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Evaluation of Mineral Elements Content of Senegal Fruits

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Abstract

This study determined mineral value and antioxidant activity of Senegal fruits for contributing to improving healthy diet and preventing some chronic diseases. Mineral element contents of *Dialium guineense*, *Landolphia heudelotti*, *Mangifera indica*, *Cyperus esculentus* and *Saba senegalensis*, which are widely available and consumed, were studied. The results by ICP-OES spectrophotometry after acid mineralization showed highest levels of (per 100 g fruits), calcium (158 mg), potassium (1018 mg), magnesium (532 mg), zinc (26 mg) with juice of *Landolphia heudelotti* fruit pulp. *Mangifera indica* pulp is richer in sodium (89 mg), phosphorus (556 mg), sulphur (384 mg) and silicon (110 mg). *Dialium senegalensis* pulp is richer in iron (23 mg) and manganese (19 mg). Lyophilized *Cyperus esculentus* rhizomes analyzed by atomic absorption spectrophotometry gave highest concentrations of (per 100 g fruits), calcium (2550 mg), potassium (11,843 mg) and magnesium (7669 mg) but sodium content (22 mg) is lower. *In vitro* antioxidant activity evaluation with the DPPH radical showed for 10 mg/ml concentration, highest inhibition percentage for *Saba senegalensis* 4.03%, followed by *Landolphia heudelotti* and *Dialium guineense*, which were significantly similar 2.29% and 2.20% respectively, *Mangifera indica* 1.7% and finally *Cyperus esculentus* 0.5%, but much lower compared to the ascorbic acid equal to 96.32% used as a reference.

Keywords

Fruits, Senegal, Mineral Elements, Antioxidant Activity

1. Introduction

Currently, non-transmissible diseases (NTDs), including cardiovascular disease,

cancers, obesity and type 2 diabetes, cause more deaths each year. Poor diet, lack of physical activity, tobacco and alcohol are factors in the epidemiology of these diseases and are very important in public health [1] [2].

Fruits and vegetables are an important part of a healthy diet and, if consumed daily in sufficient quantities, they could help prevent serious diseases such as cardiovascular diseases and cancers [3] [4] [5] [6]. For example, according to the World Health Organization (WHO), low consumption of fruits and vegetables is the cause of about 31% of ischemic heart diseases and 11% of strokes worldwide. Indeed, globally, up to 2.7 million lives could be saved each year [1] by sufficient consumption of fruits and vegetables as dietary sources of fibers, vegetable proteins and protective micronutrients [7] [8] [9] [10] [11].

In this context, a minimum daily intake of 400 g of fruits and vegetables (excluding potatoes and other starchy tubers) is recommended to prevent chronic diseases such as heart diseases, cancers, diabetes, obesity [1] [12] [13] and to prevent or reduce several micronutrient deficiencies, particularly in the least developed countries [1].

In 2016, Senegal was among the least developed countries, ranked 165th in the world economy, 29th in Africa and 4th in the western part. It is characterized by low economic growth and high dependence on official development assistance. The prevalence rates of NTDs are more than 5.5% for diabetes and nearly 24% for high blood pressure [14]. Despite relatively low rainfall, a great diversity of local fruits is available in Senegal. The development of local resources and food self-sufficiency seem essential for sustainable development. Thus, the objective of this study is to determine the nutritional value, particularly mineral value, of 5 local fruits that are widely consumed in this country: *Dialium guineense*, *Landolphia heudelotti*, *Mangifera indica*, *Cyperus esculentus* and *Saba senegalensis*.

Dialium guineense Willd (Fabaceae) or *Dalium nitidum* or Black Tamarind corresponds to a tree 10 to 15 m high. The pulp surrounding the seed is acidic, it is sucked to quench thirst or macerated in cold water as a drink [8] [15]-[20]. The pulp is used, with other astringent drugs, for the treatment of diarrhoea, as well as the bark of the trunk [21] [22] and as an antimicrobial in wound healing [23]. In some localities, the consumption of fruit infusion is recommended against fever [8].

