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Leafy vegetables consumed in Southern Côte d'Ivoire: a source of high value nutrients

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1 SUMMARY

In tropical Africa, leafy vegetables are traditionally cooked and eaten as a relish together with a starchy staple food. Nevertheless, scientific report on their nutritive potential is scanty. In order to promote and to contribute to their wider utilization, leafy vegetables consumed in Southern Côte d'Ivoire *Basella alba (épinard)*, *Colocasia esculenta (taro)*, *Corchorus olitorius (kplala)*, *Solanum melongena (aubergine)* and *Talinum triangulare (tikliti)*) were studied. The physicochemical and nutritive properties of these leafy vegetables were investigated and the results obtained were as follow: moisture (73.66 - 90.41%), crude proteins (9.64 - 21.17%), crude fibres (11.46 - 24.46%), ash (8.38 - 22.57%), carbohydrates (40.17 - 56.42%), crude lipids (2.67 - 8.50%) and food energy (244.77 - 291.11 kcal/100g). The mineral elements contents were high with remarkable amount of K (1652.06 - 9402.42 mg/100g), Ca (1103.07 - 4838.79 mg/100g), Mg (562.02 - 3161.6 mg/100g), P (190.94 - 1348.05 mg/100g) and Fe (27.29 - 78.74 mg/100g). The Ca/P ratio was desirable and ranged from 2.09 to 8.40. These leafy vegetables also contained appreciable levels of vitamin C (45.67 - 74.33 mg/100g) and polyphenols (123.58 - 292.87 mg/100g). The studied leafy vegetables highlighted antioxidant activity varying from 65.11 to 78.71%. All these results suggest that the studied leafy vegetables if consume in sufficient amount would contribute greatly to the nutritional requirement for human health and to the food security of Ivorian population.

2 INTRODUCTION

Green leafy vegetables constitute essential components of human diet in Africa generally and particularly in West Africa (Kubmarawa *et al.*, 2009). Communities in Africa have a long history of using traditional leafy vegetables to supplement their diets (Chweya & Eyzaguirre, 1999). The varieties of leafy vegetables utilized are diverse and they are cooked and eaten as a relish together with a starchy staple food, usually in the form of porridge (Vainio-Mattila, 2000). Leafy vegetables dishes are often prepared with a single plant species or combination of different species in order to add flavour, taste, colour and aesthetic appeal to diet (Marshall, 2001; Fasuyi, 2006). Leafy vegetables are important protective foods and highly beneficial for the maintenance of health and prevention of diseases as they contain valuable food ingredients which can be utilized to build up and repair the body (Falade *et al.*, 2003). Indeed, these plants are valuable sources of nutrients especially in rural areas where they contribute substantially to protein, minerals, vitamins, fibre and other nutrients, which are usually in short supply in daily diets (Mohammed & Sharif, 2011). They are also a very good source of antioxidants (Gupta & Prakash, 2011; Sikora & Bodziarczyk, 2012). Epidemiological studies indicate that increased intake of leafy vegetables is associated with decreased risk of cancers, cardiovascular disease, cataract, and other age-related diseases

