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Research Article

Nutritional Composition of Five Spontaneous Wild Plants Used as Human Foods in Côte d'ivoire Areas (West Africa), a Potential Role in Household Food Security

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Abstract

Objective: The present investigation was undertaken to investigate the proximate, mineral, vitamin and phytochemical constituents of five spontaneous plant species widely consumed in Côte d'Ivoire: *Solanum nigrum* (Fouébrou), *Ceratotheca sesamoides* (Nanogo), *Sesamum radiatum* (Mangnrin), *Abelmoschus tuberculatus* (Kogogban), *Myrianthus arboreus* (Tikriti). **Materials and Methods:** Proximate values were determined according to standard methods and the energy content was calculated. Food plants mineral analysis was performed by atomic absorption spectrophotometric methods. The data were statistically analyzed. **Results:** Proximate composition of the plant foods samples ranged in 6.9-11.0% moisture, 11.0-13.3% ash, 14.6-19.5% crude fiber, 20.3-29.0% protein, 3.0-22.0% lipid, 34.0-55.3% carbohydrate and 331.0-430.3 kcal/100 g calorific values. Vitamin B9 and β-carotene compositions varied in 432.3-13480.0 and 0.2-0.4 mg/100 g, respectively. The elemental analysis of the six leaves in mg dry matter indicated that the leaves contained appreciable levels of potassium (1238-4228 mg/100 g), calcium (1058-2446 mg/100 g), magnesium (393-607 mg/100 g) and iron (0.3-0.8 mg/100 g). The antinutrient composition for phytic acid, oxalic acid and total polyphenols were ranged in 720-1300, 700-837 and 2012-8299 mg/100 g, respectively. The different ratios sodium/potassium (<1) and oxalates/calcium (<2.5) were under the respective critical value for all the species. **Conclusion:** These results revealed that these leaves can be used to combat micronutrient deficiency, also called "hidden hunger", a main cause of health problems and high mortality for groups at risk, mainly children and pregnant women in tropical Africa.

Key words: Antinutrient, proximate composition, spontaneous food plants, folate, antioxidant properties

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In tropical Africa, micronutrient deficiency, also called hidden hunger, is a main cause of health problems, high mortality and low economic productivity. According to the FAO/WHO, nutritionists emphasize that a daily portion of various vegetables is essential for a well balanced diet, in particular for children and pregnant women[1]. For this purpose, spontaneous leafy vegetables play an important role in the diets of world populations, particularly in Africa[2]. Some indigenous leafy vegetables grow in the wild and are readily available in the field, as they do not require any formal cultivation. Many of them are resilient, adaptive and tolerate adverse climatic conditions more than the exotic species[3]. Consequently, they contribute to poverty reduction because of their relatively low cost and their ability to generate income in a relatively short period of time compared to cereals[4]. Spontaneous leafy vegetables are sources of vitamins and minerals and their consumption, in conjunction with staple food crops, can provide a balanced and healthy diet, especially where malnutrition is wide spread[5]. Moreover, the organic status awareness of these products create a real interest for consumers since epidemiological studies have linked the dietary habits and the prevalence of certain diseases such as cancer, obesity and cardiovascular diseases[6,7]. Among the 207 leafy vegetables are widely consumed in tropical Africa, about 20 leafy vegetables species belonging to 6 botanical families are widely consumed and cultivated by Ivorian populations[8,9]. The consumption of these leafy vegetables is linked to the region and ethno-botanical studies have stated that most people in Northern Côte d'Ivoire consume indigenous green leafy vegetables[9,10]. Earlier reports have highlighted the nutritive potential of fresh leafy vegetables[11-13] but there is a lack of scientific data with regards to the mostly spontaneous leafy vegetables in Côte d'Ivoire. *Solanum nigrum* (Fouébrou), *Ceratotheca sesamoides* (Nanogo), *Sesamum radiatum* (Mangnrin), *Abelmoschus tuberculatus* (Kogogban) and *Myrianthus arboreus* (Tikriti) are widely consumed in rural and urban areas of Côte d'Ivoire and notwithstanding the long-term use of the vegetables leaves in various traditional dishes preparations, there is paucity of information on their nutritional composition. Therefore, the present study was aimed at evaluating the nutritional composition of these spontaneous plant species.

MATERIALS AND METHODS

Sampling: Five spontaneous plant species were selected for the study: *Solanum nigrum* (locally known as Fouébrou), *Ceratotheca sesamoides* (Nanogo), *Sesamum radiatum* (Mangnrin), *Abelmoschus tuberculatus* (Kogogban) and *Myrianthus arboreus* (Tikriti). They were collected fresh and at maturity from the local farmers in the Gagnoa district of West-Central Côte d'Ivoire. These species grow spontaneously in forests, fallow lands and cocoa and coffee plantations[14]. The samples were harvested in the field with a random sampling procedure. The choice of Gagnoa district was based on ethno-botanical surveys carried out by Kouame *et al.*[14]. These plants were previously authenticated by National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Côte d'Ivoire).

