# PROXIMATE COMPOSITION AND NUTRITIVE VALUE OF LEAFY VEGETABLES CONSUMED IN NORTHERN CÔTE D'IVOIRE

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**Abstract**

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 contribute to their wider utilization and valorization, leafy vegetables consumed in Northern Côte d'Ivoire (*Amaranthus hybridus*, *Andasonia digitata*, *Ceiba patendra*, *Hibiscus sabdariffa* and *Vigna unguiculata*) have focused our attention. The physicochemical and nutritive properties of these leafy vegetables were investigated and the results obtained were as follow: moisture (69.93 - 87.40%), crude proteins (13.12 - 22.26%), crude fibres (12.11 - 33.00%), ash (7.25 - 26.79%), carbohydrates (26.19 - 59.99%), crude lipids (1.17 - 4.90%) and food energy (134.87 - 312.92 kcal/100g). The mineral elements contents were high with remarkable amount of K (848.3 - 3970 mg/100g), Ca (1331.15 - 4680 mg/100g), Mg (345.55 - 2110 mg/100g), P (343.53 - 1320 mg/100g) and Fe (30.71 - 90.00 mg/100g). The Ca/P ratio was desirable and ranged from 2.75 to 9.99. These leafy vegetables also contained appreciable levels of vitamin C (30.00 - 60.01 mg/100g) and polyphenols (134.07 - 294.83 mg/100g). The studied leafy vegetables highlighted antioxidant activity varying from 69.05 to 80.21%. All these results indicate 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.

**Keywords:** Leafy vegetables, proximate composition, nutritive value, antioxidant properties

## Introduction

In tropical Africa where the daily diet is dominated by starchy staples, these plants contribute significantly to household food security and add variety to cereal-based staple diets (Van-den-Heever, 1997). Indeed, african leafy vegetables (ALVs) are the cheapest and most readily available sources of proteins, vitamins, minerals and essential amino acids (Martin and Meitner, 1998).. Traditionally, leafy vegetables are cooked and eaten as a relish together with a starchy staple food, usually in the form of porridge (Vainio-Mattila, 2000). These dishes can be prepared with a single plant species or a combination of different species in order to add flavor, taste, color and aesthetic appeal to diet (Marshall, 2001; Fasuyi, 2006). Leafy vegetables also provide very important sources of employment in peri-urban areas because of their generally short labour-intensive production systems, low levels of investment and high yield (Schippers, 2000).

The health promoting and protecting attributes of ALVs is clearly linked to their nutritional and non-nutrient bioactive properties. Indeed, they have long been, and continue to be reported to significantly contribute to the dietary vitamin and mineral intakes of local populations (Nordeide *et al*., 1996). These micronutrients are essential food nutrients useful for the body as protective agent against diseases; thus necessary for health and growth (Ertan *et al*., 2002; Falade *et al*., 2003). Inadequate intake of micronutrients known as “hidden hunger” contributes to the increasing rates of illness and death from infectious diseases and disability such as mental impairment (Black, 2003). Therefore, leafy vegetables may be used as basic strategy for fighting against poverty, hunger, malnutrition and under nourishment (Barminas *et al*., 1998).

Despite of their availability, the frequency of consumption of African leafy vegetables 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 and Msuya, 2004). The preference of leafy vegetables species depends on the gender and age of consumers, as well as 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 micronutrients than those found in most exotic areas (Steyn *et al*., 2001).

In spite of the nutritional contribution of ALVs 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). In Northern Côte d’Ivoire, most people consume indigenous green leafy vegetables such as *Amaranthus hybridus* "boronbrou", *Andasonia digitata* "baobab", *Ceiba patendra* "fromager", *Hibiscus sabdariffa* "dah" and *Vigna unguiculata* "haricot" through confectionary soups (CNRA, 2011). The soups prepared using these plant species are often eaten with a sorghum or millet flour food named "tô". However, literature on the nutritive value of these consumed leafy vegetables is very scanty. This study was therefore under-taken to evaluate the proximate nutrient content, mineral and anti-nutritional factors of leafy vegetables consumed in Northern Côte d'Ivoire in order to provide necessary information for their wider utilization and contribution to food security.