(Tanumihardjo & Yang, 2005). Despite their availability, the frequency of leafy vegetables consumption has decreased over the years, probably because they are often considered to be inferior in their taste and nutritional value compared to exotic vegetables such as spinach (*Spinacea oleracea*) and cabbage (*Brassica oleracea*) (Weinberger & Msuya, 2004). In addition, preference of African leafy vegetables (ALVs) species depends on the gender, age of consumers, cultural background and geographical location (Jansen-Van-Rensberg *et al.*, 2004). However, several studies have indicated that leafy vegetables consumed in Africa contain higher level of micronutrient than those found in most exotic areas (Steyn *et al.*, 2001). Furthermore, several recent publications (Nesamvuni *et al.*, 2001; Jansen-Van-Rensburg *et al.*, 2004) have assessed the nutritional value of traditional and indigenous leafy vegetables. In spite of the nutritional contribution of leafy vegetables to local diets and their health maintenance and protective properties, there has been very little concerted effort towards exploiting these biodiversified and healthy resources for improving nutritional status of populations in sub-Saharan Africa (Kwenin *et al.*, 2011). Ethno-botanical studies have stated that populations in Southern Côte d'Ivoire use for consumption, green leafy vegetables such as *Basella alba* "epinard", *Colocasia esculenta* "taro", *Corchorus olitorius* "kplala", *Solanum melongena* "aubergine" and *Talinum triangulare* "mamichou" through confectionary soups (Gautier-Beguin, 1992; N'guessan, 1995). However, these leafy vegetables are under-exploited because of inadequate scientific knowledge on their nutritive potentials. Therefore, the aim of this work is to evaluate the proximate nutrient content, mineral and anti-nutritional factors of leafy vegetables consumed in Southern Côte d'Ivoire in order to provide necessary information for their wider utilization and contribution to food security.

3 MATERIALS AND METHODS

3.1 Plant materials: Leafy vegetables were collected at maturity from cultivated farmlands located at Dabou (Abidjan District). These plants were authenticated by National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Côte d'Ivoire). The collected plants were destalked, washed with distilled water, drained at ambient temperature and oven-dried (Memmert, Germany) at 60 °C for 72 h (Chinma & Igyor, 2007). The dried materials obtained were ground with a laboratory crusher (Culatti, France) equipped with a 10 µm mesh sieve. The dried powdered samples obtained were stored in polythene bags at 4 °C until further analyses.

3.2 Chemicals: All solvents (n-hexane, petroleum ether, acetone, ethanol and methanol) were purchased from Merck. Standards used (glucose, gallic acid, tannic acid, quercetin, β-carotene) and reagents (metaphosphoric acid, vanillin, Folin-Ciocalteu, DPPH) were purchased from Sigma-Aldrich. All chemicals used in the study were of analytical grade.

3.3 Physicochemical analysis: moisture, ash, proteins and lipids were determined using AOAC (1990) official methods. pH was determined as follow: 10 g of dried powdered sample was homogenized with 100 mL of distilled water and then filtered through Whatman No. 4 filter paper. The pH value was recorded after the electrode of pH-meter (Hanna, Spain) was immersed into the filtered solution. For crude fibres, 2 g of dried powdered sample were digested with 0.25 M sulphuric acid and 0.3 M sodium hydroxide solution. The insoluble residue obtained was washed with hot water and dried in an oven (Memmert, Germany) at 100 °C until constant weight. The dried residue was then incinerated, and weighed for the determination of crude fibre content. Carbohydrates and calorific value were calculated using the following formulas (FAO, 2002):

Carbohydrates: 100 – (% moisture + % proteins + % lipids + % ash + % fibres).

Calorific value: (% proteins x 2.44) + (% carbohydrates x 3.57) + (% lipids x 8.37). The results of ash, fibre, protein, lipid and carbohydrate contents were expressed on dry matter basis.

3.4 Determination of vitamin C: The amount of vitamin C in analysed samples was determined by titration using the method described by Pongracz *et al.* (1971). About 10 g of ground fresh leaves were soaked for 10 min in 40 mL metaphosphoric acid-acetic acid (2 %, w/v). The mixture was centrifuged at 3000 rpm for 20 min and the supernatant obtained was diluted and adjusted with 50 mL of bi-distilled water. Ten (10) mL of this mixture was titrated to the end with dichlorophenol-indophenol (DCPIP) 0.5 g/L.

3.5 Determination of carotenoids: Carotenoids content was carried out according to Rodriguez-Amaya (2001). Two (2) g of ground fresh leaves were mixed three times with 50 mL of acetone until loss of pigmentation. The mixture obtained was filtered through Whatman No. 4 filter paper and total carotenoids were extracted with 100 mL of petroleum ether. Absorbance of extracted fraction was then read at 450 nm by using a spectrophotometer (PG Instruments, England). Total carotenoids content was subsequently estimated using a calibration curve of β-carotene (1 mg/mL) as standard.

