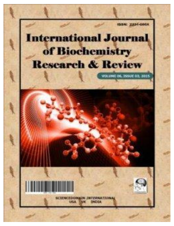

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Evaluation of Nutritive Value of Two Traditional African Vegetables (*Corchorus olitorus* and *Hibiscus sabdariffa*) Commonly Consumed in Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration between all authors. Author DKD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NKK and YDN managed the analyses of the study. Author GNA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Leafy vegetables play an important role as essential components of diet for rural populations in tropical Africa. The aim of this study was to evaluate the nutritive value of two leafy vegetable species (*Corchorus olitorus* and *Hibiscus sabdariffa*) consumed widely as sauces in Côte d'Ivoire.
Methodology: The proximate composition, minerals, nutritive and anti-nutritional components of fresh leafy vegetables were determined according to standard methods for nutritional guidelines.

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Results: The results obtained were as follows: moisture (85.75 - 86.29% Fresh basis), proteins (13.13 - 21.00% Dry basis), ash (7.00 - 9.14% Dry basis), carbohydrates (26.03 - 42.97% Dry basis) and lipids (4.35 - 4.74% Dry basis). The mineral contents were Phosphorus (0.44 – 0.62 g/100 g), Calcium (0.71 – 1.41g/100 g), Magnesium (1.31 – 2.00 g/100 g), and high amount of Iron (4.96 – 5.41 g/100 g). The result of computed antinutrient to mineral molar ratios suggest that Iron and Calcium bioavailability may not be impaired when the two leafy vegetables were consumed. These leafy vegetables were good sources of polyphenols (80.00 - 103.00 mg/100 g).

Conclusion: The leaves of *Corchorus olitorus* and *Hibiscus sabdariffa* contain appreciable amount of nutrients and minerals which could participate in the maintenance of a good nutritional status of the people in Côte d'Ivoire.

Keywords: African leafy vegetable; physicochemical composition; nutritional status; Côte d'Ivoire.

1. INTRODUCTION

The growing awareness in recent years of the health promoting has directed increased attention to vegetables as vital components in daily diets [1]. Despite this diversity, sub-Saharan Africa has the lowest level of vegetable consumption in the world and the highest level (15%) of malnutrition [2]. The traditional leafy vegetables are rich in micronutrients needed by humans for good health, growth and could contribute significantly to food security, which is a requirement for human development [3,4]. Promotion of traditional vegetables consumption can help to reduce food insecurity and improve nutrition [5]. Traditional African vegetables have values and properties that make them useful for farmers and consumers. Also, leafy vegetables are important sources of minerals, vitamins, fiber, amino acids and health promoting phytochemicals with antioxidant, antibiotic and anticancer and other nutraceutical properties [6]. Green leafy vegetables are not only rich in nutrients but also possess medicinal properties [7]. Intake of fruit and vegetable has been associated with a number of health benefits, such us reducing risk of cardiovascular disease and different types of cancer [8]. This association is often attributed to different antioxidant components, such as vitamin C, polyphenols and other phytochemical compounds. Unfortunately, many of these plants have not been put into maximum use except in times of nutritional stress [9]. Among these plants, there are *Corchorus olitorus* and *Hibiscus sabdariffa*, which negligence has been attributed to insufficient information on potential to serve as food security [10]. These vegetables can be used to alleviate micronutrient deficiency if cultivated, popularized and improved [11]. The aim of the present work was to determine the physicochemical, minerals and anti-nutritionals composition of the leaves of *Corchorus olitorus* and *Hibiscus sabdariffa* consumed in Côte d'Ivoire to reveal their nutritional potentials.

2. MATERIALS AND METHODS

2.1 Material

Corchorus olitorus and *Hibiscus sabdariffa* were previously authenticated by National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Côte d'Ivoire). The fresh leaves of *Corchorus olitorus* and *Hibiscus sabdariffa* were collected at maturity in the Gagnoa region (West-Central of Côte d'Ivoire).