Sample preparation and drying: All collected samples were put into clean, dry sample containers and transferred to the Laboratory of Food Biochemical and Tropical Products Technology (Abidjan, Côte d'Ivoire) immediately for the flour preparation. The leafy vegetables were washed in fresh running water to eliminate dust, dirt, possible parasites or their eggs, after, they were again washed with deionized water. Only the edible leaf tissue was used for analyses. The fresh leaves were air dried in the laboratory to remove the surface water, thereafter oven-dried (Thitec 250, France) at 45°C for 72 h. The leaves were milled into powder using an electric blender (Bimby mod. 2200, Vorwerk, Wuppertal, Germany) and stored in polyethylene bags at room temperature prior to analysis.

Chemicals and reagents: All chemical reagents were obtained from Sigma Chemical Co. (St. Louis, MO, USA), unless otherwise stated. Ultra-pure water with a resistivity of 18.2 M was used in all experiments provided by ELGA (Flex III, U.K) water purification system.

Experimental analysis

Proximate analysis: The proximate analysis (protein, lipids, fibre, ash, moisture and carbohydrates) of dry samples of the plant leaves were determined by the method described by AOAC[15]. Moisture was determined by gravimetric method, heating in an oven at 105 ± 1°C until constant mass, total nitrogen was determined according to the Kjeldahl method and converted into protein, using factor 6.25, total lipids were extracted by the Soxhlet technique with hot solvent (hexane) and afterwards were determined by gravimetry, ash was determined by gravimetry of incinerated sample, in muffle, at 550°C. The total carbohydrate content was calculated by using the equation: 100-(moisture+protein+lipid+ash). The caloric value of samples was calculated using the Atwater conversion factors: 9 kcal g^{-1} of lipid, 4 kcal g^{-1} of carbohydrate and 4 cal g^{-1} of protein.

Mineral determination: For mineral determinations[15], glass and polypropylene materials were soaked in concentrated nitric acid (specific gravity = 1.41 g cm^{-3}) for 15 min and then rinsed 3 times with distilled deionized water before use. Mineral constituents comprising potassium (K), magnesium (Mg), iron (Fe), calcium (Ca), copper (Cu), manganese (Mn) and zinc (Zn) were determined by atomic absorption spectrophotometry (Unicam Analytical system, Model 919, Cambridge, UK), whereas, sodium (Na) determination was determined using a lame photometer (Jenway, PF 7, Essex UK). All samples were previously subjected to dry digestion at 450°C. To dissolve the ashes, 3 mL of concentrated HCl (specific gravity = 1.19 g cm^{-3}) were added, the vessel was covered with a watch glass and gently warmed (~70°C) for 3.5 h, leaving at the end of heating about 1 mL of liquid. The solution was then transferred to a 10 mL volumetric flask and the volume was completed with water. The solution was then used for individual mineral determination using spectrophotometer and flame photometer. These measurements were carried out in triplicates, with two measurements per analysis. All minerals were expressed in mg/100 g dry weight basis.

Antioxidant properties

Total phenolic compound content: The phenolic compounds were extracted following the procedure described by N'Dri *et al.*[16] and determined by the Folin-Ciocalteu assay[17]. Briefly, a dried sample (1 g) was extracted with 10 mL of 80% methanol at room temperature and then reacted with a 10-fold diluted Folin-Ciocalteu reagent. Sodium carbonate at a concentration of 6% (w/v) was added and the final volume was made up with deionized water. After incubation at room temperature for 15 min, the mixture's absorbance was measured against the gallic acid standard (the blank being prepared under the same conditions as before but without extract) at 725 nm using a spectrophotometer (PG Instruments, England). Total phenolic content was expressed as mg gallic acid equivalent (GAE)/100 g sample.

Vitamin essay: The determination of carotenoids (Pro-vitamin A) was carried out by high-performance liquid chromatography (HPLC) analysis according to Miglio *et al.*[18]. Briefly, 0.1 g of sample was extracted with tetrahydrofuran containing 0.01% BHT (2,6-Diter-butyl-p-cresol) as the antioxidant agent, dried under nitrogen flow in dark tubes, resuspended in dicloromethane and analyzed using a HPLC (Shimadzu LC10, Japan) controlled by Class VP software (Shimadzu, Japan) with a diode array detector (SPD-20A Shimadzu, Japan) and a Prodigy column (5 µm ODS3 100A, 250×4.6 mm, Phenomenex, Torrance, CA, USA). The injection volume was 20 µL and the carotenoids were eluted with a flow of 0.8 mL min^{-1}, following this linear gradient: Starting condition: 82% A and 18% B, at 20 min: 76% A and 24% B, at 30 min: 58% A and 42% B, at 40 min: 40% A and 60% B and at 45 min: 82% A and 18% B. Phase A was a mixture of acetonitrile, n-hexane, methanol and dichloromethane (2:1:1:1, v/v/v/v), while phase B was acetonitrile. Identification of the peaks in the HPLC chromatogram of the carotenoid extract was carried out by a comparison of UV-Vis spectra or with retention times of eluted compounds with pure standards at 450 nm for β-carotene.

