Original article

Relative contribution of banana and plantain products to the nutritional requirements for iron, zinc and vitamin A of infants and mothers in Cameroon

Fernande G. Honfo[a]*, A.P. Polycarpe Kayodé[b], Ousmane Coulibaly[a], Abdou Tenkouano[c]

[a] International Institute of Tropical Agriculture, 08 BP 0932, Cotonou, Benin, f.honfo@cgiar.org u.coulibaly@cgiar.org

[b] Université d'Abomey-Calavi, Faculté des Sciences Agronomiques, Département de nutrition et de Sciences Alimentaires (UAC/FSA/DNSA), BP 526, Cotonou, Benin
polykap@yahoo.fr

[c] International Institute of Tropical Agriculture, BP 2008, Yaoundé, Cameroon
a.tenkouano@cgiar.org

* *Correspondence and reprints*

Received 16 February 2007
Accepted 7 May 2007

Fruits, 2007, vol. 62, p. 267–277

DOI: 10.1051/fruits:2007023
www.fruits-journal.org

***Resumen Español**, p. 277*

Relative contribution of banana and plantain products to the nutritional requirements for iron, zinc and vitamin A of infants and mothers in Cameroon.

Abstract — Introduction. Banana and plantain (ban+plant) play a substantial role in people's diet in Cameroon. A survey was carried out in 240 households in four localities to determine the daily consumption of (ban+plant)-derived foods and the contribution of these foods to iron (Fe), zinc (Zn) and vitamin A intake by children of less than 5 years of age and mothers. **Materials and methods**. The daily consumption level was assessed by a 24-h dietary recall during three consecutive days. The Fe, Zn and β-carotene (precursor of vitamin A) contents of (ban+plant) products were determined and the bioavailability of these micronutrients was estimated using the [phytate:Fe] and [phytate:Zn] molar ratios. **Results**. On a dry-weight basis, Fe content in (ban+plant)-based foods ranged from (0.78 to 1.32) mg·100 g^{-1}; Zn content from (0.22 to 0.41) mg·100 g^{-1} and β-carotene content from (336 to 724) µg·100 g^{-1}. Phytate content was between (0.17 and 1.23) g·100 g^{-1}, with [phytate:Fe] and [phytate:Zn] molar ratios above the estimated bioavailability thresholds of 10–14 and 15, respectively, for all dishes. The daily quantities consumed by rural and urban subjects were not significantly different. The daily supply of Fe by (ban+plant) to children and mothers was 5% and 2%; Zn supply was 3% and 4%, respectively. In contrast, the daily vitamin A supply by (ban+plant) foods was relatively significant, reaching 13% on average per day for both children and mothers. In certain cases, this contribution was as high as 20%. **Conclusion**. Estimated bioavailability of Fe and Zn is low in (ban+plant) that, therefore, poorly contribute to Fe and Zn intake in the households. However, (ban+plant) are a good source of β-carotene and can make a substantial contribution to meeting vitamin A requirements of children and their mothers.

Cameroon / *Musa* (bananas) / *Musa* (plantains) / food nutrient content / nutrient availability / nutritional requirements

Contribution des produits à base de banane et de plantain à la couverture des besoins nutritionnels en fer, zinc et vitamine A chez les enfants et leurs mères au Cameroun.

Résumé — Introduction. Les bananes et plantains (ban+plant) jouent un rôle substantiel dans l'alimentation humaine. Une enquête a été menée dans 240 ménages répartis dans quatre localités du Cameroun afin d'évaluer la contribution des repas à base de (ban+plant) dans la couverture des besoins en micronutriments d'enfants de moins de 5 ans et de leur mère. **Matériel et méthodes**. La consommation des (ban+plant) a été déterminée par la méthode de rappel de 24 h durant 3 j consécutifs. Les compositions en fer, zinc, β-carotène (précurseur de la vitamine A) et phytate de ces repas ont été déterminées et la biodisponibilité de ces micronutriments a été estimée en utilisant les rapports molaires [phytate:Fe] et [phytate:Zn]. **Résultats**. La teneur en fer des repas à base de (ban+plant) a varié de (0,78 à 1,32) mg·100 g^{-1} en base sèche ; la teneur en zinc a été de (0,22 à 0,41) mg·100 g^{-1} ; celle en β-carotène a été de (336 à 724) mg·100 g^{-1}. La composition en phytate a varié entre (0,17 et 1,23) g·100 g^{-1} en base sèche et les rapports [phytate:Fe] et [phytate:Zn] calculés ont été respectivement supérieurs aux seuils de 10–14 et 15. Les quantités quotidiennes de (ban+plant) consommées par les sujets ruraux et urbains n'ont pas été significativement différentes. L'apport quotidien de Fe par (ban+plant) aux enfants et aux mères a été de 5 % et 2 % ; l'apport de Zn a été de 3 % et 4 %, respectivement. En revanche, l'offre quotidienne en vitamine A par (ban+plant) a été relativement important atteignant en moyenne 13 % pour les enfants et leurs mères. Dans certains cas, elle est allée jusqu'à 20 %. **Conclusion**. La biodisponibilité estimée en fer et zinc dans les (ban+plant) se révèle donc faible. Cependant, les (ban+plant) constituent une bonne source de β-carotène et pourraient donc contribuer substantiellement à atteindre les besoins en vitamine A des enfants et de leurs mères.