2.2 Methods

2.2.1 Sample preparation

Leaves were put into clean and dry sample containers and transferred to the Laboratory of Food Biochemical and Tropical Products Technology (Nangui Abrogoua University, Abidjan, Côte d'Ivoire) immediately for powder preparation. The leafy vegetables were washed in fresh running water to eliminate dust, dirt, possible parasites or their eggs, and were washed again 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, there after 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 (21 ± 01°C) prior to analysis.

2.2.2 Chemical composition

The proximate analyses (protein, lipids, fiber, ash, moisture and carbohydrates) of powder of the leaves were determined by the Association of Official Analytical Chemist's method [12].

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) [13]. The pH was measured directly using a pH meter calibrated with standard buffers. Total crude fiber was determined according to the technique described by Prosky *et al.* using sulfuric acid [14]. The caloric value of samples was calculated using the Atwater conversion factors: 9 $kcal.g^{-1}$ of lipids, 4 $kcal.g^{-1}$ of carbohydrates and 4 $kcal.g^{-1}$ of proteins [15].

2.2.3 Mineral analysis

Minerals were determined by American the Association of Cereal Chemist's method [16]. 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 magnesium (Mg), iron (Fe), calcium (Ca), and phosphorus (P) were determined by atomic absorption spectro-photometry (Unicam Analytical system, Model 919, Cambridge, 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 hated (~70°C) for 3.5 h, leaving about 1 mL of liquid at the end of heating. The solution was then transferred to a 10 mL volumetric flask and brought to the volume 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.

2.2.4 The Anti-nutritionals compounds

Corchorus olitorus and *Hibiscus sabdariffa* leaves were analyzed for content of oxalates according to Day and Underwood method [17]. Phytates was extracted and separated by ion-exchange chromatography according to chromophore method of Mohamed et al. [18] before being quantified colorimetrically using an Ultraspec 3000 spectrophotometer at 500 nm

[19]. Polyphenols content (expressed as gallic acid equivalent, mg/100 g dry weight) was determined by colorimetry, using the Folin-Ciocalteu's method described by Singleton *et al.* [20].

2.2.5 Data analysis

Data were analyzed using STATA 12 (Stata Corp LP, College Station, Texa, USA). Student's t-test was used to assess comparisons between both samples at a probability (*P*) of 0.05.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Physicochemical properties

The physicochemical content of the leafy vegetables is presented in Table 1. Significant (*P* = .05) differences were observed for all parameters between *Corchorus olitorus* and *Hibiscus sabdariffa*, except for moisture. The two leaves were acidic (pH = 2.45 – 2.81) and had good source of energy (180.62 – 236.00 kcal/100g). The *H. sabdariffa* leaf had higher carbohydrate content (42.97%) than the value (26.03%) in *C. olitorus*. *C. olitorus* and *H. sabdariffa* had 4.35% and 4.74% respectively. The protein content was higher in *C. olitorus* (21.00%) than that of *H. sabdariffa* leaves (13.15%) but the fiber content (32.01%) was lower in *H. sabdariffa* than in *C. olitorus* leaf (41.67%). Ash content was lower in *C. olitorus* (7.00 %) than *H. sabdariffa* (9.14 %).

3.1.2 Minerals compound

The mineral content of the leafy vegetables is presented in Table 2. and differed significantly (*P* = .05) between *Corchorus olitorus* and *Hibiscus sabdariffa***.** The leaves are very important source of minerals. Calcium in *H. sabdariffa* leaves (1.41**%**) was higher than the one of *C. olitorus* (0.71%) and iron content in *C. olitorus* (4.96**%**) was lower than *H. sabdariffa* (5.41**%**). Besides magnesium content in *H. sabdariffa* 2.00**%** was higher than that of *C. olitorus* (1.31**%**). The leaves of *Hibiscus sabdariffa* had higher phosphorus value (0.62%) than the value (0.44%) in *C. olitorus*.