Landolphia heudelotti (Apocynaceae) is a sarmentose shrub bushy presenting clumps from 2 to 5 cm high, or vine that can reach 15 m high. The fruits are spherical matte green berries that become orange-yellow when ripe; then a fine pulp sticks strongly to the seeds. Fruits are sold on local markets, the juice from the pulp is acidic and used as a seasoning. The decoction of leaves or roots has enteralgic properties without purgative effect [8]. The latex produced by the plant was used for rubber production for a long time before being replaced by rubber and synthesis [8].

Mangifera indica L. (Anacardiaceae) or mango is a large fruit tree that can reach 10 to 25 meters in height. It has a stocky barrel and a dense shade foliage.

The fleshy fruit is an oblong drupe attached to a long peduncle, of variable size depending on the variety. According to Pousset [14], all parts of mango are used in traditional medicine as an antidiarrheal. Some parts of the plant have been proven to be antidysenteric, antiamibiase, antioxidant, anti-inflammatory and can be used as analgesics [8] [24] [25].

Cyperus esculentus L. (Cyperaceae) or Tiger Nuts, an annual plant with tuberized rhizomes, is pantropical and cultivated in all dry regions of Africa. It is a perennial species that grows in small clumps, with a single flowering axis, but is connected to many son feet by spherical rhizomes, with a sweet taste. Depending on the locality, the leaves are used against migraines, the rhizome as a galactogen, stomachic, against headaches, diarrhoea, stomach aches, indigestion and bloating. This rhizome is an energy food [26] [27] [28] and is recommended in the prevention of heart attacks, thrombosis, colon cancer, diabetes and obesity [29] [30]. These properties are justified because of the high content of soluble glucose, vitamin E, fibers and minerals [29].

Saba senegalensis A. DC. Pichon (Apocynaceae) or guava vine, is a large woody vine, picked up on itself or climbing. It produces a milky sap and large fruits in the form of berries which contain a pulp sticking to the seeds. Leaves in boiling decoctions and inhalations could be anti-migraine and vapours could improve declining vision and rebellious coughs. Dry root bark powder is used as a healing agent on wounds and burns. Stem latex is hemostatic, coagulant, antitussive, antituberculous and emetic [8] [31]. Finally, the fruit is highly consumed because it is succulent, seasoned, in juice or marmalade, increasing the added value of the plant. Thus, *Saba senegalensis* has been the subject of domestication and planting studies [32].

In this study, the mineral contribution for these 5 fruits will be detailed along with the antioxidant activity of each.

2. Experimental

2.1. Material

2.1.1. Plant Material

Fruit samples of *Dialium guineense*, *Landolphia heudelotti* were collected in Casamance region and *Mangifera indica* was collected in Dakar. The rhizomes of *Cyperus esculentus* and the fruits of *Saba senegalensis*, were purchased at the Colobane market (Dakar). However, according to our surveys, most of these forest fruits sold in the markets would come from Casamance region.

The studied samples of these different fruits are mainly pulps and only rhizomes for *Cyperus esculentus* (**Figure 1**).

2.1.2. Reagents and Equipment

All reagents used were of purity for residue analysis. This study involved notably a lyophilization of samples with a Christ Martin™ alpha 1 - 2 LD Plus freeze-dryer, a mineralization with a Berghof microwave oven, a determination of the concentrations of elements using an inductively coupled plasma atomic

Figure 1. Studied fruits samples.

emission spectrometer (ICP-OES Agilent Technologies 5100, software ICP expert 7.4.1.0), a Varian SpectrAA 220 atomic absorption/emission spectrophotometer with air/acetylene flame for *Cyperus* samples and determinations of antioxidant activities with a UV-Visible spectrophotometer ATI Unicam.