Cameroun / *Musa* (bananes) / *Musa* (plantains) / teneur en nutriments (alim hommes) / disponibilité d'élément nutritif / besoin nutritionnel

1. Introduction

Micronutrient deficiencies cause major nutritional and health problems to human populations, primarily in developing countries. Trace metal deficiencies are commonly reported in children, and women of reproductive age [1, 2]. Thus, inadequate intake of iron (Fe) is the prevailing nutritional deficiency in the world and is the main cause of anaemia [3, 4]. Likewise, zinc (Zn) deficiency in the diet leads to various growth and reproduction disorders and often results in death, especially in developing countries [5, 6]. More than half of pregnant women and one-third of children of less than 5 years of age in the world suffer from nutritional anaemia and Fe deficiency to various degrees [3]. In Cameroon, for example, 58% of children of less than 5 years of age and 32% of women are Fe-deficient [7], and 27.7% of the population are at risk of inadequate Zn intake [6]. Vitamin A deficiency is considered as a priority global health problem [7, 8] causing increased mortality among children and women in developing countries, acting as the leading cause of preventable blindness, and increasing the risk of disease and death from severe infections [9–11]. Even mild vitamin A deficiency can suppress the immune system and, hence, predispose children to common diseases, including respiratory tract infections, measles and diarrhea [12].

Fruit and vegetables are an important source of essential elements. Minerals and vitamins play a vital role in the proper development and good health of the human body, and fruits are considered the chief source of minerals and vitamins needed in the human diet [13].

Among fruit crops, banana (*Musa* sp. AAA group) and plantain (*Musa* sp. AAB group) are major staple foods for over 100 M people in sub-Saharan Africa[1] [14]. In Africa, Cameroon is one of the most important banana- and plantain-producing, consuming and exporting countries. The total production of banana and plantain is estimated at 1.83 Mt with 35% of bananas, and 65% of plantains and other cooking bananas [15]. According to Trèche [16], 69.4% of plantains and other cooking bananas are used for human consumption, while 8.0% are used for animal feed in Cameroon. They are widely consumed by the entire population and many different dishes are prepared according to the socio-cultural behaviour and the food habits of the population driven by market demand [17, 18].

Banana and plantain contribute significantly to food security and can play a key role in meeting nutritional requirements of the population [19]. However, some studies have shown that bananas and plantains contain some anti-nutritional factors such as phytate, that form insoluble complexes with essential minerals such as Fe and Zn at physiological pH levels, and those complexes are responsible for reducing the bioavailability of the nutrients [20, 21]. Hence, the molar ratio of phytate to Fe or Zn was suggested as an index to estimate the availability of Fe and Zn in the food [4].

Our study was carried out with the aim of determining Fe, Zn, β-carotene and phytate contents in banana- and plantain-based foods commonly consumed in Cameroon in order to assess their contribution to meeting Fe, Zn and vitamin A requirements of both children and their mothers.

2. Materials and methods

2.1. Surveys

Surveys were conducted between March and April 2006 around four localities in Cameroon: Bafia in the centre, Bamenda in the north-west, Bertoua in the east and Ebolowa in the south of the country. In each community, sub-samples of 30 urban and 30 rural households were randomly selected, totalling 240 households. These households were selected based on the presence of a child of less than 5 years of age, fully weaned, together with his/her biological mother. This criterion was chosen to

[1] See: Banana diversity, Int. Netw. Improv. Banan. Plantain (INIBAP), 2002, Available at: http://www.inibap.org/publications/factsheet-eng.htm.

determine the importance of banana and plantain in the diet of the fully weaned children. The housewives selected for the study differed from each other in terms of standard of living and socio-cultural backgrounds. Data were collected from the selected households using a structured questionnaire that was administered to the child's mother. The questionnaire included the following aspects: socio-demographics (age, household size, occupation and educational background), and food consumption pattern (types of banana and plantain varieties used, processing methods and derived foods, quantity thereof daily consumed by mothers and children).

The daily consumption of banana and plantain foods was assessed by a 24-h dietary recall method during three consecutive days [22]. The three days were randomly allocated from Monday to Sunday. On each day and in each household, the child's mother was invited to recall all the types and quantities of banana and plantain foods fed to their child and eaten by herself during the last 24 h. The quantities consumed were estimated using local containers, and the results were later converted into standard units. The amount of each dish was estimated daily for each subject.

2.2. Processing and sampling

One bunch of ripe plantain and one bunch of unripe plantain of the 'Essong' and 'Ebang' varieties, and unripe banana, were purchased from the local market. The traditional processing practices identified in the households were used to process banana and plantain during the survey. Different types of meals (fried, boiled and roasted) of each ripe plantain variety were cooked; boiled unripe plantain and banana porridge were also cooked. All samples processed were in duplicate with the same processing method and cooking time. Samples of plantain chips and ripe banana were purchased from the local market. These products represent the common forms in which plantain and banana are consumed in Cameroon. For each product, an aliquot of 70–100 g was sampled and packed in aluminum foil, wrapped in polyethylene bags, placed in an insulated icebox and transported to the laboratory. The containers were sealed to avoid product loss and influx of humidity; they were then labelled. The samples were stored at – 20 °C until analysis of Fe, Zn and β-carotene (precursor of vitamin A).

2.3. Laboratory analyses

For total Fe and Zn determination, Fe and Zn were extracted by dry ashing in a muffle furnace at 500 °C; the resulting ash was dissolved in a diluted mixture of hydrochloric and nitric acids (HCl/HNO_3), and analysed using an atomic absorption spectrophotometer [23]. Measurements were performed in triplicate at the laboratory of the International Institute of Tropical Agriculture (IITA) in Cameroon.