3.6 Determination of polyphenols: Polyphenols content was determined using the method reported by Singleton *et al.* (1999). A quantity (1 g) of dried powdered sample was soaked in 10 mL of methanol 70 % (w/v) and centrifuged at 1000 rpm for 10 min. An aliquot (1 mL) of supernatant was oxidized with 1 mL of Folin–Ciocalteu's reagent and neutralized by 1 mL of 20 % (w/v) sodium carbonate. The reaction mixture was incubated for 30 min at ambient temperature and absorbance was measured at 745 nm by using a spectrophotometer (PG Instruments, England). The polyphenols content was obtained using a calibration curve of gallic acid (1 mg/mL) as standard.

3.7 Determination of flavonoids: The total flavonoids content was evaluated using the method reported by Meda *et al.* (2005). Briefly, 0.5 mL of the methanolic extract was mixed with 0.5 mL methanol, 0.5 mL of $AlCl_3$ (10%, w/v), 0.5 mL of potassium acetate (1 M) and 2 mL of distilled water. The mixture was allowed to incubate at ambient temperature for 30 min. Thereafter, the absorbance was measured at 415 nm by using a spectrophotometer (PG Instruments, England). The total flavonoids were determined using a calibration curve of quercetin (0.1 mg/mL) as standard.

3.8 Determination of tannins: Tannins of samples were quantified according to Bainbridge *et al.* (1996). For this, 1 mL of the methanolic extract was mixed with 5 mL of vanillin reagent and the mixture was allowed to incubate at ambient temperature for 30 min. Thereafter, the absorbance was read at 500 nm by using a spectrophotometer (PG Instruments, England). Tannins content of samples was estimated using a calibration curve of tannic acid (2 mg/mL) as standard.

3.9 Determination of oxalates: The titration method as described by Day & Underwood (1986) was performed. One (1) g of dried powdered sample was weighed into 100 mL conical flask. A quantity (75) mL of sulphuric acid (3 M) was added and stirred for 1 h with a magnetic stirrer. The mixture was filtered through Whatman No. 4 filter paper and 25 mL of the filtrate was titrated while hot against $KMnO_4$ solution (0.05 M) to the end.

3.10 Determination of phytates: The method described by Wheeler & Ferrel (1971) was used for determination of phytates content. A quantity (0.5 g) of dried powdered sample was mixed with 25 mL of trichloroacetic acid (3%, w/v) and centrifuged at 3500 rpm for 15 min. The supernatant obtained was treated with $FeCl_3$ solution and the iron content of the precipitate was determined using spectrophotometric method at 470 nm. A 4:6 Fe/P atomic ratio was used to calculate the phytic acid content.

3.11 Antioxidant activity: Antioxidant assay was carried out using the 2, 2-diphenyl-1-pycrilhydrazyl (DPPH) spectrophotometric method outlined by Choi *et al.* (2002). About 1 mL of 0.3 mM DPPH solution in ethanol was added to 2.5 mL of sample solution (1 g of dried powdered sample mixed in 10 mL of methanol and filtered through Whatman No. 4 filter paper) and was allowed to react for 30 min at room temperature. Absorbance values were measured with a spectrophotometer (PG Instruments, England) set at 415 nm. The average absorbance values were converted to percentage antioxidant activity using the following formula:

Antioxidant activity (%) = 100 – [(Abs of sample – Abs of blank) x 100/Abs positive control]

3.12 Mineral analysis: The mineral content was estimated by dry ashing of dried powdered sample (5 g) in a muffle furnace (Pyrolabo, France). The ash obtained was dissolved in 5 mL of HCl/HNO_3 and analyzed using the atomic absorption spectrophotometer (AAS model, SP9).

3.13 Statistical analysis: All the analyses were performed in triplicate and data were analyzed using EXCELL and STATISTICA 7.1 (StatSoft). Differences between means were evaluated by Duncan's test. Statistical significant difference was stated at $p < 0.05$.