2.2. Methods

2.2.1. Determination of the Concentrations of Elements

Frozen samples of fruits were lyophilized and a mass of 0.2 ± 0.01 g was weighed 3 times for each. They were then subjected to an acid mineralization consisting of a contact time of one hour with 10ml of mixture of HCl 37% (2 volumes) and HNO_3 68% (1 volume) in Teflon bombs. The mineralization was performed during 50 minutes in the microwave oven (room temperature to 170˚C (10 min), 170˚C (10 min), 170˚C to 100˚C (10 min), 100˚C (10 min), 100˚C to 80˚C (5 min), 80˚C (5 min). Thus, mineralization was carried out in triplicate for each fruit sample. The mineralized samples were then collected in a volumetric flask and the volume adjusted precisely to 50 ml with ultrapure water and stored further in the refrigerator at +4˚C. A filtration step using a syringe equipped with a microfilter (0.45 µm diameter) was performed before analysis with the ICP-OES spectrophotometer.

The following elements were specifically targeted using ICP-OES: Al (396,15 nm), As (188,980 nm), B (249,678 nm), Ca (422,673 nm), Cd (226,502 nm), Co (258,033 nm), Cr (267,716 nm), Cu (327,395 nm), Fe (238,204 nm), Ge (206,866 nm), K (766,491 nm), Li (670,783 nm), Mg (279,078 nm), Mn (257,610 nm), Mo (204,598 nm), Na (589,512 nm), Ni (216,555 nm), P (213,618 nm), Pb (217,000 nm), S (181,972 nm), Si (288,158 nm), Ti (344,188 nm), Zn (213,817 nm). Calibration was performed using nine points (2 decades) of dilution of a stock solution containing the whole elements at different concentrations. The stock solution was obtained by dilution of certified individual element or multi-element solutions at 1000 and 10,000 ppm.

2.2.2. Determination of the Antioxidant Activity

In this study, *in vitro* evaluation of antioxidant activity was performed by visible

spectrophotometry with the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical according to the procedures described [33] [34]; the maximal absorption of the reduced DPPH radical is detected at 517 nm in ethanol. Antioxidant activity is defined by the index of the reduction of radical activity in percentage or percentage inhibition of oxidant activity noted PI. Thus, the absorbance of the reaction mixture, free radical and antioxidant sample (Abs sample), is related to the absorbance of the mixture without antioxidant (Abs witness) at a time t by the following relationship [34]:

$$\mathrm{PI}\% = \left(\left(\mathrm{Abs\ Witness} - \mathrm{Abs\ sample}\right)/\mathrm{Abs\ Witness}\right)\times 100$$

A mixture of 0.5 g ± 0.01 of fruit samples with 25 ml of ethanol was stirred at room temperature one hour with ultrasound and macerated for 48h before being filtered and evaporated with rotavapor. The dry residue was taken back with 1 ml of ethanol and represented then the stock solution. 0.1 ml of this stock solution of ethanolic extract from fruit samples was added to 3.9 ml of 4% DPPH-. This mixture was placed in a dark place and the reading was taken after 30 minutes on a spectrophotometer at 517 nm. Each reading was repeated three times.

3. Results and Discussion

3.1. Concentrations of Minerals

The four targeted fruits (*Dialium guineense*, *Landolphia heudelotti*, *Mangifera indica*, *Saba senegalensis*) and the dried rhizome of *Cyperus esculentus* are containing rather different concentrations of minerals (**Figure 2**). Comparing the fruits, the highest levels of calcium (158 mg/100g), potassium (1018 mg/100g), magnesium (532 mg/100g) and zinc (26 mg/100g) are obtained with the juice from the mechanical expression of the pulp of *Landolphia heudelotti* fruit. Comparatively, Mango flesh pulp (*Mangifera indica*) is richer in sodium (89 mg/100g), phosphorus (556 mg/100g), sulphur (384 mg/100g) and silicon (110 mg/100g) while the pulp of *Dialium senegalensis* is richer in iron (23 mg/100g) and manganese (19 mg/100g). Globally, the pulp of *Saba senegalensis* is poorer in quite all elements.

