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Macro-nutrients in edible parts of food crops in the region of Moanda, Gabon

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ABSTRACT

The assessment of nutritive foodstuffs quality is an important step in the estimation of dietary intake of metals. This study aimed to assess accumulation and the daily intake of macro-elements magnesium, calcium, potassium and sodium in edible parts of plants grown in Moanda area. The ranges of concentrations were 246 - 5645 mg/kg, 1167 - 35,105 mg/kg, 158 - 12,563 mg/kg and 88 - 795 mg/kg for Mg, Ca, K and Na, respectively. Mg and K levels were significantly higher in fruits than in tubers. The trend of accumulation in the edible parts of plants was generally: Ca > K > Mg > Na. The daily intakes of Mg and Ca were the highest and indicated food crops in Moanda had a good nutritive quality.

Keywords: Food Crops; Macro-Nutrients; Daily Intake; Moanda

1. INTRODUCTION

Food crops hold an important place in well-balanced diets, and increasing consumption of vegetable and fruits is advisable [1]. For example, leafy vegetables represent an important source of proteins, vitamins and minerals for humans, and they act as buffering agents for acidic products formed during the digestion process [2]. Eleven elements are named essential nutrients. Six of them are used in large quantities (magnesium, phosphorus, potassium, calcium, nitrogen and sulphur) and are named macro-elements, and five elements are used in small quantities (boron, copper, iron, manganese and zinc) and named trace-elements. They are transferred from soil to plant and are receiving major attention [3]. The level of these elements in soils is very important for crop growth successful. If they are deficient or improperly balanced, normal growth does not occur. Plant growth maybe retarded because these elements are actually lacking in the soil, they become available too slowly. Because that, they are not adequately balanced by other nutrients. Likewise, insufficient levels of essential elements in crops can to cause serious diseases to human and animal [4-6].

WHO has recommended selective studies of individual foodstuffs as an important step in the estimation of dietary intake of metals [7]. The present work aimed to assess the accumulation of major essential nutrients (Ca, Mg, K and Na) in food plants, and to estimate their daily intake by Moanda inhabitants who consume these plants.

2. MATERIALS AND METHODS

2.1. Sampling, Preparation and Analyses

Ten kinds of food crops samples were randomly collected in plantations located 15 km south of Moanda City, South-East Gabon (13˚10'E - 13˚15'E, 1˚25'S - 1˚35'S) in December 2009. All collected plant samples reached the maturation. Samples were washed with distilled water and with deionized water to eliminate the air-borne pollutants and soil particles. Then they were blotted dry with tissue paper. The edible part of each vegetable was removed with a knife; they were dried at 70˚C until constant weight. Samples were finely ground (0.2 mm) and kept in polyethylene bags. The selected plants are listed in **Table 1**.

Dried plant materials were put into a platinum dish. The capsule was introduced in an oven whose temperature was gradually increased up to 500˚C and maintained for 2 hours. The ash obtained was mineralized by hydrochloric acid 6 N. Calcium, magnesium, potassium and sodium in the sample were determined using atomic absorption spectrometry. Instrument optimization was set according to the manufacturer's instruction manual. Prior to analysis, the nebulizer was cleaned by aspirating 20 ml of deionized water. The blank and standards were aspirated first, followed by the unknown samples. Deionized water was aspirated between each sample after duplicate readings were taken. The unknown element concentrations were determined from the calibration graph.

Table 1. Studied plants and edible parts.

Usual plant name	Edible part	Scientific name of plant
Pepper	Fruits	*Capsicum frutescens*
Nkoumou	Leaves	*Gnetum africanum*
Okra	Fruits	*Abelmoschus calei*
Eggplant	Fruits	*Solanum melongena*
Lemon grass	Leaves	*Cymbopogon citratus*
Yam	Tubers	*Dioscorea spp*
Cassava	Leaves Tubers	*Manihot esculenta Crantz*
Amaranth	Leaves	*Amaranthus cruentus*
Roselle with small red leaves	Leaves	*Hibiscus sabdariffa*
Roselle with large green leaves	Leaves	*Hibiscus sabdariffa*

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. Double distilled deionized water was used throughout the study. Glassware was properly cleaned, and the reagents were of analytical grade. Standard plant reference materials (DC 73349) from China National Analysis Center for Iron were analyzed as a part of the quality assurance-quality control protocol (accuracies within 100% ± 10%). Blank and drift standards were run after ten determinations to maintain instrument calibration. The coefficient of variation of replicate analyses was determined for the measurements to calculate analytical precision.