For β-carotene determination, samples of (0.01 to 0.9) g were collected after homogenisation and subjected to the extraction of β-carotene by High-Performance Liquid Chromatography (HPLC) using Tetra Hydro Furan, as described by Takyi [24]. Samples were analysed in triplicate at the Noguchi Institute of Medical Research, University of Legon, Ghana. Retinol activity equivalent was calculated using the conversion factor 12:1 from β-carotene value.

For phytate determination, the phytate concentration in different banana and plantain foods was determined by colorimetry (Shimadzu UV 240, Kyoto, Japan) following four stages, *i.e.*, extraction, precipitation, mineralisation and quantification of the liberated phosphorus, described by Makower [25] and modified by Zeder [26]. Although Makower's method is not as specific as some HPLC methods, it nevertheless was used [27, 28] to quantify phytate in food products that have not undergone bioprocessing, such as germination and fermentation. Analyses were performed in triplicate and were done at the Laboratory of Nutrition and Food Sciences, University of Abomey-Calavi, Benin.

[Phytate:Fe] and [phytate:Zn] ratios were calculated using the following formulas, respectively: {[mg of phytate / molar mass of phytate (660)] / [mg of Fe / molar mass of Fe (55.85)]} and {[mg of phytate / molar mass of phytate] / [mg of Zn / molar mass of Zn (65.39)]} [29].

2.4. Data analysis

The average quantities of each banana- and plantain-based food consumed daily were calculated per subject (children and mothers) based on data recorded over three days. Data were analysed using the Statistical Package for the Social Sciences, version 12 (SPSS 12, 2003) and were expressed as mean values and standard deviations. A one-way ANOVA model with the Least Significant Difference (LSD) test was used to compare means between groups.

3. Results and discussion

3.1. Household consumption patterns

The socio-demographic characteristics of the surveyed households were as follows: their ethnic origin is diverse; the predominant were Ngamba (20%), Bafia (18%) and Boulou (14%). Most of the mothers' ages ranged from 20–29 years (51%) in all locations and 7% of them were more than 40 years old. Forty percent of the mothers attended primary school while 7.9% of them were illiterate. Agriculture was the dominant activity for most women (33%); 26% were housewives and 23% were traders. Most of the children in the surveyed households were aged between 24–35 months (43%) and 36–47 months (33%).

For their consumption, the households surveyed used different banana and plantain varieties including 'Ebang', 'Essong', 'Elat', 'Gros Michel', 'Grande Naine', 'Banane Cochon' and 'French clair'. This is similar to the findings by Ngoh Newilah *et al.* [30]. However, the predominant varieties for most households were 'Ebang' and 'Essong'. Households used various recipes to process banana and plantain, at different ripening stages (boiled, chips, fried, porridge, pounded and roasted), some of which had previously been reported for Cameroon [17, 30] and South-East Asia [31].

There were significant differences between rural and urban consumers of banana- and plantain-based foods in terms of the quantity consumed. Thus, the daily intake of boiled unripe plantain by rural consumers was higher than that of their urban counterparts ($P < 0.05$) (*table I*). In contrast, boiled ripe plantain was equally consumed in both areas, but urban consumers expressed higher preference for this type of food, evidenced by its most frequent consumption in urban areas. It appears that the preference of urban consumers for the ripe plantain food was associated with the sweeter flavour of the ripe plantain compared with the unripe one. No significant differences between urban and rural consumption levels were found for other foods, although fried plantain was more frequently consumed in urban areas.

Analysis by locality showed a significant difference between the quantities of boiled ripe plantain, ripe banana and roasted plantain consumed by children per day. High consumption of boiled ripe plantain and ripe banana were observed among the children of Bafia locality, while high consumption of roasted plantain was registered for Bamenda's children. However, a significant difference between the daily consumption level of boiled ripe plantain and banana porridge was observed among the mothers. Indeed, Bafia's mothers consumed more boiled ripe plantain; whereas banana porridge was more consumed by the mothers in Bamenda. Statistical analyses did not reveal any correlation between the consumption level and the social factors such as ethnic groups, educational level or main activity.

3.2. Iron, zinc and β-carotene contents

No significant differences in Fe, Zn and β-carotene contents were observed between the two plantain varieties, 'Essong' and 'Ebang' (*table II*); however, greater concentrations were found in unripe compared with ripe fruits of both varieties.

Fe concentration ranged from (0.78 to 1.32) mg·100 g^{-1} on a dry-weight basis with an average of 1.1 mg·100 g^{-1} (0.70 mg·100 g^{-1} on a wet basis). This average value was comparable with the value of 0.6 mg·100 g^{-1} reported by the USDA [32] in edible parts of

Table I.
Average daily quantity of banana and plantain meals (g of edible portion) consumed by children and mothers surveyed in Cameroon, according to the area where they are living (mean ± standard deviation; in brackets: number of persons that consumed the considered product at least once during a 3-d survey).