4 RESULTS

4.1 Physicochemical properties: The proximate composition of the vegetables examined in this study is presented in Table 1. The physicochemical parameters generally differ significantly ($p < 0.05$) from a leafy vegetable to another. All samples contained between 74 % and 90 % moisture. The ash content ranged from 8.53 ± 0.15 % (*C. olitorius*) to 22.20 ± 0.37 % (*T. triangulare*). There was a variation in the fibres content of the investigated leafy vegetables species, ranging from 11.49 ± 0.03 % (*C. olitorius*) to 24.00 ± 0.46 % (*C. esculenta*). The fat content of the remaining species was in the range 2.7- 8.5 %. Proteins content ranged from 9.80 ± 0.16 % in *C. esculenta* to 21.12 ± 0.05 % in *C. olitorius* leaves. *C. olitorius* yielded the highest carbohydrate content (55.58 ± 0.84 %) while the highest calorific value (277.57 ± 13.54 kcal/100 g) was for *S. melongena*.

Table 1: Physicochemical properties of leafy vegetables consumed in Southern Côte d'Ivoire

Parameters	Leafy vegetables				
	B. alba	*C. esculenta*	*C. olitorius*	*S. melongena*	*T. triangulare*
Moisture (%)	89.82 ± 1.24^{ab}	82.35 ± 2.83^{cd}	84.28 ± 0.34^{c}	74.38 ± 0.72^{e}	90.20 ± 0.21^{a}
pH	5.92 ± 0.01^{c}	6.21 ± 0.00^{b}	6.52 ± 0.01^{a}	5.32 ± 0.02^{d}	5.33 ± 0.02^{de}
Ash (%)	19.79 ± 0.44^{c}	15.03 ± 0.23^{d}	8.53 ± 0.15^{e}	20.32 ± 2.36^{ab}	22.20 ± 0.37^{a}
Crude fibres (%)	16.50 ± 0.30^{b}	24.00 ± 0.46^{a}	11.49 ± 0.03^{e}	13.70 ± 0.65^{cd}	13.98 ± 1.50^{c}
Lipids (%)	6.85 ± 0.05^{b}	8.35 ± 0.15^{a}	3.28 ± 0.30^{d}	2.73 ± 0.06^{e}	4.90 ± 0.06^{c}
Proteins (%)	9.86 ± 0.10^{d}	9.80 ± 0.16^{de}	21.12 ± 0.05^{a}	12.34 ± 0.09^{c}	17.18 ± 0.05^{b}
Carbohydrates (%)	47.00 ± 0.89^{d}	42.85 ± 2.68^{e}	55.58 ± 0.84^{a}	50.91 ± 3.16^{bc}	52.77 ± 2.08^{b}
Calorific energy (kcal/100g)	249.18 ± 4.41^{e}	252.34 ± 14.55^{d}	277.40 ± 6.26^{b}	277.57 ± 13.54^{a}	271.32 ± 8.17^{bc}

Data are represented as means ± SD (n=3). Means in the lines with no common superscript differ significantly ($p < 0.05$).

Table 2: Nutritive and antioxidant properties of leafy vegetables consumed in Southern Côte d'Ivoire