## 1. Materials and Methods

### 1.1 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.

### 1.2 Plant Materials

Leafy vegetables were collected fresh and at maturity from cultivated farmlands located at Dabou (latitude: 5°19′14″ North; longitude: 4°22′59″ West) (Abidjan District). These plants were authenticated by National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Côte d'Ivoire). The preliminary treatment of these leafy vegetables was done according to Chinma and Igyor (2007) and modified as following: the collected plants were destalked, washed with distilled water, drained at ambient temperature and oven-dried (Memmert, Germany) at 60 °C for 72 h. 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.

### 1.3 Physicochemical Analysis

Proximate analysis was carried out using the AOAC (1990) standard methods. Moisture was determined by drying a representative 10 g drained leaves in an oven (Memmert, Germany) at 105 °C until constant weight. Ash content was determined by the incineration of a dried powdered sample (5 g) in a muffle furnace (Pyrolabo, France) at 550 °C for 12 h until the ash turned white. 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. Crude proteins were estimated by the Kjeldahl method. Total proteins were calculated by multiplying the evaluated nitrogen by 6.25. Lipids content was determined by hexane extraction for 7 h in a Soxhlet apparatus. 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 fibres content. Carbohydrates and calorific value were calculated using the 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.

## 1.4. Nutritive and antioxidant analysis

### 1.4.1 Vitamin C determination

The amount of vitamin C in analyzed samples (fresh leaves) 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 point with dichlorophenol-indophenol (DCPIP) 0.5 g/L.

### 1.4.2 Carotenoids determination

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 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.

### 1.4.3 Polyphenols determination

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.

### 1.4.4 Flavonoids determination

The total flavonoids content was evaluated using the method reported by Meda *et al*. (2005). 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.

### 1.4.5 Tannins determination

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.

### 1.4.6 Oxalates determination

The titration method as described by Day and 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 point.

### 1.4.7 Phytates determination

The method described by Wheeler and 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 estimate the phytic acid content.

### 1.5 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]

### 1.6 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).

### 1.7 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 $p < 0.05$.

## 2. Results and Discussion

### 2.1 Physicochemical properties

The proximate composition of the selected leafy vegetables is shown in Table 1. All the physicochemical parameters generally differ significantly ($p < 0.05$) from a leafy vegetable to another. The moisture content varied from 70.45 ± 0.52 % for *C. patendra* to 86.05 ± 1.35 % for *H. sabdariffa.* These values of moisture corroborated with results (60 – 90 %) of investigated vegetables as indicated by FAO (2006). The relatively high moisture contents reveal that the studied leafy vegetables need care for appropriate preservation as they would be prone to deterioration (Kwenin, 2011). 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 (Iheanacho and Udebuani, 2009). Ash content was relatively high with values ranging from 8.59 ± 1.34 % for *A. hybridus* to 25.67 ± 1.12 % for *C. patendra*. These values indicate that these vegetables species may be considered as good sources of minerals when compared to values (2 – 10 %) obtained for cereals and tubers (FAO, 1986). In addition, high level (12.11 - 33 %) of crude fibres in these leafy vegetables would be advantageous for their active role in the regulation of intestinal transit, increasing dietary bulk due to their ability to absorb water (Jenkin *et al.*, 1986). The values obtained (1.17 – 4.90 %) for lipids in these vegetables species confirmed the findings of many authors which showed that leafy vegetables are poor sources of lipids (Ejoh *et al*., 1996). However, it's important to note that 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). Therefore, the consumption of these leafy vegetables in large amount may be recommended to individuals suffering from obesity. The crude proteins content ranged between 13.25 ± 0.13 % and 21.96 ± 0.30 %. The proteins content of *V. unguiculata* (21.96 ± 0.30 %) was higher than that reported for some high value leafy vegetables such as *Momordica balsamina* (11.29 %) and *Moringa oleifera* (20.72 %) (Asaolu *et al*., 2012). It's worth precising that plant foods which 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 are good sources of proteins and could play a significant role in providing cheap and available proteins for rural communities. Assuming complete protein absorption, 100 g of the studied leaves would respectively contribute for about 18.6 to 30.92 % of the daily protein requirement (71 g/day) of pregnant and lactating mothers (FND, 2005). The carbohydrate contents (26.19 – 57.48 %) were higher than 20, 23.7 and 39.05 % reported for *Senna obtusfolia*, *Amaranthus incurvatus* and *Momordica balsamina* leaves, respectively (Hassan and Umar, 2006). These values are however; lower than those reported for *Corchorus tridens* (75 %) and sweet potato leaves (82.8 %) (Asibey-Berko and Tayie, 1999). The recommended dietary allowance (RDA) values for children, adults, pregnant and lactating mothers are 130 g, 130, 175 and 210 g, respectively. It implies that 12.5 to 27.72 % of the daily requirement could be reached when 100 g of dried studied leaves are consumed. Except for *C. patendra* (142.61 ± 7.74 kcal/100 g), the estimated calorific values compared favourably to 248.8 – 307.1 kcal/100 g reported in some Nigerian vegetables (Antia *et al*., 2006). Asibey-Berko and Tayie (1999) also reported comparable energy value in some Ghanaian green leafy vegetables. Thus, the calorific value agreement with general observation that vegetables have low energy values (Lintas, 1992).