Consumer	Type of area surveyed	Ripe banana	Boiled unripe plantain	Boiled ripe plantain	Fried plantain	Roasted plantain	Plantain or banana porridge
Children	Rural	160.12 ± 93.7 (34)	234.48 ± 106.4 (69)**	198.46 ± 102.7 (65)	115.50 ± 66.9 (28)	119.67 ± 52.3 (14)	349.61 ± 114.2 (28)
	Urban	126.55 ± 76.0 (41)	172.0 ± 69.1 (46)	239.3 ± 134.5 (77)	139.30 ± 64.3 (57)	162.25 ± 82.36 (24)	337.71 ± 132.5 (33)
Mothers	Rural	354.58 ± 114.9 (17)	425.33 ± 201.4 (63)**	433.20 ± 206.6 (40)	316.03 ± 109.8 (18)	235.06 ± 74.9 (22)	687.84 ± 321.1 (43)
	Urban	317.94 ± 146.3 (32)	327.08 ± 119.3 (35)	385.37 ± 106.7 (86)	294.57 ± 170.7 (44)	240.17 ± 146.3 (29)	724.90 ± 268.9 (30)

** Significant difference at 5%.

Table II.
Average Fe, Zn, β-carotene and corresponding equivalence in vitamin A content on a dry-weight basis in different banana- and plantain-based foods consumed in Cameroon (standard deviation in brackets).

Type of banana considered	Banana- and plantain-based foods	Moisture (%)	Iron $(mg \cdot 100\ g)^{-1}$	Zinc $(mg \cdot 100\ g)^{-1}$	β-carotene $(\mu g \cdot 100\ g)^{-1}$	Vitamin A $(\mu g\ RAE \cdot 100\ g)^{-1}$
Plantain Essong variety	Unripe	60.60	0.96 (0.05)	0.29 (0.02)	567.06 (127.25)	47.26 (10.64)
	Ripe	61.70	0.96 (0.07)	0.23 (0.01)	456.14 (29.43)	38.17 (2.45)
	Boiled unripe	62.45	1.08 (0.05)	0.30 (0.01)	434.95 (164.37)	36.25 (13.69)
	Boiled ripe	63.87	1.17 (0.05)	0.25 (0.02)	450.13 (314.52)	37.51 (26.21)
	Fried ripe	46.16	1.02 (0.05)	0.25 (0.01)	398.84 (185.94)	33.24 (15.74)
	Roasted	57.84	0.96 (0.05)	0.29 (0.02)	529.38 (38.20)	44.12 (3.19)
Plantain Ebang variety	Unripe	58.66	0.97 (0.03)	0.26 (0.01)	493.79 (0.48)	41.15 (13.89)
	Ripe	60.53	0.91 (0.04)	0.26 (0.03)	375.71 (66.24)	31.31 (5.52)
	Boiled unripe	64.00	0.99 (0.08)	0.33 (0.03)	354.38 (20.33)	29.54 (1.69)
	Boiled ripe	60.06	1.11 (0.06)	0.28 (0.02)	355.42 (89.72)	29.62 (7.48)
	Fried ripe	34.65	0.89 (0.01)	0.25 (0.02)	425.61 (39.41)	35.47 (3.27)
	Roasted	58.42	1.02 (0.06)	0.25 (0.02)	362.71 (96.16)	30.18 (8.03)
Plantain chips	Thin slices	2.95	1.01 (0.04)	0.41 (0.02)	336.45 (27.71)	28.04 (2.48)
	Thick slices	6.31	1.32 (0.04)	0.22 (0.01)	724.43 (438.23)	60.37 (36.52)
Ripe banana	Small fingers	72.46	0.93 (0.05)	0.41 (0.03)	23.94 (2.86)	1.83 (0)
	Big fingers	78.50	0.78 (0.04)	0.27 (0.01)	93.20 (34.07)	7.77 (2.84)
	Porridge	70.71	1.28 (0.03)	0.42 (0.01)	206.31 (5.91)	17.19 (0.49)

RAE: Retinol activity equivalents (conversion factor 12:1 from β-carotene).

raw plantain and values of (0.42 to 0.65) mg·100 g^{-1} found by Hardisson *et al.* [33] in the edible portion of some bananas from the island of Tenerife. Fe content was highest in plantain chips, probably due to the ingredients such as palm oil used for their preparation, and lowest in fried plantain. Banana porridge also had high iron content (1.28 mg·100 g^{-1}), certainly because of the ingredients (oil, pepper, tomato and smoked or dried crayfish) used for the preparation.

Zn values ranged from (0.22 to 0.41) mg·100 g^{-1} with an average of 0.32 mg·100 g^{-1} on a dry-weight basis (0.23 mg·100 g^{-1} on a wet basis). In comparison, the USDA [32] reported an average of 0.14 mg·100 g^{-1} in edible parts of raw plantain, while Hardisson *et al.* [33] found Zn content range from (0.10 to 0.24) mg·100 g^{-1}. Unripe plantain and plantain chips contained the highest values of Zn, followed by banana porridge and ripe banana fruits, especially the small finger variety.

β-carotene content in plantain foods ranged from (336 to 724) g·100 g^{-1} with an average of 530 g·100 g^{-1} on a dry-weight basis (502.62 g·100 g^{-1} on a wet basis), appearing to be higher than in other staple foods, such as cassava and yam, in Cameroon. The β-carotene contents in the samples of our study were lower than those reported by Englberger [34] in Micronesian bananas, but similar to the 457 g·100 g^{-1} value reported by the USDA [32]. Carotene levels generally increase with cooking, but this depends on the cooking mode: indeed, long duration and high temperature destroy carotenoids [34]. In our study, carotene levels increased with cooking, but not in all cases, *e.g.*, boiled plantain contained lower values of β-carotene than the raw fruit because of the carotenoid diffusion in the water. Maturity also appeared to affect carotene content, with unripe plantain containing higher values of β-carotene [(493 and 567) g·100 g^{-1}] than ripe ones [(376 and 456) g·100 g^{-1}]. As expected, chips processed with red palm oil were particularly rich in β-carotene (724 g·100 g^{-1}) due to the richness of red palm oil in β-carotene [35]. The lowest β-carotene contents were found in the ripe banana and banana porridge, and were significantly different from values observed in plantain fruits and derived foods. This illustrates nutritional differences between bananas and plantains, in agreement with the views of Stover and Simmonds [36].