2.2. Daily Intake of Elements

The estimated daily intake (EDI) of elements depended on both the element concentration in crops and the amount of consumption of the respective food crop. In this study, the daily intake was considered for each edible part of plants. The estimated daily intake (EDI) of Mg, Ca, K and Na through edible parts of food crops was calculated according to the following **Eq.1** [8]:

$$\mathrm{DIM} = [\mathrm{M}] \times \mathrm{K} \times \mathrm{I} \quad (1)$$

where [M]: macro-element concentration in plants ($mg \cdot kg^{-1}$), K: conversion factor used to convert fresh part consumed of plant weight to dry weight, estimated to 0.085, I: daily intake of consumed plants in kg. The average daily food crops intakes for adults and children were considered to be 0.345 and 0.232 kg/person/day, respectively [9].

2.3. Statistical Analysis

Pearson's correlation coefficients were calculated and one-way ANOVA method to test the significant differences of macro-element content in edible parts of crop foods regions was employed, the level of significance was set at $p < 0.05$. Statistical analyses were performed with the software XLSTAT (version 2010).

3. RESULTS AND DISCUSSION

3.1. Metal Concentrations in Edible Parts of Food Crops

Elemental composition of samples, reported on dry weight basis, is given in **Table 2**. On comparative basis, the tubers had less Mg and K levels than the fruits ($p < 0.042$ and $p < 0.049$, respectively). Ca and Na presented no significant differences for the three plant parts. Furthermore, certain edible parts showed interesting element uptake. Thus, *Abelmoschus calei* (fruits), *Amaranthus cruentus* and green *Hibiscus sabdariffa* (leaves) had the highest levels of Mg (5154, 5374 and 4247 mg/kg respectively); *Solanum melongena* (fruits), *Amaranthus cruentus* and green *Hibiscus sabdariffa* (leaves) had the highest levels of Ca (15,049, 21,384 and 32,721 mg/kg respectively); *Capsicum frutescens* had the highest levels of K (11,902 mg/kg) green *Hibiscus sabdariffa* (leaves) had the highest levels of Na (745 mg/kg). When *Gnetum africanum* was the most consumed vegetable in the East region of Gabon, it was the poorest of food crops studied because it accumulated the lowest macro-element concentrations. The trend of accumulation in the edible parts of plants was generally: Ca > K > Mg > Na.

Macro-elements are essential minerals required for the diverse physiological and biochemical functions in the human body. They are absorbed by human and animals via foods as plants. The levels of macro-elements and others minerals in plants are influenced by their interactions and the soil nature and chemical composition [10].

Milk and other dairy products are excellent sources of calcium, both qualitatively and quantitatively. However, in some countries, milk consumption is limited due to the undesirable effects of lactose intolerance [11]. Green leafy vegetables, seeds and legumes are good alternative sources of calcium, in addition to cow milk and fish with bones. Thus, *Amaranthus cruentus*, green *Hibiscus sabdariffa* and *Solanum melongena* could be considered good or excellent source of calcium because its concentrations were higher than 1000 mg/kg [12].

The magnesium chief function in the body includes bone mineralization, building of proteins, and a magnesium deficiency results in osteoporosis [13]. Therefore, magnesium role with regard to bone quality and nutrition is really indispensable. In this study, fruits and leaves had higher Mg concentrations than tubers. Mg, as a constituent of chlorophyll, is contained in large quantities of green leafy vegetables. Mainly centered on plant foods, the African traditional diet appears to have sufficient Mg

Table 2. Metal concentrations in edible parts of dry food crops (mg/kg).

		Mg	Ca	K	Na
Leaves	*Gnetum africanum*	257 ± 12 f	1382 ± 310 e	168 ± 10 g	94 ± 6 d
	Cymbopogon citratus	562 ± 27 ef	5447 ± 380 d	6652 ± 387 de	479 ± 108 b
	Amaranthus cruentus	4248 ± 436 b	21,384 ± 1492 b	10,269 ± 598 ab	471 ± 31 b
	Hibiscus sabdariffa (*red*)	2245 ± 108 c	3248 ± 549 de	7935 ± 462 cd	455 ± 29 b
	Hibiscus sabdariffa (*green*)	5375 ± 258 a	32,722 ± 2283 a	8378 ± 1243 bcd	745 ± 48 a
	Manihot esculenta	2235 ± 107 c	2473 ± 430 e	7974 ± 464 cd	436 ± 28 b
Fruits	*Capsicum frutescens*	2002 ± 630 cd	3032 ± 212 de	11,903 ± 1649 a	531 ± 63 b
	Abelmoschus calei	5155 ± 247 a	2344 ± 164 e	9932 ± 473 f	457 ± 30 b
	Solanum melongena	1270 ± 61 de	15,049 ± 1050 c	4357 ± 254 abc	282 ± 16 c
Tubers	*Dioscorea spp*	623 ± 30 ef	4010 ± 280 de	3930 ± 652 f	397 ± 26 bc
	Manihot esculenta	412 ± 62 f	3091 ± 216 de	5407 ± 315 ef	480 ± 31 b

content. However, due the increasing consumption of fatty and animal foods, plant diet decreases.