Water-soluble vitamins (folic acid) were analyzed with high-performance liquid chromatography (HPLC) as described and detailed by Hasan *et al.*[19]. A mass of each sample (5 g) was weighed and transferred into conical flask and 25 mL of extraction solution was added, kept on shaking water bath at 70°C for 40 min. Extraction solution was made by mixing 50 mL of acetonitrile with 10 mL of glacial acetic acid and the volume was finally made up to 1000 mL with double distilled water. Thereafter, the sample was cooled down, filtered and finally the volume was made up to 50 mL with extraction solution. Then sample filtered through 0.45 µm filter tips and aliquots of 20 µL from this solution was injected into the HPLC by using auto-sampler (Shimadzu LC10, Japan). Analytical reversed phase C-18 column (ODS column, 250×4.6 mm, 5 µm, Phenomenex, Inc.) was used for the separation in mode isocratic (acetonitrile: 55 mL, tetrahydrofuran: 37 mL and water: 8 mL). The mobile phase rate is 1.5 mL and the detection wavelength is 325 nm. The 20 µL aliquots of the standard solutions and sample solutions were injected. The standard solution of vitamin B9 (folic acid) was prepared by dissolving 11.2 mg of folic acid in 25 mL of double distilled water.

During the extraction process, samples were always protected from direct exposition to light and kept on ice to minimize vitamins degradation.

Antinutritional factors

Phytic acid content: Phytic acid was determined by the new chromophore method of Mohamed *et al.*[20]. Briefly, a mass of 0.5 g of the sample is homogenized in 25 mL of 3% trichloroacetic acid (TCA) for 45 min and then centrifuged at 3500 rpm for 15 min. To 5 mL of the supernatant obtained are added 3 mL of 1% iron chloride prepared in hydrochloric acid

(1 N) and then heated on a water bath for 45 min. After cooling the mixture, 5 mL of hydrochloric acid (HCl) is added and the mixture is then left to stand for 2 h. Five milliliters of 1.5 N sodium hydroxide are then added to the mixture obtained above, the whole is carried on a water bath for 15 min and centrifuged again at 3500 rpm for 15 min after cooling. One milliliter of the supernatant is removed, to which added 4.5 mL of distilled water, 4.5 mL of ortho-phenanthroline reagent. The optical density is read at 470 nm on the spectrophotometer against a blank.

Oxalates: Oxalates content was determined by using the method described by Day and Underwood[21]. Briefly, 1 g of dried powder was weighed into 100 mL conical flask. Then 75 mL of 1.5 N H_2SO_4 was added and the solution was carefully stirred intermittently with a magnetic stirrer for about 1 h and then filtered using Whatman No. 1 filter paper. Sample extract of 25 mL (filtrate) was collected and titrated hot (80-90°C) against 0.1 N $KMnO_4$ solution to the point when a faint pink colour appeared that persisted for at least 30 sec.

Statistical analysis: One way analysis of variance (ANOVA) with replicates were used to analyse the significant difference among the results of samples. Multiple comparisons were made for all experiments using least significant difference test (Duncan's multiple range test) at a probability (p) of 0.05 and the results are expressed as mean±standard deviation (SD). Analysis was performed in triplicates.

RESULTS

Physicochemical properties: The proximate composition of the vegetables examined in this study is presented in Table 1. The physicochemical parameters generally differed significantly ($p<0.05$) from a leafy vegetable to another. The moisture content in all samples ranged from 6.9±0.2 to 11.0±0.0%. The ash content ranged from 11.0±0.0% (Nanogo and Tikriti) to 13.0±0.0% (Kogogban). There was a variation in the fibres content of the investigated leafy vegetables species, ranging from 14.6±0.0% (Mangnrin) to 19.5±0.0% (Fouèbrou). Fresh Fouébrou leaves had the highest protein content with 29.0±0.0%. Mangnrin and Tikriti had 6.0±0.0 and 3±0.0%, respectively as lipid contents.

Nutritive and antinutritional properties: Table 2 shows nutritive and antinutritional properties of the selected leafy vegetables. There was a significant difference ($p<0.05$) between most of these parameters. Vitamin B9 content ranged from 432.3±3.2 mg/100 g for Mangnrin to 13480±1.0 mg/100 g for Nanogo. The β-carotene content depended on the leafy vegetables species and varied from 0.2±0.0 mg/100 g for Nanogo to 0.4±0.0 mg/100 g for Kogogban. Total polyphenol of Nanogo had the highest value with 8299±12 mg/100 g. The selected leafy vegetables used in this study contained also anti-nutrients, amounts varied from 382±2 to 900±3 mg/100 g for oxalates and 720±3 to 1300±3 mg/100 g for phytates.