Parameters (mg/100g)	Leafy vegetables				
	B. alba	*C. esculenta*	*C. olitorius*	*S. melongena*	*T. triangulare*
Vitamin C	70.00 ± 0.00^{ab}	55.00 ± 4.33^{c}	70.00 ± 4.33^{a}	40.00 ± 0.10^{e}	50.00 ± 4.33^{cd}
Carotenoids	3.36 ± 0.17^{a}	1.79 ± 0.00^{e}	2.70 ± 0.08^{b}	2.68 ± 0.01^{bc}	2.29 ± 0.00^{d}
Polyphenols	132.32 ± 8.74^{e}	289.37 ± 3.50^{a}	244.20 ± 3.51^{b}	166.94 ± 1.75^{c}	135.87 ± 2.28^{d}
Tannins	76.62 ± 0.00^{d}	184.41 ± 2.60^{a}	122.79 ± 1.49^{b}	118.57 ± 0.23^{c}	36.36 ± 0.02^{e}
Flavonoids	23.00 ± 0.00^{c}	12.87 ± 0.64^{e}	74.30 ± 1.69^{a}	27.20 ± 0.00^{b}	22.00 ± 0.00^{cd}
Oxalates	650.00 ± 39.00^{b}	580.00 ± 39.00^{c}	780.00 ± 39.00^{a}	95.00 ± 0.00^{e}	520.00 ± 0.00^{d}
Phytates	19.78 ± 0.00^{e}	26.27 ± 3.22^{d}	38.75 ± 0.10^{b}	41.67 ± 0.00^{a}	29.40 ± 0.01^{c}

Data are represented as means ± SD (n=3). Means in the lines with no common superscript differ significantly ($p < 0.05$).

4.2 Nutritive and antioxidant properties: Nutritive and antioxidant properties of the selected leafy vegetables are shown in Table 2. There was a significant difference ($p < 0.05$) between most of these parameters. Vitamin C content ranged from 40.00 ± 0.10 mg/100 g for *S. melongena* to 70.00 ± 0.00 mg/100 g for *B. alba*. The carotenoids content depends on the leafy vegetables species and varied from 1.79 ± 0.00 mg/100 g for *C. esculenta* to 3.36 ± 0.17 mg/100 g for *B. alba*. Analysis of polyphenols has revealed that *C. esculenta*, *C. olitorius* and *S. melongena* were major sources with contents of 289.37 ± 3.50, 244.20 ± 3.51 and 166.94 ± 1.75 mg/100 g, respectively. *C. esculenta* leaves showed the highest value (184.41 ± 2.60 mg/100 g) of tannins while the highest value (74.30 ± 1.69 mg/100 g) of flavonoids was for *C. olitorius*. The selected leafy vegetables used in this study contained also anti- nutrients, which amounts varied from 95.00 ± 0.00 to 780 ± 0.00 mg/100 g for oxalates and 19.78 ± 0.00 to 41.67 ± 0.00 mg/100 g for phytates. Antioxidant activity of the selected leafy vegetables is depicted by the figure 1. *C. esculenta* and *C. olitorius* showed antioxidant values of 78.71 ± 0.22 % and 76.30 ± 0.03 %, respectively.

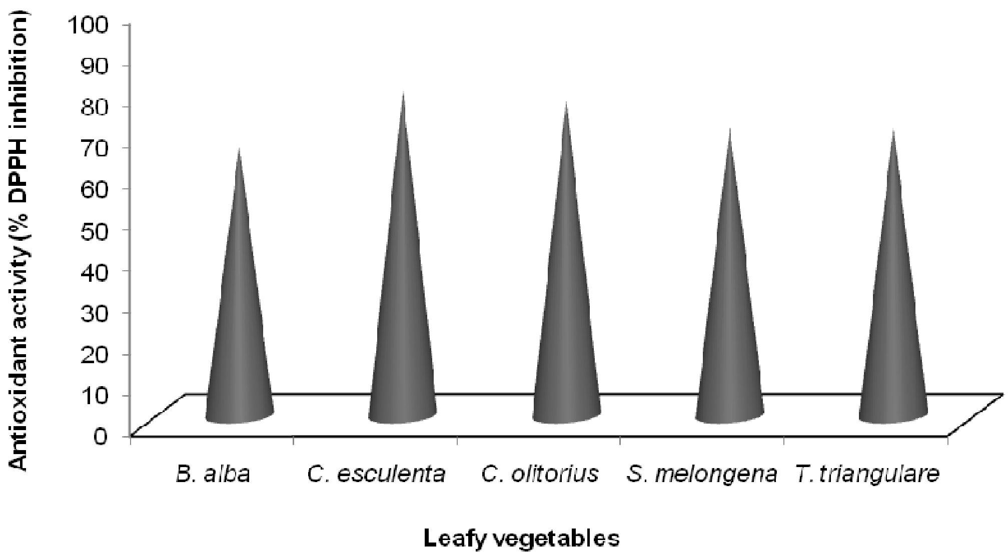

Figure 1: Antioxidant activity of leafy vegetables consumed in Southern Côte d'Ivoire