The potassium level was > 3000 mg/kg in all samples, exception of *Gnetum africanum*. Na level was < 1000 mg/kg in all samples. K is an abundant ion in the plant and human cells and is required for a wide array of functions, ranging from the maintenance of electrical potential gradients across cell membranes, to the generation of turgor, to the activation of numerous enzymes [14], while Na is the principal ion in the fluid outside of cells. Na and K together with Cl are electrolytes that maintain normal fluid balance inside and outside cells and a proper balance of acid and bases in the body. A large portion of energy in the body is dedicated to maintaining sodium/potassium concentration gradients, underscoring the importance of the balance between sodium and potassium in sustaining life. Tight control of cell membrane potential is critical for heart function, as well as nerve impulse transmission and muscle contraction [15].

Nutrient correlation analysis showed significant relations between the four elements, exception between Ca and K (**Table 3**). Interactions between chemical elements may be both antagonistic and synergistic, and their imbalanced reactions may cause a real chemical stress in plants. These interactions may also refer to the ability of one element to inhibit or stimulate the absorption of other elements in plants. Interaction processes are controlled by several factors and these mechanisms are still poorly understood [16]. Thus, an antagonistic effect of K on the Ca content was exerted in the studied edible parts of plants. This antagonism between Ca and K is quoted in the literature [17].

3.2. Average Daily Mineral Intake

The levels of the minerals indicated that the local food crops could be valuable and important contributors in the diets of people of Gabon. The mean food crops contribution of daily intakes and the recommended Intakes of Mg, Ca, K and Na for both adults and children were presented in **Table 4** [18,19]. The average daily intake was 5.1 - 157.6 mg/day for Mg, 27.2 - 959.6 mg/day for Ca, 3.3 - 349.0 mg/day for K and 1.9 - 21.9 mg/day for Na. In general, local food crops offered greater nutritional contributions to the recommended intakes of Mg and Ca (2% - 82% and 3% - 81% of recommended daily intakes, respectively) than K and Na (2% - 8% and 0% - 2% of recommended daily intakes, respectively). Furthermore, because of the high recommended daily intakes of Mg between children and adults, contributions to this element were more two times for children than for adults.

Table 3. Correlation matrix of accumulated macro-nutrients in food crops.

	Mg	**Ca**	**K**	**Na**
Mg	**1**			
Ca	**0.585*****	**1**		
K	**0.645*****	0.220	**1**	
Na	**0.594*****	**0.491****	**0.667*****	**1**

4. CONCLUSION

The mineral composition of food crops in this study showed that they could be rich sources of macro-nutrients, and contribute significantly to daily intake of calcium and magnesium, particularly. International and national health agencies are working in the world to knowledge the food composition and developing new standards, but in developing countries like Gabon these studies are still scarce or lacking. Thus, more studies could be led in the order to assess the complete nutritional contribution of principal meals.

Table 4. Estimated daily intake of metals by edibles parts of plants of Moanda.

		Mg		Ca		K		Na	
		Children	Adults	Children	Adults	Children	Adults	Children	Adults
Leaves	*Gnetum africanum*	5.1	7.5	27.2	40.5	3.3	4.9	1.9	2.8
	Cymbopogon citratus	11.1	16.5	107.4	159.7	131.2	195.1	9.4	14.0
	Hibiscus sabdariffa (*red*)	44.3	65.8	64.0	95.2	156.5	232.7	9.0	13.3
	Hibiscus sabdariffa (*green*)	106.0	157.6	645.3	959.6	165.2	245.7	14.7	21.9
	Amaranthus cruentus	83.8	124.6	421.7	627.1	202.5	301.1	9.3	13.8
	Manihot esculenta	44.1	65.6	48.8	72.5	157.2	233.8	8.6	12.8
Fruits	*Capsicum frutescens*	39.5	58.7	59.8	88.9	234.7	349.0	10.5	15.6
	Abelmoschus calei	101.6	151.2	46.2	68.7	195.9	291.2	9.0	13.4
	Solanum melongena	25.0	37.2	296.8	441.3	85.9	127.8	5.6	8.3
Tubers	*Dioscorea spp*	12.3	18.3	79.1	117.6	77.5	115.2	7.8	11.6
	Manihot esculenta	8.1	12.1	60.9	90.6	106.6	158.6	9.5	14.1
	Recommended Intakes for Individual Elements[1]	130.0	420.0	800.0	1300.0	3800.0	4700.0	1200.0	1500.0

[1]: [18,19].

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