3.3. Phytate content and [phytate:Fe] and [phytate:Zn] molar ratios

Phytate contents ranged between (0.17 and 1.23) g·100 g^{-1} with a mean value of 0.45 g·100 g^{-1} on a dry-weight basis (*table III*). These values were higher than the (0.06 to 0.37) g·100 g^{-1} reported by Baiyeri and Tenkouano [37]. These authors worked with the Nigerian local variety 'Agbagba' and hybrids derived from Nigerian landraces. Varietal differences were observed in our own study, with high phytate contents recorded in foods derived from 'Essong'. Regardless of the variety, there was a significantly ($P < 0.05$) lower phytate content in ripe fruits compared with unripe fruits of plantain, with a 40% decrease.

Phytate is the major chelator of Fe and Zn, which affects the bioavailability of these minerals [38, 39]. The degree to which phytate inhibits Fe and Zn absorption has been defined by the [phytate:Fe] and [phytate:Zn] molar ratios, respectively [38, 40]. Bioavailability of these minerals is impaired with ratios above the thresholds of 10–14 and 15, for Fe and Zn, respectively [29, 40]. In our study, the [phytate:Fe] and [phytate:Zn] molar ratios exceeded the threshold values (*table III*). Thus, the estimated bioavailability of Fe and Zn from banana or plantain foods is low, particularly in foods derived from unripe fruits. Food preparations such as boiled ripe plantain and ripe banana had [phytate:Fe] ratios close to the threshold, suggesting a better Fe availability compared with other preparations. Similar findings were reported by Suntharalingam and Ravindran [41] for certain varieties of cooking banana (*Musa* spp., ABB group). This lends support for the exploration of alternatives such as the use of biological fortification via genetic improvement

Table III.
Phytate content on a dry-weight basis and [phytate:Fe] and [phytate:Zn) molar ratios in different banana- and plantain-based foods consumed in Cameroon.

Type of banana considered	Banana- and plantain-based foods	Phytate ($g \cdot 100\ g^{-1}$)	[Phytate:Fe][1]	[Phytate:Zn][2]
Plantain Essong variety	Unripe	0.57 ± 0.12	50.6 ± 10.6	196.1 ± 41.0
	Ripe	0.33 ± 0.11	29.0 ± 9.7	141.6 ± 47.4
	Boiled unripe	0.52 ± 0.16	41.1 ± 12.5	173.3 ± 52.8
	Boiled ripe	0.26 ± 0.10	19.1 ± 7.2	104.9 ± 39.6
	Fried ripe	0.51 ± 0.13	42.0 ± 10.8	200.7 ± 51.5
	Roasted	0.30 ± 0.08	26.6 ± 7.1	103.2 ± 27.3
Plantain Ebang variety	Unripe	0.41 ± 0.09	35.4 ± 7.9	154.6 ± 34.3
	Ripe	0.24 ± 0.09	22.0 ± 8.4	90.0 ± 34.3
	Boiled unripe	0.25 ± 0.09	21.3 ± 7.7	74.8 ± 27.0
	Boiled ripe	0.22 ± 0.09	16.9 ± 6.9	78.6 ± 31.8
	Fried ripe	0.49 ± 0.13	46.5 ± 12.4	193.9 ± 51.5
	Roasted	0.29 ± 0.08	24.2 ± 6.6	115.8 ± 31.7
Chips of plantain	Thin slides	1.23 ± 0.24	103.4 ± 20.1	298.2 ± 58.0
	Thick slides	0.61 ± 0.18	39.4 ± 11.5	276.8 ± 81.1
Ripe banana	Small fingers	0.17 ± 0.07	15.0 ± 6.4	39.9 ± 13.9
	Big fingers	0.19 ± 0.07	20.6 ± 7.6	69.8 ± 25.7
	Porridge	0.28 ± 0.08	18.6 ± 5.3	66.3 ± 18.9

[1] [mg of phytate / molar mass of phytate (660)] / [mg of iron / molar mass of iron (55.85)].

[2] [mg of phytate / molar mass of phytate] / [mg of zinc / molar mass of zinc (65.39)].

and/or chemical processing (*e.g.*, fermentation) to alter phytate content and increase the bioavailability of Fe and Zn in food products derived from banana and plantain.

3.4. Relative contribution to mineral requirements

The effective supply of nutrients by banana and plantain to individuals depends on the amount of these foods eaten, their nutrient contents and the bioavailability of these nutrients. In our study, six types of banana- and plantain-based foods were acknowledged as the most commonly consumed by the surveyed populations. Therefore, the daily supply of minerals by banana- and plantain-derived foods was obtained by taking the mean of the total supply provided by all six food types. Thus, the relative micronutrient supply of foods derived from banana and plantain was calculated based on the Fe, Zn and β-carotene contents in the food preparations and the daily intake thereof (*tables IV, V*). The results showed that boiled, porridge and roasted forms of plantains provided more minerals than other preparations, both in urban and rural areas.