Table 1. Physicochemical properties of *Corchorus olitorus* and *Hibiscus sabdariffa* leafy vegetables

Parameters (% Dry basis)	*H. sabdariffa*	*C. olitorus*
pH	2.81 ± 0,00[a]	2.45 ± 0.00[b]
Moisture (% Fresh matter)	85.75 ± 0,76[a]	86.29 ± 0.85[a]
Carbohydrates	42.97 ± 0.00[a]	26.03 ± 0.03[b]
Proteins	13.15 ± 0.00[b]	21.00 ± 0.88[a]
Lipids	4.74 ± 0.07[a]	4.35 ± 0.00[b]
Fibers	30.01 ± 0.84[b]	41.67 ± 0.00[a]
Ash	9.14 ± 0.02[a]	7.00 ± 0.00[b]
Energetic value (kcal/100g)	236.00 ± 0.00[a]	180.62 ± 0.00[b]

Data are expressed as Means ± Standard Deviation (n=3). Means in the same line with no common superscript differ significantly (P = .05)

Table 2. Mineral composition of *Corchorus olitorus* and *Hibiscus sabdariffa* leafy vegetables

Minerals composition (% Dry basis)	*H. sabdariffa*	*C. olitorus*
Calcium	1.41 ± 0.06[a]	0.71 ± 0.00[b]
Iron	5.41 ± 0.40[a]	4.96 ± 0.03[b]
Magnesium	2.00 ± 0.00[a]	1.31 ± 0.00[b]
Phosphorus	0.62 ± 0.01[a]	0.44 ± 0.00[b]

Data are expressed as Means ± Standard Deviation (n=3). Means in the same line with no common superscript differ significantly (P = .05)

Table 3. Antinutritional factors and computed antinutrients/mineral molar ratios of *C. olitorus* and *H. sabdariffa* leafy vegetables

Parameters	*H. sabdariffa*	*C. olitorus*
Phytates (%)	0.01 ± 0.00[b]	0.05 ± 0.00 [a]
Polyphenols (%)	1.03 ± 0.00[b]	1.40 ± 0.00[a]
Oxalates (%)	1.23 ± 0.00[a]	0.80 ± 0.00[b]
Oxalates /Ca	0.87 ± 0.00	1.12 ± 0.00
Oxalates / Fe	0.16 ± 0.00	0.13 ± 0.00
Phytates/Ca	0.07 ± 0.00	0.00 ± 0.00
Phytates/Fe	0.01± 0.00	0.00 ± 0.00

Data are expressed as Means ± Standard Deviation (n=3). Means in the same line with no common superscript differ significantly (P = .05)

3.1.3 Antinutritional compounds

The antinutrients of *Corchorus olitorus* and *Hibiscus sabdariffa* are shown in Table 3. They differed significantly (*P* = .05). Phytates and Polyphenols contents were higher in the leaves of *C. olitorus* than in *H. sabdariffa* with the values of 0.05 g/100 g and 1.40 g/100 g respectively while oxalate was higher in *H. sabdariffa* leaves (1.23%) than in *C. olitorus* (0.80%). The computed molar ratios of oxalate/calcium and phytate/calcium were lower than 2.5. All the samples analyzed had their oxalates/iron and phytates/iron molar ratio less than 1.

3.2 Discussion

The nutrient values obtained in the present study were close to the values reported by Korotimi et al. [21] for leafy vegetables. These authors reported a higher moisture content for *C. olitorus* leaves compared to values in the present study. The relatively high moisture contents reveal that the studied leafy vegetables need care for appropriate preservation as they would be prone to deterioration [22]. Indeed, the high moisture content may induce a greater activity of water soluble enzymes and co-enzymes involved in metabolic activities of these leafy vegetables [23]. The results of lipid content were within the range (0.5-7.62%) reported for leafy vegetables [24]. The values of the percentage fat (in %) for the leaves of *C. olitorus*, and *H. sabdariffa* were 4.35 and 4.74 respectively which were lower than those of *Talinum triangulare* (5.09), *Amarantus hybridus* (4.80) [25]. However high contents of lipid in human diet are principal sources of obesity and other related diseases. Dietary fat composition can interfere in the development of obesity due to the specific roles of some fatty acids that have different metabolic activities, which can alter both fat oxidation and deposition rates, resulting in changes in body weight and/or composition [26]. A diet providing 1.20% of its caloric of energy as fat is said to be sufficient for human being as excessive fat consumption is implicated in certain cardiovascular disorders [23,27]. The leaves of *Corchorus olitorus* and *Hibiscus sabdariffa* have high level of protein and could be used as food protein supplement. The fibre and carbohydrate contents of both the leaves of *Corchorus olitorus* and *Hibiscus sabdariffa* observed in this study were lower than reported values for a number of tropical plants [28]. It is reported that carbohydrate provides energy to the cells in the body, particularly the brain, which is the carbohydrate-dependent organ in the body [29]. It is necessary for maintenance of the plasma level. It spares the body protein from being easily digested and helps to prevent protein from being used up [30]. 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 [31].