Table 1: Proximate composition of leafy vegetables

	Spontaneous leafy vegetables				
Composition	Kogogban	Fouébrou	Nanogo	Mangnrin	Tikriti
Moisture (%)	6.9±0.2^{c}	10.0±0.0^{b}	11.0±0.0^{a}	10.0±0.0^{b}	10.0±0.0^{b}
Ash (%)	13.0±0.0^{b}	13.3±0.0^{a}	11.0±0.0^{c}	13.0±0.0^{b}	11.0±0.0^{c}
Crude fiber (%)	18.4±0.0^{b}	17.1±0.0^{c}	16.7±0.0^{d}	14.6±0.0^{e}	19.5±0.0^{a}
Protein (%)	22.0±0.1^{b}	29.0±0.0^{a}	22.0±0.0^{b}	20.3±0.1^{d}	20.7±0.0^{c}
Lipid (%)	22.0±0.1^{a}	13.7±0.0^{c}	14.0±0.0^{b}	6.0±0.0^{d}	3.0±0.0^{e}
Carbohydrate* (%)	36.0±0.0^{a}	34.0±0.0^{d}	42.0±0.0^{f}	50.7±0.0^{h}	55.3±0.0^{i}
Energy (kcal/100 g)**	430.3±1.0^{a}	375.1±0.0^{d}	382.0±0.0^{e}	337.9±0.2^{g}	331.0±0.0^{h}

Data are expressed as dry matter basis. Data in the same row with different superscript letters are significantly different ($p<0.05$) as assessed by Duncan's multiple range test. Data are means (SD) of three independent experiments. *Calculated by difference of moisture content, ash, fiber, lipids and protein. **Energy value = 4×total carbohydrates (%)+4×protein (%)+9×lipids (kcal/100 g) (%)

Table 2: Nutritive and antinutritional properties of leafy vegetables

Vernacular name	Vitamin B9	β-carotene	Total polyphenols	Oxalates	Phytates
Kogogban	1080.0±1.0^{d}	0.4±0.0^{a}	6040±30^{b}	382±2^{a}	1070±54^{b}
Fouébrou	7801.7±1.5^{c}	0.4±0.0^{b}	2755±6^{d}	900±3^{a}	900±2^{c}
Nanogo	13480.0±1.0^{a}	0.2±0.0^{e}	8299±12^{a}	900±3^{a}	900±3^{c}
Mangnrin	432.3±3.2^{e}	0.2±0.0^{d}	2012±3^{e}	700±3^{a}	720±3^{d}
Tikriti	11642.3±2.5^{b}	0.3±0.0^{c}	4378±2^{c}	837±3^{a}	1300±3^{a}

Results expressed as mg/100 g dry weight basis. The average values assigned to the same letters in the same column are not significantly different ($p<0.05$)

Table 3: Mineral composition of leafy vegetables

Vernacular name	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
Kogogban	4228 ± 2^{a}	1336 ± 2^{c}	444 ± 2^{d}	0.3 ± 0.0^{e}	0.3 ± 0.0^{d}	0.05 ± 0.0^{c}	0.03 ± 0.0^{e}	0.02 ± 0.0^{c}
Fouébrou	2987 ± 2^{b}	1497 ± 3^{b}	473 ± 2^{c}	0.4 ± 0.0^{a}	0.3 ± 0.0^{c}	0.05 ± 0.0^{b}	0.03 ± 0.0^{d}	0.01 ± 0.0^{d}
Nanogo	1238 ± 3^{e}	1060 ± 2^{d}	393 ± 2^{e}	0.4 ± 0.0^{c}	0.8 ± 0.0^{a}	0.07 ± 0.0^{a}	0.03 ± 0.0^{c}	0.02 ± 0.0^{b}
Mangnrin	2459 ± 2^{c}	2446 ± 289^{a}	515 ± 2^{b}	0.3 ± 0.0^{d}	0.4 ± 0.0^{b}	0.05 ± 0.0^{d}	0.03 ± 0.0^{b}	0.03 ± 0.0^{a}
Tikriti	2234 ± 2^{d}	1058 ± 3^{e}	607 ± 1^{a}	0.4 ± 0.0^{b}	0.3 ± 0.0^{e}	0.04 ± 0.0^{e}	0.03 ± 0.0^{a}	0.01 ± 0.0^{e}

Results expressed as mg/100 g dry weight basis. Different letters in each column represent significant differences ($p<0.05$)

Table 4: Different ratio of leafy vegetables

Vernacular name	Na/K	Oxalate/Ca	Phytate/Ca
Kogogban	0.0	0.3	0.8
Fouébrou	0.0	0.6	0.6
Nanogo	0.0	0.8	0.8
Mangnrin	0.0	0.3	0.3
Tikriti	0.0	0.8	1.2

Mineral composition: Significant differences ($p<0.05$) were noted in the content of minerals between the five varieties (Table 3). The species analyzed in this study contained high amounts of potassium ranged from 1238±3 to 4228±2 mg/100 g, respectively for Nanogo and Kogogban. The calcium levels were between 1058±3 mg/100 g (Tikriti) and 2446±289 mg/100 g (Mangnrin). All the analysed plants were excellent sources of magnesium, ranging from 393±2 mg/100 g (Nanogo) to 607±1 mg/100 g (Tikriti). The analysis showed that Nanogo was the richest in fresh iron with 0.8±0.0 mg/100 g while Tikriti had the highest sodium content. Manganese, copper and zinc were quantified between 0.04±0.0 and 0.07±0.0 mg/100 g, 0.03±0.0 and 0.03±0.0 mg/100 g, 0.01±0.0 and 0.03±0.0 mg/100 g, respectively.