The dietary recommendations put forward by the FAO for children less than 5 years old are 14 mg of iron, 10 mg of zinc and 400 µg Retinol Activity Equivalents (RAE) of vitamin A per day [42]. Corresponding values for non-pregnant and non-lactating women are 48 mg of iron, 12 mg of zinc and 800 µg RAE of vitamin A [42]. Our data suggest that banana and plantain foods provided 0.75 mg of iron, 0.26 mg of zinc and 5 µg RAE of vitamin A, only meeting 5% of children's daily requirements for iron, 2% for zinc, and 13% for vitamin A, in both rural and urban settings (*table VI*). Likewise, banana and plantain provided approximately

Table IV.
Means of daily iron, zinc and vitamin A supply by banana and plantain foods among the children who consumed the dishes according to a survey carried out in Cameroon (standard deviation in brackets).

Banana and plantain dishes	Iron (mg)		Zinc (mg)		Vitamin A (µg RAE)	
	Rural area	Urban area	Rural area	Urban area	Rural area	Urban area
Ripe banana	0.29 (0.2)	0.23 (0.2)	0.11 (0.1)	0.09 (0.1)	7.69 (4.5)	6.07 (7.3)
Boiled unripe plantain	0.96 (0.4)	0.71 (0.5)	0.26 (0.1)	0.19 (0.1)	75.81 (34.4)	55.61 (44.7)
Boiled ripe plantain	0.71 (0.4)	0.86 (0.5)	0.18 (0.1)	0.22 (0.2)	74.14 (38.4)	89.40 (100.5)
Fried plantain	0.44 (0.3)	0.53 (0.4)	0.13 (0.1)	0.15 (0.1)	38.74 (22.4)	46.72 (43.1)
Roasted plantain	0.65 (0.3)	0.88 (0.4)	0.18 (0.1)	0.24 (0.1)	47.08 (20.6)	63.83 (64.8)
Plantain or banana porridge	1.33 (0.4)	1.28 (0.5)	0.42 (0.2)	0.41 (0.2)	60.10 (19.6)	58.05 (45.6)

RAE: Retinol activity equivalents (conversion factor 12:1 from β-carotene).

Table V.
Means of daily iron, zinc and vitamin A supply by banana and plantain foods among the mothers who consumed the dishes according to a survey carried out in Cameroon (standard deviation in brackets).

Banana and plantain dishes	Iron (mg)		Zinc (mg)		Vitamin A (µg RAE)	
	Rural area	Urban area	Rural area	Urban area	Rural area	Urban area
Ripe banana	0.64 (0.2)	0.58 (0.3)	0.25 (0.1)	0.22 (0.1)	17.02 (5.5)	15.26 (7.0)
Boiled unripe plantain	1.74 (0.8)	1.34 (0.5)	0.47 (0.2)	0.36 (0.1)	137.51 (65.1)	105.74 (38.6)
Boiled ripe plantain	1.56 (0.8)	1.39 (0.4)	0.39 (0.2)	0.35 (0.1)	161.84 (77.2)	143.97 (39.8)
Fried plantain	1.20 (0.4)	1.12 (0.7)	0.35 (0.1)	0.32 (0.2)	106.00 (36.8)	98.80 (57.2)
Roasted plantain	1.27 (0.4)	1.30 (0.8)	0.35 (0.1)	0.36 (0.2)	92.47 (29.5)	94.48 (57.6)
Plantain or banana porridge	2.61 (1.2)	2.75 (1.0)	0.83 (0.4)	0.87 (0.3)	118.24 (55.2)	124.61 (46.2)

RAE: Retinol activity equivalents (conversion factor 12:1 from β-carotene).

Table VI.
Contribution of banana and plantain in the iron, zinc and vitamin A supply (mean, standard deviation in brackets) to the children and their mothers.

People concerned	Area concerned	Iron (mg)	Zinc (mg)	Vitamin A (µg RAE)	Iron (%)	Zinc (%)	Vitamin A (%)
Children	Rural	0.73 (0.4)	0.21 (0.1)	50.59 (25.6)	5.21 (2.6)	2.12 (1.2)	12.65 (6.4)
	Urban	0.75 (0.4)	0.22 (0.1)	53.28 (27.3)	5.34 (2.6)	2.16 (1.1)	13.32 (6.8)
Mothers	Rural	1.50 (0.7)	0.44 (0.2)	105.51 (49.72)	3.13 (1.4)	3.65 (1.7)	13.19 (6.2)
	Urban	1.41 (0.7)	0.41 (0.2)	97.15 (44.13)	2.94 (1.5)	3.45 (1.9)	12.14 (5.5)

RAE: Retinol activity equivalents (conversion factor 12:1 from β-carotene).

1.50 mg of iron and 0.44 mg of zinc to the surveyed mothers in both rural and urban zones, meeting 3% of this group's daily requirement for iron and 4% for zinc, with no difference between rural and urban areas (*table VI*). Contrasting with this, banana- and plantain-derived foods could potentially provide as much as 105 µg RAE of vitamin A to rural mothers and 97 µg RAE to urban mothers per day. These values corresponded to 13% and 12% of vitamin A requirements of mothers in rural and urban areas, respectively, reaching up to 20% for some populations, due to larger intakes.

4. Conclusion

Our work provided data on the iron, zinc and β-carotene contents in banana and plantain foods commonly consumed in Cameroon and their intake by consumers in both rural and urban areas. There was no significant difference in micronutrient contents, while some differences existed in their bioavailability between the two varieties of plantain considered ('Essong' and 'Ebang'). No variations were observed in the consumption levels by rural and urban people for most food preparations. However, urban subjects consumed more foods prepared from ripe plantain (boiled and fried), while rural subjects showed preference for unripe plantains and their derived foods. The contribution of banana and plantain to vitamin A supply was relatively significant in both rural and urban areas. The total iron and zinc supplies from banana- and plantain-based foods were low, and, moreover, the high [phytate:iron] and [phytate:zinc] molar ratios suggest that the estimated bioavailability of Fe and Zn was low. Biofortification and/or product fermentation could be used to increase the bioavailability and the total content of these trace elements in products.