The levels of a dozen of elements: Al, As, B, Cd, Co, Cr, Cu, Ge, Li, Ni, Pb, Ti were also investigated in these fruits. However, the recorded absorbances using ICP-AES were systematically lower than the limits of detection of each element. With all the limits of detection measured between 25 and 175 µg/kg, it is possible to state that these elements are only present in the form of ultra-traces and that their concentrations never reach 175 µg/kg in the fruits.

The composition in minerals of *Cyperus esculentus* was determined using atomic absorption and emission spectroscopy. The results obtained for this fruit are rather different from others because the dried rhizome part was analyzed. The concentrations of calcium (2550 mg/100g), potassium (11,843 mg/100g) and magnesium (7669 mg/100g) were very high compared to the levels observed in the other samples. However, the concentration in sodium (22 mg/100g) is in the

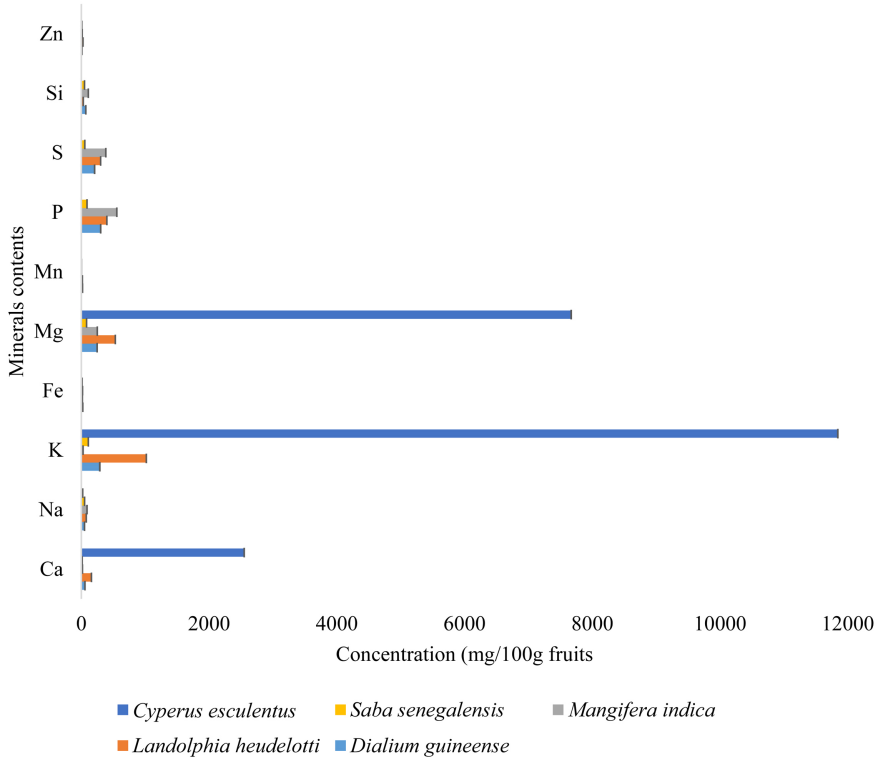

Figure 2. Fruits minerals concentrations.

same order and even a little lower.

According to the results, the various medicinal uses can be justified by the content of mineral elements, in particular calcium, iron, potassium, magnesium, manganese, phosphorus, sulphur and silicon.

3.2. Comparison of the Concentrations of Minerals in Studied Fruits with Other Fruits

The mineral composition of the studied fruits is compared with other fruits that also grow in Senegal. The data, from the literature, for these other fruits, which are known to be nutritious, are reported in **Figure 3**. They concern the fruit pulp of *Adansonia digitata* (baobab) [8], banana or *Musa* spp, orange or *Citrus sinensis*, date or *Phoenix reticulata* and *Detarium senegalense* [35] [36]. Some of these reference fruits are the most consumed in Senegal.

