium; Mg=Magnesium; Zn=Zinc; Na= Sodium

3.2 Soluble Minerals

The digested mineral compositions (mg/100g) of three banana and plantain hybrids are shown in Table 2. Ogoni red gave the highest digestible calcium (334.52mg/100g). FHIA 17 recorded the highest amount of sodium (272.27mg/100g), followed by Two fingers (266.95mg/100g) and FHIA 34 (188.67mg/100g). Potassium and iron (1161.01mg/100g and 13.42mg/100g) were higher in FHIA 17. The result showed significant difference (P<0.05) in iron, calcium, potassium, magnesium and sodium in all the hybrids. However, there was no significant difference (P>0.05) observed between Two fingers and FHIA 34 in zinc and calcium contents, this is consistent with the report of Adeniji *et al.*, [2].

Table 2: Soluble Fraction (Minerals) after In-vitro Digestion of Plantain and Banana Hybrids with Pepsin and Pancreatin (mg/100g)

Samples	Ca	Na	K	Mg	Fe	Zn
A	213.01^c	272.27^a	1161.02^b	102.60^c	13.42^a	0.39^b
B	147.08^e	68.97^f	1331.71^a	74.48^d	3.29^f	0.48^a
C	209.98^d	188.67^c	1150.76^c	108.68^b	10.85^b	0.31^f
D	334.52^a	122.55^d	770.51^e	45.22^f	4.34^d	0.36^d
E	305.27^b	266.95^b	969.13^d	63.84^e	9.62^c	0.31^f
F	130.28^f	115.52^e	481.65^f	120.84^a	3.35^e	0.38^c

$^{a-f}$ Means with the same superscript in the same column are not significantly different (P>0.05)
Key: A=FHIA 17; B=FHIA 21; C=FHIA 34; D=Ogoni red; E=Two fingers; F=Agbagba; Ca=Calcium; Fe=iron; K=Potassium; Mg=Magnesium; Zn=Zinc; Na= Sodium

3.3 Percentage Bioavailable Minerals

The percentage bioavailable minerals are presented in Table 3. Calcium showed a range from 73.51% to 95.59%, with sample F (Agbagba) as the highest. These values were higher than 37.4% bioavailable calcium noted in "amala" formulated with 100% plantain flour, and 40.9% bioavailable calcium in cookies formulated with 85% plantain flour and 15% Bambara groundnut protein concentrate, as reported by earlier researchers (Kiin-Kabari *et al.*, 2015) [17]. Difference in calcium bioavailability was probably due to product formulation and processing methods (Kiin-Kabari *et al.*, 2015) [17]. Ogoni red plantain cultivar gave the highest bioavailable sodium (92.89%) and iron (57.86%), while FHIA 17 and agbagba recorded the least bioavailable sodium (54.85%) and iron (35.04%), respectively. Sample C (FHIA 34) was highest in potassium (81.57%), magnesium (90.90%), and zinc (86.11%). The relative high percentage of the hybrids in calcium and magnesium as much as 80 – 95% validates it in line with the food and Nutrition Board of the National Research Council (NRC) recommendation for an adult male and female's daily requirements. Calcium is important in blood clotting, muscles contraction and in certain enzymes in metabolic processes (Abulude *et al*., 2006) [1] and also essential for bone formulation and teeth development in children (Kiin-Kabari *et al.,* 2015) [17]. Magnesium is an essential micronutrient needed for nervous system health (Möttönen and Uhari, 1997) [18]. Mineral solubility has been widely employed in literature to predict mineral availability (Wolters *et al.,* 1993; Hemalatha *et al.,* 2007) [25, 13]. Bioavailability of minerals is affected by the presence of some natural chelating agents on the solubility of mineral elements (Ekholm *et al.*, 2003) [10]. Availability could be enhanced with processing methods that reduces the effect of phytic acid (PA), which binds metals such as ca, zn and fe, and thus increasing the bioavailability of such minerals (Chaoui *et al.*, 2003; Eltayeb *et al.*, 2007) [7, 11].

Table 3: Percentage (%) Bioavailable Mineral in Banana and three Plantain Hybrids

Samples	Ca	Na	K	Mg	Fe	Zn
A	82.81^{d}	54.85^{f}	60.28^{e}	72.82^{c}	45.97^{c}	41.93^{f}
B	88.76^{c}	56.68^{e}	80.69^{b}	63.84^{d}	40.46^{d}	67.60^{e}
C	73.51^{f}	60.87^{d}	81.74^{a}	90.90^{a}	51.96^{b}	86.11^{b}
D	74.63^{e}	92.89^{a}	66.20^{c}	42.41^{f}	57.86^{a}	87.80^{a}
E	93.44^{b}	73.42^{c}	58.55^{f}	32.57^{e}	35.22^{e}	75.60^{c}
F	95.59^{a}	80.50^{b}	64.96^{d}	93.33^{b}	35.04^{f}	69.09^{d}

$^{a-f}$ Means with the same superscript in the same column are not significantly different (P>0.05)

Key: A=FHIA 17; B=FHIA 21; C=FHIA 34; D=Ogoni red; E=Two fingers; F=Agbagba; Ca=Calcium; Fe=iron; K=Potassium; Mg=Magnesium; Zn=Zinc; Na= Sodium

4. Conclusion

The highest total sodium (496.34mg/100g), potassium (1925mg/100g), iron (29.19mg/100g) and zinc (0.93mg/100g) were recorded by FHIA 17 banana hybrid and least total sodium (121.67mg/100g) by FHIA 21 banana hybrid. The highest amount of calcium (448.19mg/100g) was obtained from Ogoni red plantain cultivar. Agbagba plantain hybrid gave the highest Ca and Mg bioavailability, at 95.59% and 93.33% respectively. Ogoni red hybrid recorded the highest Na, Fe, and Zn bioavailability of 92.89%, 57.86%, and 87.80% respectively, while FHIA 34 banana hybrid showed the highest bioavailability of K at 81.74%. The least bioavailable mineral in all the samples was Fe, with Agbagba plantain giving only 35.04% indicating that not all the minerals detected in the products were bioavailable when digested enzymatically into soluble forms.

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