Acknowledgements

We gratefully acknowledge financial support from the Harvest Plus Challenge Programme through Contract No. 5001 to the International Institute of Tropical Agriculture (IITA). We also extend our sincere thanks to all those who participated in the data collection in Cameroon.

References

[1] Frossard E., Chunwongse J., Tanksley S.D., Potential for increasing the content and bioavailability of Fe, Zn and Ca in plants for human nutrition, J. Sci. Food Agric. 80 (2000) 861–879.

[2] Gibson R.S., Hotz C., Temple L., Yeudall F., Mtitimuni B., Ferguson E.L., Dietary strategies to combat deficiencies of iron, zinc, and vitamin A in developing countries: development, implementation, monitoring, and evaluation, Food Nutr. Bull. 21 (2000) 219–231.

[3] Anon., Third report on the world nutrition situation, United Nations Adm. Comm. Coord. / Subcomm. Nutr. (UNACC/SCN), Geneva, Switzerland, 1997.

[4] Hallberg L., Hulthén L., Prediction of dietary iron absorption: an algorithm for calculating absorption and bioavailability of dietary iron, Am. J. Clin. Nutr. 71 (2000) 1147–1160.

[5] Brown K.H., Person J.M., Rivera J., Allen L.H., Effect of supplemental zinc on the growth and serum zinc concentrations of pre-pubertal children: a meta-analysis of randomised trials, Am. J. Clin. Nutr. 75 (2002) 1062–1071.

[6] Hotz C., Brown K., Assessment of the risk of zinc deficiency in populations and options for its control, Food Nutr. Bull. 25 (1) (2004) 194–195.

[7] Anon., Vitamin and mineral deficiency, a global progress report, UNICEF and Micronutrient Initiative, UNICEF, New York, USA, 2004.

[8] Anon., Trace elements in human nutrition and health, World Health Organ. (FAO/WHO), Geneva, Switzerland, 1996.

[9] Sommer A., West K.P., Vitamin A deficiency: health, survival, and vision, Oxford Univ. Press, New York, USA, 1996.

[10] Mclarean D.S., M. Frigg., Sight and life manual on vitamin A deficiency disorders (VADD), 2nd ed., Task Force Sight and Life, Basel, Switzerland, 2001.

[11] Anon., Progrès en vue de l'élimination des troubles dûs à la carence en vitamine A,

Rapport d'une consultation conjointe d'experts, OMS/UNICEF, Genève, Switzerland, 2002, 36 p.

[12] Cervinskas J., Lotfi M., Vitamin A deficiency: key resources in its prevention and elimination, IDRC, Micronutrient Initiative 59, Ottawa, Canada, 1995, 59 p.

[13] Chauhan K.S., Pundir J.P.S., Singh S., Studies on the mineral composition of certain fruits, Haryana J. Hortic. Sci. 20 (3–4) (1991) 210–213.

[14] Sharrock S., Frison E., *Musa* production around the world – trends, varieties and regional importance, in: INIBAP Annu. Rep., INIBAP, Montpellier, France, 1998, pp. 42–47.

[15] Anon., Bulletin of statistics, FAO Bull. 2 (2) (2002).

[16] Trèche S., Importance de l'utilisation des racines, tubercules et bananes à cuire en alimentation humaine dans le monde, Cah. Rech. Dév. 43 (1997) 95–109.

[17] Grimaldi J., Bikia A., Le grand livre de la cuisine camerounaise, Sopecam, Yaoundé, Cameroun, 1985.

[18] Dury S., Bricas N., Tchango Tchango J., Temple L., Bikoi A., The determinants of urban plantain consumption in Cameroon, Food Qual. Prefer. 32 (3) (2002) 81–82.

[19] Ajayi A.R., Aneke M.O., Consumption and expenditure patterns of banana and plantain consumers in Nsukka Urban, Nigeria, Infomusa 11 (1) (2002) 50–53.

[20] Monsen E.R., Iron nutrition and absorption: dietary factors which impact iron bioavailability, J. Am. Diet. Assoc. 88 (1988) 786–790.

[21] Allen L.H., Ahluwalia N., Improving iron status through diet. The application of knowledge concerning dietary iron bioavailability in human populations, OMNI opportunities for micronutrients interventions, John Snow, Inc./OMNI Project, Washington, DC, USA, 1997.

[22] Bingham S.A., Nelson M., Alison P., Methods for data collection at an individual level, in: Cameron M.E., van Staveren W.A. (Eds.), Manual on methodology for food consumption studies, Oxford Univ. Press, Oxford, UK, 1988.

[23] Benton Jones Jr., Vernon W., Sampling, handling and analyzing plant tissue samples, in: Westerman R.L. (Ed.), Soil testing and plant Analysis, 3rd ed., SSSA Book Ser. N°3, 1990.

[24] Takyi E.K., Children's consumption of dark green leafy vegetables with added fat enhances serum retinol, J. Nutr. 129 (1999) 1549–1554.

[25] Makower R.U., Extraction and determination of phytic acid in bean (*Phaseolus vulgaris*), Cereal. 47 (1970) 228.