### 3.2. 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. The leaves of *A. digitata*, *A. hybridus* and *V. unguiculata* contained appreciable amount (60 – 78.66 mg/100 g) of vitamin C (ascorbic acid) except for those of *H. sabdariffa* and *C. patendra* whose values were below the standard value (40 mg/day) recommended by FAO

(2004). It's is important noting 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 and Gutteridge, 1999). As for the carotenoids content, it depends on the leafy vegetables species and varied from 1.55 ± 0.02 mg/100 g for *V. unguiculata* to 5.04 ± 0.02 mg/100 g for *C. patendra* (Table 2). In plants, vitamin A occurs in the form of provitamin A carotenoids which amount determines their bioavailability in human diet (Rodriguez-Amaya, 2001; West *et al*., 2002). Furthermore, carotenoids contents of *A. hybridus* and *C. patendra* could cover the standard values (3.6 - 4.8 mg/day) recommended by FAO (2004). Analysis of polyphenols has revealed that *C. patendra*, *H. sabdariffa* and *A. hybridus* are major sources with contents of 293.08 ± 1.75, 251.12 ± 0.10 and 238.67 ± 5.25 mg/100 g, respectively. 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 and Shahidi, 2004). Flavonoids such as myricetin, quercetin, kaempferol, isorhamnetin and luteolin have been reported in leafy vegetables by Trichopoulou *et al*. (2000). These polyphenols levels may explain the antioxidant activity values (75 – 85 %) of the studied leafy vegetables (Figure 1). Indeed, plant extracts that contain appreciable 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 *et al*., 1996; Amic *et al*., 2003). The selected leafy vegetables used in this study contained also anti-nutrients which amounts vary from 780.00 ± 0.00 to 1310 ± 78.00 mg/100 g for oxalates and 17.25 ± 0.00 to 86.45 ± 0.10 mg/100 g for phytates. Phytic acid is the major phosphorus storage compound in leafy vegetables and this compound chelates multivalent metal ions such as zinc, calcium and iron, reducing their bioavailability (Champ, 2005; Schlemmer *et al*., 2009). Hurrel *et al*. (1992) reported that a phytic acid intake of 4-9 mg/100 g (dry matter) decreases iron absorption by 4-5 folds in human. The oxalates content in this study was 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 high in these anti-nutrients may result in kidney disease (Hassan and Umar, 2004; Hassan *et al*., 2007). These results indicate that the consumption in large amounts of the fresh studied leaves may have adverse effects on human health. Nevertheless, the anti-nutrients present in these plants could easily be detoxified by soaking, boiling or frying (Ekop and Eddy, 2005).