Firstly, Achoba *et al*. [16] already analyzed the pulp of *Dialium guineense* in the early 1990s. The Nigerian species exhibited concentrations of 213 mg/100g, 42 mg/100g, 11 mg/100g and 98 mg/100g respectively for Ca, Mg, Na and K. In addition, we showed that *Dialium guineense* has also a high content in Fe and Mn (23 mg/100g and 19 mg/100g respectively). These contents in Fe and Mn are the highest we found in the four studied juices (**Figure 2**). Studies led by Haddad [8], also for *Dialium guineense*, have shown lower concentrations of Ca (104 mg/100g), P (71 mg/100g) and Fe (2.6 mg/100g). *Dialium guineese*, compared to the reference fruits (**Figure 3**), is richer in Fe than *Adansonia* (8.6 mg/100g),

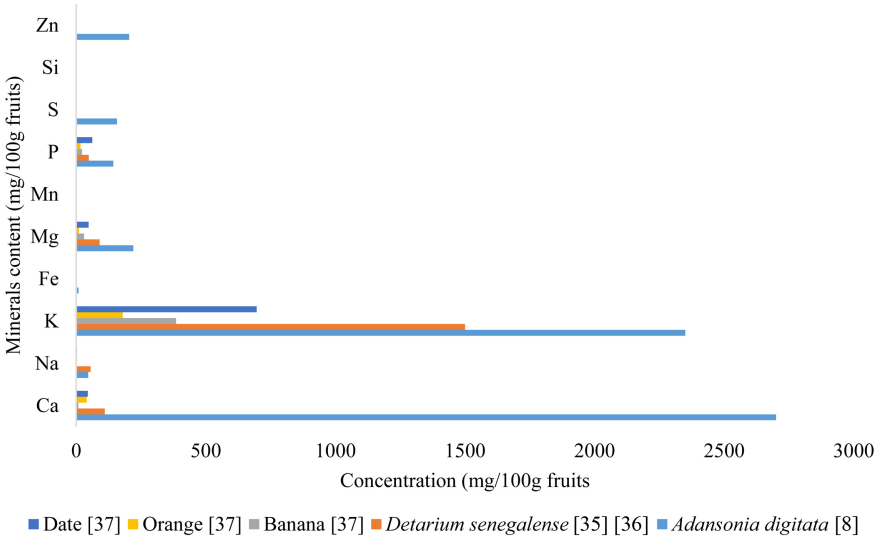

Figure 3. Minerals concentrations according to bibliographic data of the fruits taken as reference.

in Mn than date (0.3 mg/100g), which have the highest levels of these elements among the reference fruits.

Landolphia heudelotti could represent an important source of magnesium (532 mg/100g) if compared to other fruits of reference (**Figure 3**). It is twice that of *Adansonia digitata* [8], more than 5 times that of *Detarium senegalense* [35] [36] and more than 10 times that of banana, orange or date [37].

Among the four studied fruits, *Mangifera indica* pulp has the highest Na, P, S and Si contents. This fruit could then represent a great intake of notably phosphorous as it is 5 times higher than that of *Adansonia digitata* [8] which has the higher content in that element along the reference fruits (**Figure 3**). Moreover, this mango is a little richer in sodium than all reference fruits and notably *Detarium senegalensis* [35] [36].

S*aba senegalensis* pulp exhibits relatively low contents of calcium (14 mg/100g) and potassium (110 mg/100g). However, if compared to other fruits of reference (**Figure 3**), it contains significant quantities of sodium (51 mg/100g) and iron (12 mg/100g).