[26] Zeder C., Analysis of phytic acid content in food (spectrophotometric), Labor für Humanernaehrung der ETHZ, Rueschlikon, Switzerland, 1998.

[27] Hurrell R.F., Reddy M.R., Burri J., Cook J.D., Phytate degradation determines the effect of industrial processing and home cooking on iron absorption from cereal-based foods, Brit. J. Nutr. 88 (2002) 117–123.

[28] Kayodé A.P.P., Diversity, users' perception and food processing of sorghum: implications for dietary iron and zinc supply, Wageningen Univ., Thesis, Wageningen, The Netherlands, 2006, 152 p.

[29] Saha P.R., Weaver C.M., Mason A.C., Mineral bioavailability in rats from intrinsically labeled whole wheat flour of various phytate levels, J. Agric. Food Chem. 42 (1994) 2531–2535.

[30] Ngoh Newilah G., Tchango Tchango J., Fokou E., Etoa F.X., Processing and food uses of bananas and plantains in Cameroon, Fruits 60 (4) (2005) 245–253.

[31] Sharrock S., Use of *Musa*, in: INIBAP Annu. Rep., INIBAP, Montpellier, France, 1996, pp. 42–44.

[32] Anon., National nutrient database for standard reference, USDA, Release 17, New York, USA, 2004.

[33] Hardisson A., Rubio C., Baez A., Martin M., Alvarez R., Diaz E., Mineral composition of the banana (*Musa acuminata*) from the island of Tenerife, Food Chem. 73 (2001) 153–161.

[34] Englberger L., Carotenoid-rich bananas in Micronesia, Infomusa 12 (2) (2004) 2–5.

[35] Benadé A.J.S., A place for palm fruit oil to eliminate vitamin A deficiency, Asia Pac. J. Clin. Nutr. 12 (3) (2003) 369–372.

[36] Stover R.H., Simmomds N.W., Bananas, 3rd ed., Longman, London, UK, 1987.

[37] Baiyeri K.P., Tenkouano A., Genetic and cropping cycle effects on proximate composition and antinutrient contents of flour made from eleven *Musa* genotypes, Glob. J. Pure Appl. Sci. 12 (2) (2006) 177–182.

[38] Gibson R.S., Ferguson E.L., An interactive 24-h recall for assessing the adequacy of iron and zinc intakes in developing countries, ILSI Press, Wash., DC, USA, 1999.

[39] Davies N.T., Olpin S.E., Studies on the phytate:zinc molar contents in diets as a determinant of Zn availability to young rats, Br. J. Nutr. 41 (1979) 591–603.

[40] Oberleas D., Harland B.F., Phytate content of food: effect on dietary zinc bioavailability, J. Am. Diet. Assoc. 79 (1981) 433–436.

[41] Suntharalingam S., Ravindran G., Physical and biochemical properties of green banana flour, Plant Foods Hum. Nutr. 43 (1993) 19–95.

[42] Latham M.C., La nutrition dans les pays en développement, FAO, Rome, Italie, 2001.

Contribución de los productos a base de banano y de plátano para la cobertura de las necesidades nutricionales en hierro, cinc y en vitamina A, en los niños y en sus madres, en Camerún.

Resumen — Introducción. Los bananos y los plátanos (ban+plát) desempeñan un papel importante en la alimentación humana. Se llevó a cabo una investigación en 240 hogares repartidos en cuatro localidades de Camerún, con el fin de evaluar la contribución de las comidas a base de (ban+plát) en la cobertura de las necesidades en micronutrientes de niños menores de 5 años de edad y de sus madres. **Material y métodos**. Se determinó el consumo de (ban+plát) mediante el método de reejecución de 24 h durante 3 d consecutivos. Se determinaron de estas comidas las composiciones en hierro, cinc, β-caroteno (precursor de la vitamina A) y fitato; y, se estimó la biodisponibilidad de estos micronutrientes, gracias a la utilización de las fracciones molares [fitato:Fe] y [fitato:Zn]. **Resultados**. El contenido en hierro de estas comidas a base de (ban+plát) varió de (0,78 a 1,32) mg·100 g^{-1} en base seca; el contenido en cinc fue de (0,22 a 0,41) mg·100 g^{-1}; y el contenido en β-caroteno fue de (336 à 724) mg·100 g^{-1}. La composición en fitatos varió entre (0,17 y 1,23) g·100 g^{-1} en base seca; y, las relaciones [fitato:Fe] y [fitato:Zn] calculadas fueron respectivamente superiores a los topes de 10–14 y 15. Las cantidades cotidianas de (ban+plát) consumidas por los sujetos rurales y urbanos no fueron significativamente diferentes. El aporte cotidiano de Fe mediante (ban+plát) en los niños y en las madres fue de un 5% y de un 2%; el aporte de Zn fue de un 3% y de un 4%, respectivamente. Sin embargo, la oferta cotidiana en vitamina A mediante (ban+plát) fue relativamente importante alcanzando de media un 13% para los niños y sus madres. En ciertos casos, alcanzó hasta el 20%. **Conclusión**. La biodisponibilidad estimada en hierro y en cinc en los (ban+plát) se mostró por lo tanto escasa. No obstante, los (ban+plát) constituyen una buena fuente de β-caroteno y podrían, por ello, contribuir sustancialmente a alcanzar las necesidades en vitamina A de los niños y de sus madres.

Camerún / *Musa* (bananos) / *Musa* (plátanos) / contenido de nutrientes (alimentos) / disponibilidad de nutrientes / necesidades de nutrientes