Table 4 shows the different ratio of the species. The oxalate/calcium and the phytate/calcium ratios were lower than 2. All the samples analyzed had their sodium/potassium ratio less than 1 (Table 4).

DISCUSSION

Physico-chemical parameters generally differed significantly ($p<0.05$) from one leaf vegetable to another. Moisture varied from 6.9±0.2 to 11.0±0.0 and provides a lower water soluble. The lower moisture content of leafy vegetables is not surprising since the fresh leaves were air dried in the laboratory to remove the surface water, thereafter oven-dried previously. Due to their ash content ranging from 11.0±0.0% (Nanogo and Tikriti) to 13.0±0.0% (Kogogban), selected leafy vegetables could be considered good minerals relative to values (2-10%) for cereals and tubers[22]. The crude fibres content of the leafy vegetable species studied is consistent with the results of Acho *et al.*[12] oscillating between 11.49% (*Corchorus olitorius*) and 24.00% (*Colocasia esculenta*).

The fiber contents of these leafy vegetables were in agreement with those of Nigerian vegetables such as "Oha" (*Pterocarpus soyauxii*) 13.1%, "Nturukpa" (*Pterocarpus santalinoides*) 10.55% and "Okazi" (*Gnetum africanum*) 24.6%[23]. The consumption of selected leafy vegetables could be beneficial for populations because the high fiber content of foods facilitates digestion by increasing gastrointestinal function and preventing constipation, thereby, reducing the incidence of metabolic diseases such as diabetes mellitus and hypercholesterolemia. It also contributes to the prevention of colon cancer by binding to carcinogenic chemicals away from the cells that cover the colon[24,25]. Protein levels (20.3±0.1 to 29.0±0.0%) can be superimposed on those of other Ivorian, according to Zoro *et al.*[11] and Acho *et al.*[12]. According to Aberoumand[26], leaves that provide more than 12% of their calorific value from proteins are a good source of protein. Therefore, this suggests that all the leafy vegetables studied would be good sources of protein and could play an important role in the provision of available and inexpensive proteins thus, improving the poor diets of rural communities. In addition, the higher protein intakes may be beneficial for various health outcomes, such as weight management, maintaining muscle mass, preventing osteoporosis and reducing the risk of cardiovascular disease[27,28]. With adequate intake, the daily protein requirements (0.80 g kg^{-1}/day) could be largely covered[29]. As far as total carbohydrate is concerned, leafy vegetables are not considered as a good source of carbohydrate. The carbohydrate contents (34.0±0.0-55.3±0.0%) of the leaves were similar to those of vegetables such as *Moringa oleifera* (36.60-38.90%)[30]. The high levels of vitamin B9 were above the 400 µg/day of daily intake recommended for folate. Several authors have shown that folates are found in large quantities in fresh green leafy vegetables[31,32]. Therefore, these leaves in general and those of Nanogo particulary are good sources of folic acid and may be recommended in pregnant women for the prevention of macrocytic anemia and fetal malformations (due to tube defects neuronal) and in the elderly in maintaining cardiovascular and cognitive health[33,34]. The β-carotene content of Kogogban (0.4±0.0 mg/100 g) is higher than those obtained by Adegunwa *et al.*[35] in Nigeria, who reported β carotene levels in fresh samples varying from

0.240-0.264 mg/100 g in *Talinum triangulare* and *Basella alba*, respectively. According to Sluijs *et al.*[36], diets high in β-carotene were shown to be associated with a reduced occurrence of type 2 diabetes in generally healthy men and women. Therefore, adequate intake of these leafy vegetables could, therefore, be a source in provitamin A intake for rural populations.

The studied leaves revealed the presence of polyphenol at appreciable rates indicating a potential antioxidant activity. Wong *et al.*[37] showed that plants with an appreciable amount of polyphenols also exhibited strong antioxidant activity and contributed to their medicinal properties. The consumption of a large amount of these leaves could, thus, contribute to reducing the oxidative stress intimately linked to aging, to the occurrence of cancer, atherosclerosis, inflammation and neurodegenerative diseases such as Parkinson's disease and Alzheimer's disease[38,39]. The fresh leafy vegetables selected for this study also contain antinutrients ranging from 382±2 to 900±3 and 720±3 to 1300±3 mg/100 g, respectively for oxalates and phytates. These results are superimposable to those obtained by Acho *et al.*[12] in Côte d'Ivoire. The toxicity of oxalates and phytates in humans has been set at 2-5 g/day and diet consumption rich in these anti-nutrients may lead to nephropathy[40,41]. These antinutrients form complexes with divalent cations such as calcium, magnesium, zinc and iron, thus reducing their bioavailability[42]. These results indicate that consumption of large quantities of freshly studied leaves can have adverse effects on human health. In addition, the anti-nutrients present in these plants could easily be reduced and detoxified by soaking, boiling or frying[43,44].