The dried rhizome of *Cyperus esculentus* is containing very high contents of Ca (2550 mg/100g), K (11843 mg/100g) and Mg (7669 mg/100g) in comparison with other fruits (**Figure 3**). High quantities for this rhizome were already determined for species grown in Senegal by Ndiaye *et al*. [28] with 26 mg/100g of Ca, 896 mg/100g of K and 105 mg/100g of Mg. The level of potassium is then rather important in the studied rhizome; on another hand, the sodium content of the dried rhizome (22 mg/100g) is very low. Similarly, by comparing these results with other rhizomes [38], the levels found were as follows: *Zingiber officinale* (Zingiberaceae) or ginger, for 100 g of raw root, 16 mg Ca, 0.6 mg Fe, 43 mg Mg, 34 mg P, 415 mg K, 13 mg Na, 0.34 Zn; *Curcuma longa* (Zingiberaceae) or turmeric, with: 183 mg of Ca, 41.42 mg of Fe, 193 mg of Mg, 2525 mg of K, 38

mg of Na, 4.35 of Zn, 0.6 mg of Cu, 7, 8 mg of Mn, 4.5 µg of Se. They are also significantly lower.

Thus, the recommended minimum daily intakes (Table 1), related to Directive 2008/100/EC, which are respectively 120 mg, 375 mg, 600 mg, 120 mg, 45 mg, 0.525 mg and 2.25 mg for Ca, Na, K, P, Mg, Mn and Zn could be largely covered by the consumption of the studied fruits according to the recommendation of the WHO.

3.3. Antioxidant Activity

Comparing the whole fruit studied, at a 10 mg/ml concentration, *Saba* had the highest PI at 4.03%, followed by *Landolphia* and *Dialium*, which exhibit similar PI values of 2.29% and 2.20% respectively. Value for *Mangifera indica* was 1.7% and that of *Cyperus* was 0.5%. Global values obtained for all fruits are much lower compared to the PI (96.32%) of the ascorbic acid used as a reference. The IC_{50} of *Landolphia* (194 mg/ml) and *Saba* (150 mg/ml) could be determined for an IC_{50} equal to 0.147 mg/ml for ascorbic acid. These results, which are low *in vitro*, can be increased in the human body. Indeed, some elements such as Mn, Zn, Cu and Zn are essential to the antioxidant activity of enzymes such as superoxide dismutase and glutathione peroxidase [9] [24] [39].

Table 1. Recommended Daily Intake (RDI) for minerals.

Nutrient name (unit)	RDI value of directive 90/496/EEC + RI 3/3/1992*	RDI value of Directive 2008/100/EC	Minimum (% of RDI)	Maximum (% of RDI))
Calcium (mg)	800	800	120 (15)	1600 (200)
Chloride (mg)	3500*	800	525 (15)	7000 (200)
Chromium (µg)	125*	40	18.75 (15)	187.5 (150)
Fluoride (mg)	-	3.5	-	-
Phosphorus (mg)	800	700	120 (15)	1600 (200)
Iron (mg)	14	14	2.1 (15)	28 (200)
Iodine (µg)	150	150	22.5 (15)	225 (150)
Potassium (mg)	4000*	2000	600 (15)	6000 (150)
Cuivre (mg)	1.1*	1	0.165 (15)	1.65 (150)
Magnesium (mg)	300	375	45 (15)	450 (150)
Manganese (mg)	3.5*	2	0.525 (15)	5.25 (150)
Molybdenum (µg)	150*	50	22.5 (15)	225 (150)
Sodium (mg)	2500*	-	375 (15)	5000 (150)
Selenium (µg)	70*	55	10.5 (15)	105 (150)
Zinc (mg)	15	10	2.25 (15)	22.5 (150)

4. Conclusions

This study revealed interesting levels of essential or important mineral elements in local fruits, as well as their antioxidant activities. These fruits of forest origin, which are relatively easy to access and available in the markets, could contribute to improving the nutritional status of populations and thus the prevention of certain diseases.

In perspective, it is envisaged to extend this study to other local vegetable products in order to have its own mineral databases and furthermore elaborate diets adapted to our context of low income countries.

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Declaration of Conflicting Interests

The author(s) declare(s) that there is no conflict of interest.

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