4.3 Mineral composition: Mean values for mineral content of the selected leafy vegetables are presented in Table 3. The species analysed in this study contained remarkably high amounts of potassium (1650 – 9400 mg/100 g) and calcium (1100 – 4839 mg/100 g) with highest value (4808.79 ± 30.00 mg/100 g; 9348.42 ± 54.00 mg/100 g) for *S. melongena* and *T. triangulare*, respectively. All the analysed plants were excellent sources of magnesium, ranging from 572.02 ± 10.00 mg/100 g (*C. olitorius*) to 3063.60 ± 98.00 mg/100 g (*T. triangulare*).The phosphorus content of the leaves varied from 197.58 ± 6.64 mg/100 g (*C. olitorius*) to 1308.05 ± 40.00 mg/100 g (*S. melongena*). Sodium (Na) was quantified (1177.39 ± 0.20 mg/100 g) only in *S. melongena* while zinc (Zn) was detected (23.75 ± 0.04 mg/100 g) in *B. alba*. The evaluated leafy vegetables contained substantial quantities of iron ranged from 27.42 ± 0.13 mg/100 g (*C. olitorius*) to 78.54 ± 0.20 mg/100 g (*S. melongena*). The Ca/P ratio varied from 2.09 to 8.40 while [oxalates]/[Ca], [phytates]/[Ca] and [phytates]/[Fe] ratios were lower than 2.

Table 3: Mineral composition of leafy vegetables consumed in Southern Côte d'Ivoire

Minerals (mg/100g)	Leafy vegetables				
	B. alba	***C. esculenta***	***C. olitorius***	***S. melongena***	***T. triangulare***
Calcium (Ca)	4136.77 ± 34.00[b]	1600 ± 80.00[d]	1159.07 ± 56.00[e]	4808.79 ± 30.00[a]	1660.56 ± 55.00[c]
Magnesium (Mg)	2513.99 ± 11.00[c]	2870 ± 120[b]	572.02 ± 10.00[e]	1780.00 ± 30.00[d]	3063.60 ± 98.00[a]
Phosphorus (P)	1166.29 ± 30.00[b]	720 ± 10.00[c]	554.39 ± 34.00[d]	1308.05 ± 40.00[a]	197.58 ± 6.64[e]
Potassium (K)	2892.64 ± 80.00[d]	3380 ± 90.00[c]	1669.06 ± 17.00[e]	4014.11± 11.00[b]	9348.42 ± 54.00[a]
Sodium (Na)	ND	ND	ND	1177.39 ± 0.20a	ND
Iron (Fe)	63.33 ± 0.01[c]	70.00 ± 10.00[b]	27.42 ± 0.13[d]	78.54 ± 0.20[a]	ND
Zinc (Zn)	23.75 ± 0.04[a]	ND	ND	ND	ND
Ca/P	3.55	2.22	2.09	3.67	8.40
Na/K	-	-	-	0.29	-
Oxalates/Ca	0.15	0.36	0.67	0.019	0.31
Phytates/Ca	0.004	0.016	0.03	0.008	0.019
Phytates/Fe	0.30	0.37	1.41	0.53	-

Data are represented as means ± SD (n=3). Means in the lines with no common superscript differ significantly ($p < 0.05$). ND: non detected