The species analyzed in this study showed appreciable levels of potassium (1238±3 to 4228±2 mg/100 g). Sodium and potassium are involved in membrane and cellular exchange, thus contributing to the regulation of plasma volume, acid-base balance and muscle contraction[45]. In addition, the sodium/potassium ratio for all fresh leafy vegetables studied being less than one, this would mean that they could be used in diets of hypertensive individuals. Having regard to the recommended dietary allowance (RDA) for minerals: calcium (1000 mg/day), magnesium (400 mg/day), iron (8 mg/day) and zinc (6 mg/day) these leafy vegetables could cover RDA and contribute substantially for improving human diet[29]. Calcium plays a major role in ossification and dentition[46] and has a preventive effect on arterial hypertension in the elderly[47]. Magnesium is a cofactor in over 300 enzymatic reactions that regulate various biochemical reactions in the body including protein synthesis, muscle function, blood glucose, blood pressure and heart rate regulation[48]. Copper is the major constituent of cuproenzymes, which are involved in energy production, iron metabolism and the metabolism of neurotransmitter synthesis[49]. Iron plays an important role in the prevention of anemia while zinc is important in neurological function[50]. Anti-nutrients to nutrients ratios of leafy vegetables were calculated to predict the bioavailability of calcium. The calculated oxalates/calcium was below the critical level of 2.5 in all the species known to impair calcium bioavailability while phytates/calcium ratios is above the critical threshold of 0.5, excepted Mangnrin. However, cooking could reduce the ratio.

CONCLUSION

It is concluded that the *Solanum nigrum* (Fouébrou), *Ceratotheca sesamoides* (Nanogo), *Sesamum radiatum* (Mangnrin), *Abelmoschus tuberculatus* (Kogogban), *Myrianthus arboreus* (Tikriti) contain appreciable amount of proteins, fibres, mineral elements and good sources of vitamins (vitamin B9, β-carotene). The presence of polyphenols in appreciable amounts in the leaves contributes to their medical value. Anti-nutritional factors such as oxalates and phytates have been demonstrated even if they can be eliminated to improve their nutritional quality. Thus, the spontaneous leafy vegetables studied could significantly contribute to human health and could play a major role to combat micronutrient deficiency, also called “hidden hunger”, a main cause of health problems and high mortality for groups at risk, mainly children and pregnant women in tropical Africa. However, it is necessary to consider other aspects such as the effects of cooking time on the chemical, nutritive and antinutritive value of these leafy vegetables.

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REFERENCES

1. Grubben, G., W. Klaver, R. Nono-Womdim, A. Everaarts, L. Fondio, J.A Nugteren and M. Corrado, 2014. Vegetables to combat the hidden hunger in Africa. Chronica Hortic., 54: 24-32.
2. Johnson, M., R.D. Pace, N.L. Dawkins and K.R. Willian, 2013. Diets containing traditional and novel green leafy vegetables improve liver fatty acid profiles of spontaneously hypertensive rats. Lipids Health Dis., Vol. 12. 10.1186/1476-511X-12-168.