The mineral contents in the two leaves differed from the values reported by Agbo et al. [32]. The differences in minerals content may be due to leaf age at harvest, or the mineral fertilizer used in culture soil mineral composition and the proportion of individual mineral absorption by each plant and cultural practices [32-33]. The leafy vegetables may be considered as good sources of bioavailable minerals such as calcium (Ca), iron (Fe), magnesium (Mg) and phosphorus (P) [34]. These micro-nutrients are very important in the body. Calcium is important for construction and maintenance of bone and normal function of nerves and muscles [34]. Iron plays a role in the production of hemoglobin, myelin, melanin and it also keeps thyroid gland functioning normally [35]. Iron is essential for hemoglobin formation, normal functioning of central nervous system and in the oxidation of carbohydrates, protein and fats [36]. The deficiencies of magnesium are unusual but may lead to bone deformities, rashes, reduced hair growth [37].

Phenolic compounds concentration may vary with cultivar, agronomic conditions, maturity stage, variety, environmental conditions, fruit season, light exposure and storage conditions [38]. The phytochemical screening of *Corchorus olitorus* and *Hibiscus sabdariffa* leaves revealed presence of polyphenols. Consumption of polyphenols has been linked to lower risks of many chronic diseases including cancer, cardiovascular diseases, chronic inflammation and many degenerative diseases [39]. Polyphenolic antioxidants from dietary sources are frequently a topic of interest due to widespread scientific agreement that they may help lower the incidence of certain cancers, cardiovascular and neurodegenerative diseases, and DNA damage and even may have antiaging properties [40]. Phytochemicals in fruits can have complementary and overlapping mechanisms of action, acting as antioxidant agents, stimulants of the immune system, regulators of gene expression in cell proliferation and apoptosis, intermediaries in hormone metabolism, as well as antibacterial and antiviral agents. They play a role in prevention of degenerative diseases, particularly cardiovascular diseases and cancers [41]. The reductions in oxalates and phytates contents could improve the health status of consumers. Indeed, oxalates and phytates chelate divalent cations such as calcium, magnesium, zinc and iron, thereby reducing their bioavailability [42]. To predict the bioavailability of calcium and iron, antinutrients to mineral molar ratios were calculated. The calculated oxalates/Ca and phytates/Ca ratios molar ratios in the two species were below the critical level of 2.5 known to impair calcium bioavailability [43]. It was also observed that the calculated phytates/Fe molar ratios of the samples were below the critical level of 1. This implies that the phytates of these leafy vegetables may not hinder iron bioavailability [44]. However, the phytates /Fe molar ratios could be considerably reduced after processing such as soaking, boiling or frying [45].

4. CONCLUSION

The leaves of *Corchorus olitorus* and *Hibiscus sabdariffa* contain significant levels of nutrients and polyphenols that are essential for human health. The result of this study revealed the bioavailability of minerals like calcium and iron. Thus, the leafy vegetables studied could significantly contribute to human health and could play a major role to combat micronutrient deficiency, also called “hidden hunger”, which is a main cause of health problems and high mortality for groups at risk, mainly children and pregnant women in tropical Africa (Côte d'Ivoire).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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