5 DISCUSSION

The relatively high values of moisture obtained in this study corroborated with results (60 – 90 %) of investigated vegetables as indicated by FAO (2006). These results indicate that the studied leafy vegetables would be more prone to perishability and would need appropriate preservation (Fennema & Tannenbaum, 1996). In view to their ash contents the selected leafy vegetables may be considered as good sources of minerals when compared to values (2 – 10 %) obtained for cereals and tubers (FAO, 1986). The crude fibres contents are high when compared to *Ipomea batatas (patate)* (7.20 %) and *Vernonia amygdalina (bitter leaf)* (6.5 %) (Antia *et al*., 2006). Adequate intake of these leafy vegetables could therefore lower the risk of hypertension, constipation, diabetes, colon and breast cancer (Ishida *et al*., 2000). Considering the recommended dietary allowance (RDA) of fibres for children, adults, pregnant and lactating mothers (19, 21, 28 and 29 g/day) (FND, 2005), the consumption of 100 g dried leaves could contribute at least 57, 52, 39 and 38% of their respective daily fibres requirement. It is important to note that plant foods that provide more than 12 % of their calorific value from proteins have been shown to be good source of proteins (Ali, 2009). This suggests that all the leafy vegetables investigated would be good sources of proteins and could play a significant role in providing cheap and available proteins for rural communities. Assuming complete proteins absorption, 100 g of the studied leaves would respectively contribute for about 13.88 to 29.74 % of the daily proteins requirement (71 g/day) of pregnant and lactating mothers (FND, 2005). The studied leafy vegetables were poor sources of lipids and their consumption could be advantageous for individuals suffering from obesity. Indeed, diet providing 1 – 2 % of its caloric energy as fat is said to be sufficient to human beings, as excess fat consumption yields to cardiovascular disorders such as atherosclerosis, cancer and aging (Kris-Etherton *et al.*, 2002). As observed by Emebu and Anyika (2011) most leafy vegetables as the studied ones, are generally not good sources of carbohydrates. The estimated calorific values compared favourably to 248.8 – 307.1 kcal/100 g reported in some Nigerian vegetables (Antia et *al.*, 2006). Furthermore, Asibey-Berko & Tayie (1999) also reported comparable energy value in some Ghanaian green leafy vegetables. Thus, the calorific values agree with general observation that vegetables have low energy values (Lintas, 1992) due to their low crude fat and relatively high level of moisture (Sobowale *et al.*, 2011). The studied leafy vegetables contained appreciable amounts of vitamin C (ascorbic acid) which could cover the daily need for humans (40 mg/day) as recommended by FAO (2004). It is important to note that ascorbic acid is a water-soluble antioxidant that promotes absorption of soluble iron by chelating or by maintaining the iron in the reduced form (FAO, 2004). Besides its ability to scavenge free radicals, ascorbic acid can regenerate other antioxidants such as tocopheroxyl from their radical species (Halliwell & Gutteridge, 1999). Carotenoids are considered as sources of provitamin A in plants and their amount determine their bioavailability in human diet (Rodriguez-Amaya, 2001; West *et al.*, 2002). Adequate intake of minimum 200 g of the dried leafy vegetables could cover the standard values (3.6 - 4.8 mg/day) recommended by FAO (2004). Polyphenols are the main dietary antioxidants and posses higher in vitro antioxidant capacity than vitamins and carotenoids (Gardner *et al.*, 2000). Plant phenolics include phenolic acids, coumarins, flavonoids, stilbenes, hydrolysable and condensed tannins, lignans and lignins (Naczk & Shahidi, 2004). Flavonoids such as myricetin, quercetin, kaempferol, isorhamnetin and luteolin have been reported in leafy vegetables by Trichopoulou *et al.* (2000). These relatively high polyphenols levels of the selected leafy vegetables may be linked to their antioxidant activity. Indeed, plant extracts that contain considerable amount of polyphenols also exhibit high antioxidant activity and contribute to their medicinal properties (Wong *et al.*, 2006). The consumption in high amount of these plants could therefore lower cellular oxidative stress, which has been implicated in the pathogenesis of various neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease and amyotrophic lateral sclerosis (Rice-Evans & Miller, 1995; Amic *et al.