3. Raghuvanshi, R.S., R. Singh and R. Singh, 2001. Nutritional composition of uncommon foods and their role in meeting micronutrient needs. Int. J. Food Sci. Nutr., 52: 331-335.
4. Dansi, A., A. Adjatin, H. Adoukonou-Sagbadja, V. Falade, H. Yedomonhan, D. Odou and B. Dossou, 2008. Traditional leafy vegetables and their use in the Benin Republic. Genet. Resour. Crop Evolut., 55: 1239-1256.
5. Nnamani, C.V., H.O. Oselebe and A. Agbatutu, 2009. Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State, Nigeria. Afr. J. Biotechnol., 8: 2321-2324.
6. Li, M., Y. Fan, X. Zhang, W. Hou and Z. Tang, 2014. Fruit and vegetable intake and risk of type 2 diabetes mellitus: Meta-analysis of prospective cohort studies. BMJ Open, Vol. 4. 10.1136/bmjopen-2014-005497.
7. Wang, P.Y., J.C. Fang, Z.H. Gao, C. Zhang and S.Y. Xie, 2016. Higher intake of fruits, vegetables or their fiber reduces the risk of type 2 diabetes: A meta analysis. J. Diabetes Invest., 7: 56-69.
8. PROTA., 2004. Ressources Vegetales de l'Afrique Tropicale. In: Legumes, Grubben, G.J.H. and O.A. Denton (Eds.)., PROTA Fondation, Backhuys Publishers, Wageningen.
9. Fondio, L., C. Kouame, J.C. Nzi, A. Mahyao, E. Agbo and A.H. Djidji, 2007. Survey of indigenous leafy vegetables in the urban and peri-urban areas of Cote d'Ivoire. Acta Horticulturae, 752: 287-289.
10. Soro, L.C., L.O. Atchibri, K.K. Kouadio and C. Kouame, 2012. Evaluation de la composition nutritionnelle des legumes feuilles. J. Applied Biosci., 51: 3567-3573.
11. Zoro, A.F., L.T. Zoue, S.A.K. Kra, A.E. Yepie and S.L. Niamke, 2013. An overview of nutritive potential of leafy vegetables consumed in western Cote d'Ivoire. Pak. J. Nutr., 12: 949-956.
12. Acho, C.F., L.T. Zoue, E.E. Akpa, V.G. Yapo and S.L. Niame, 2014. Leafy vegetables consumed in Southern Cote d'Ivoire: A source of high value nutrients. J. Anim. Plant Sci., 20: 3159-3170.
13. Patricia, O., L. Zoue, R.M. Megnanou, R. Doue and S. Niamke, 2014. Proximate composition and nutritive value of leafy vegetables consumed in Northern Cote d'Ivoire. Eur. Scient. J., 10: 212-227.
14. Kouame, N.D.M.T., G.M. Gnahoua, K.E. Kouassi and D. Traore, 2008. Plantes alimentaires spontanees de la region du Fromager (Centre-Ouest de la Cote d'Ivoire): Flore, habitats et organes consommes. Sci. Nature, 5: 61-70.
15. AOAC., 1990. Official Method of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington, DC., USA.
16. N'Dri, D., T. Mazzeo, M. Zaupa, R. Ferracane, V. Fogliano and N. Pellegrini, 2013. Effect of cooking on the total antioxidant capacity and phenolic profile of some whole meal African cereals. J. Sci. Food Agric., 93: 29-36.
17. Singleton, V.L., R. Orthofer and R.M. Lamuela-Raventos, 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol., 299: 152-178.
18. Miglio, C., E. Chiavaro, A. Visconti, V. Fogliano and N. Pellegrini, 2007. Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. J. Agric. Food Chem., 56: 139-147.
19. Hasan, M.N., M. Akhtaruzzaman and M.Z. Sultan, 2013. Estimation of vitamins B-complex (B_2, B_3, B_5 and B_6) of some leafy vegetables indigenous to Bangladesh by HPLC method. J. Anal. Sci. Methods Instrum., 3: 24-29.
20. Mohamed, A.I., P.A.J. Perera and Y.S. Hafez, 1986. New chromophore method for phytic acid determination. Am. Assoc. Cereal. Chem., 63: 475-478.
21. Day, Jr., R.A. and A.L. Underwood, 1986. Quantitative Analysis. 5th Edn., Prentice-Hall Publication, London, UK., Pages: 701.
22. Iheanacho, K.M.E. and A.C. Udebuani, 2009. Nutritional composition of some leafy vegetables consumed in Imo State, Nigeria. J. Applied Sci. Environ. Manage., 13: 35-38.
23. Ekumankama, I.O., 2008. Nutrient composition of indigenous vegetables (*Pterocarpus soyanxii*, *Pterocarpus santalinoides* and *Gnetum africanum*). Nig. J. Nutr. Sci., 29: 195-200.
24. Zhao, H., J. Lin, H.B. Grossman, L.M. Hernandez, C.P. Dinney and X. Wu, 2007. Dietary isothiocyanates, *GSTM1*, *GSTT1*, *NAT2* polymorphisms and bladder cancer risk. Int. J. Cancer, 120: 2208-2213.
25. Murphy, N., T. Norat, P. Ferrari, M. Jenab and B. Bueno-de-Mesquita *et al*., 2012. Dietary fibre intake and risks of cancers of the colon and rectum in the European Prospective Investigation into Cancer and nutrition (EPIC). Plos One, Vol. 7. 10.1371/journal.pone.0039361
26. Aberoumand, A., 2009. Proximate and mineral composition of the Marchubeh (*Asparagus officinalis*) in Iran. World J. Dairy Food Sci., 4: 145-149.
27. Rodriguez, N.R. and P.J. Garlick, 2008. Introduction to protein summit 2007: Exploring the impact of high-quality protein on optimal health. Am. J. Clin. Nutr., 87: 1551S-1553S.
28. Fulgoni, V.L., 2008. Current protein intake in America: Analysis of the national health and nutrition examination survey, 2003-2004. Am. J. Clin. Nutr., 87: 1554S-1557S.
29. Food and Nutrition Board, 2005. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. National Academies Press, Washington, DC., USA., ISBN-13: 9780309085250, Pages: 1358.
30. Okiki, P.A., I.A. Osibote, O. Balogun, B.E. Oyinloye and O.O. Idris *et al*., 2015. Evaluation of proximate, minerals, vitamins and phytochemical composition of *Moringa oleifera* Lam. cultivated in Ado Ekiti, Nigeria. Adv. Biol. Res., 9: 436-443.

31. Chew, S.C., G.L. Khor and S.P. Loh, 2012. Folate content and availability in Malaysian cooked foods. Mal. J. Nutr., 18: 383-391.
32. Maharaj, P.P.P., S. Prasad, R. Devi and R. Gopalan, 2015. Folate content and retention in commonly consumed vegetables in the South Pacific. Food Chem., 182: 327-332.
33. FAO. and WHO., 2004. Vitamin and Mineral Requirements in Human Nutrition. 2nd Edn., World Health Organization, Geneva, Switzerland, ISBN-13: 9789241546126, Pages: 341.
34. Delchier, N., A.L. Herbig, M. Rychlik and C.M. Renard, 2016. Folates in fruits and vegetables: Contents, processing and stability. Compr. Rev. Food Sci. Food Saf., 15: 506-528.
35. Adegunwa, M.O., E.O. Alamu, H.A. Bakare and C.O. Oyeniyi, 2011. Proximate and bioactive contents of some selected vegetables in Nigeria: Processing and varietal effects. Am. J. Food Nutr., 1: 171-177.
36. Sluijs, I., E. Cadier, J.W.J. Beulens, D.L. van der A, A.M.W. Spijkerman and Y.T. van der Schouw, 2015. Dietary intake of carotenoids and risk of type 2 diabetes. Nutr. Metab. Cardiovasc. Dis., 25: 376-381.
37. Wong, S.P., L.P. Leong and J.H.W. Koh, 2006. Antioxidant activities of aqueous extracts of selected plants. Food Chem., 99: 775-783.
38. Mullen, W., S.C. Marks and A. Crozier, 2007. Evaluation of phenolic compounds in commercial fruit juices and fruit drinks. J. Agric. Food Chem., 55: 3148-3157.
39. Shen, S., D. Callaghan, C. Juzwik, H. Xiong, P. Huang and W. Zhang, 2010. ABCG2 reduces ROS-mediated toxicity and inflammation: A potential role in Alzheimer's disease. J. Neurochem., 114: 1590-1604.
40. Hassan, L.G. and K.J. Umar, 2004. Antinutritive factors in African locust beans (*Parkia biglobosa*). Proceedings of the 27th Annual International Conference of Chemical Society of Nigeria, September 20-24, 2004, University of Benin, Benin City, Nigeria, pp: 322-326.
41. Hassan, L.G., K.J. Umar and Z. Umar, 2007. Antinutritive factors in *Tribulus terrestris* (Linn) leaves and predicted calcium and zinc bioavailability. J. Trop. Biosci., 7: 33-36.
42. Sandberg, A.S., 2002. Bioavailability of minerals in legumes. Br. J. Nutr., 88: 281-285.
43. Ekpo, A.S. and N.O. Eddy, 2005. Comparatives studies of the level of toxicants in the seed of Indian almond (*Tecminalia catappa*) and Africa walnuts (*Coula edulis*). Chem. Class J., 2: 74-76.
44. Schlemmer, U., W. Frolich, R.M. Prieto and F. Grases, 2009. Phytate in foods and significance for humans: Food sources, intake, processing, bioavailability, protective role and analysis. Mol. Nutr. Food Res., 53: S330-S375.
45. Akpanyung, E.O., 2005. Proximate and mineral element composition of bouillon cubes produced in Nigeria. Pak. J. Nutr., 4: 327-329.
46. Turan, M., S. Kordali, H. Zengin, A. Dursun and Y. Sezen, 2003. Macro and micro mineral content of some wild edible leaves consumed in Eastern Anatolia. Acta Agric. Scand. Sect. B: Soil Plant Sci., 53: 129-137.
47. McCarron, D.A. and M.E. Reusser, 1999. Finding consensus in the dietary calcium-blood pressure debate. J. Am. Coll. Nutr., 18: 398S-405S.
48. Rude, R.K., F.R. Singer and H.E. Gruber, 2009. Skeletal and hormonal effects of magnesium deficiency. J. Am. Coll. Nutr., 28: 131-141.
49. Mejia-Rodriguez, F., T. Shamah-Levy, S. Villalpando, A. Garcia-Guerra and I. Mendez-Gomez Humaran, 2013. Iron, zinc, copper and magnesium deficiencies in Mexican adults from the national health and nutrition survey 2006. Salud Publica Mexico, 55: 275-284.
50. Yamada, M., K. Asakura, S. Sasaki, N. Hirota and A. Notsu *et al*., 2014. Estimation of intakes of copper, zinc and manganese in Japanese adults using 16-day semi-weighed diet records. Asia Pac. J. Clin. Nutr., 23: 465-472.