*, 2003). Oxalates and phytates are the major anti-nutrients quantified in the studied leafy vegetables. Oxalates contents in this study were in the range of those (0.6 % - 15.1 %) reported in some edible leafy vegetables (Badifu, 2001).Toxicity of oxalates for humans was set as 2-5 g/day and the consumption of diet rich in these anti-nutrients may result in kidney disease (Hassan & Umar, 2004; Hassan *et al.*, 2007). Phytates are the principal storage form of phosphorus and are particularly abundant in cereals and legumes (Champ, 2002). These anti-nutrients chelate divalent cations such as calcium, magnesium, zinc and iron, thereby reducing their bioavailability (Sandberg, 2002). These results indicate that the consumption in large amounts of fresh studied leaves may have adverse effects on human health. Moreover, the anti-nutrients present in these plants could easily be detoxified by soaking, boiling or frying (Ekop and Eddy, 2005). Considering the recommended dietary allowance (RDA) for minerals: calcium (1000 mg/day); phosphorus (800 mg/day); magnesium (400 mg/day) and iron (8 mg/day), these leafy vegetables could cover RDA and contribute substantially for improving human diet (FND, 2005). Calcium and phosphorus are associated for growth and maintenance of bones, teeth and muscles (Turan *et al.*, 2003). However, the Ca/P ratio higher than 1 may be advantageous for consumption of the studied leaves because diet is considered good if the ratio Ca/P is > 1 and as poor if < 0.5 (Adeyeye & Aye, 2005). In addition, consumption of *S. melongena* leaves would probably reduce high blood pressure diseases because its ratio Na/K is less than one (FND, 2005). Sodium and potassium are important intracellular and extracellular cations respectively, which are involved in the regulation of plasma volume, acid-base balance, nerve and muscle contraction (Akpanyung, 2005). As concern magnesium, this mineral is known to prevent cardiomyopathy, muscle degeneration, growth retardation, alopecia, dermatitis, immunologic dysfunction, gonadal atrophy, impaired spermato-genesis, congenital malformations and bleeding disorders (Chaturvedi *et al.*, 2004). The iron contents of the studied leaves were higher than recommended dietary allowance for males (1.37 mg/day) and females (2.94 mg/day) (FAO/WHO, 1988). According to Geissler & Powers (2005), iron plays numerous biochemical roles in the body, including oxygen binding in hemoglobin and acting as an important catalytic center in many enzymes as the cytochrome oxydase. Thus, selected leaves of this study could be recommended in diets for reducing anemia which affects more than one billion people worldwide (Trowbridge & Martorell, 2002). To predict the bioavailability of calcium and iron, anti-nutrients to nutrients ratios were calculated. The calculated [oxalates]/ [Ca] and [phytates]/ [Ca] ratios in all the species were below the critical level of 2.5 known to impair calcium bioavailability (Hassan *et al.*, 2007). It was also observed that the calculated [phytates]/ [Fe] of *C. olitorius* and *S. melongena* were above the critical level of 0.4. This implies that the phytates of these leafy vegetables may hinder iron bioavailability (Umar *et al.*, 2007). However, the [phytates]/ [Fe] ratios could be considerably reduced after processing such as soaking, boiling or frying (Ekop and Eddy, 2005).

6 CONCLUSION

The data obtained in this study show that the leaves of *Basella alba*, *Colocasia esculenta*, *Corchorus olitorius*, *Solanum melongena* and *Talinum triangulare* contain appreciable amount of proteins, fibres, mineral elements and vitamins (vitamin C and provitamin A). The presence of secondary metabolites (polyphenols, flavonoids, tannins) in appreciable amounts in the leaves contributes to their medicinal value. These species also contain some anti-nutritional factors such as oxalates and phytates, which are required to be removed to improve their nutritional quality. Thus, it can be concluded that the studied leafy vegetables could contribute significantly to the nutrient requirements of human body and should be used as a source of nutrients to supplement other major diets. However, it is necessary to consider other aspects such as the *in vivo* bioavailability of the nutrients and the effects of processing on the chemical and nutritive value of these leafy vegetables.

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