### 3.3. Mineral composition

Mean values for mineral content of the selected leafy vegetables are presented in Table 3. The species analysed in this study contained relatively high amounts of calcium (1211 – 4680 mg/100 g), potassium (848 – 3970 mg/100 g), phosphorus (362 – 1320 mg/100 g), magnesium (348 – 2110 mg/100 g) and iron (30 – 90 mg/100 g). The relationship between Ca and P revealed ratio varying from 2.75 to 9.99. Only *C. patendra* contained sodium (Na) with value of 1390 ± 40.00 mg/100 g. In view to 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). It's worth underlining that 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 might 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 and Aye, 2005). In addition, consumption of *C. patendra* 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 spermatogenesis, congenital malformations and bleeding disorders (Chaturvedi *et al*., 2004). The iron contents of the studied leafy vegetables 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 and Powers (2005), iron plays numerous biochemical roles in the body, including oxygen blinding in hemoglobin and acting as an important catalytic center in many enzymes as the cytochrome oxydase. Thus, the selected leaves of this study could be recommended in diets for reducing anemia which affects more than one billion people worldwide (Trowbridge and 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] ratios of *C. patendra* and *H. sabdariffa* 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).

## Conclusion

The aim of this study was to determine the nutrient and non-nutrient composition of the leaves of *Amaranthus hybridus*, *Andasonia digitata*, *Ceiba patendra*, *Hibiscus sabdariffa* and *Vigna unguiculata*. From the results, the studied leafy vegetables are good source of nutrients: proteins, fibres, vitamin C, carotenoids and minerals (Ca, Mg, K, P and Fe). The presence of secondary metabolites (polyphenols, flavonoids, tannins) in appreciable amounts in the plant leaves could contribute to their medicinal value. These species also contained some anti-nutritional factors such as oxalates and phytates which are required to be removed to improve their nutritional quality. All these results suggest that the studied leafy vegetables if consume in sufficient amount would contribute greatly to the human nutritional requirement for normal growth and adequate protection against diseases arising from malnutrition. Investigating the bioavailability of the nutrients content of the selected leafy vegetables with the optimization of their functional properties and nutritional values would probably lead to higher demand, wider cultivation and food security of populations.

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

| Parameters | Leafy vegetables | | | | |
|---|---|---|---|---|---|
| | *A. digitata* | *A. hybridus* | *C. patendra* | *H. sabdariffa* | *V. unguiculata* |
| **Moisture (%)** | 77.63 ± 0.15[c] | 72.98 ± 0.16[d] | 70.45 ± 0.52[e] | 86.05 ± 1.35[a] | 80.04 ± 0.56[b] |
| **pH** | 5.98 ± 0.02[d] | 6.33 ± 0.01[c] | 6.40 ± 0.01[b] | 2.45 ± 0.02[e] | 6.53 ± 0.06[a] |
| **Ash (%)** | 10.97 ± 0.40[bc] | 8.59 ± 1.34[e] | 25.67 ± 1.12[a] | 10.30 ± 0.10[d] | 11.17 ± 0.25[b] |
| **Crude fibres (%)** | 12.56 ± 0.45[e] | 17.80 ± 0.30[bc] | 31.50 ± 1.50[a] | 14.27 ± 0.04[d] | 18.00 ± 0.92[b] |
| **Lipids (%)** | 2.18 ± 0.03[c] | 2.15 ± 0.01[cd] | 1.39 ± 0.22[e] | 4.75 ± 0.15[a] | 4.23 ± 0.25[b] |
| **Proteins (%)** | 18.08 ± 0.10[b] | 13.25 ± 0.13[e] | 15.20 ± 0.05[c] | 14.47 ± 0.10[d] | 21.96 ± 0.30[a] |
| **Carbohydrates (%)** | 56.23 ± 1.25[b] | 58.21 ± 1.78[a] | 26.30 ± 0.11[e] | 56.21 ± 1.70[bc] | 44.64 ± 1.72[d] |
| **Calorific energy (kcal/100g)** | 267.03 ± 4.00[c] | 305.19 ± 7.73[a] | 142.61 ± 7.74[e] | 275.71 ± 8.55[b] | 248.35 ± 10.33[d] |

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 Northern Côte d'Ivoire

| Parameters (mg/100g) | Leafy vegetables | | | | |
|---|---|---|---|---|---|
| | *A. digitata* | *A. hybridus* | *C. patendra* | *H. sabdariffa* | *V. unguiculata* |
| **Vitamin C** | 70.00 ± 8.66[a] | 55.00 ± 0.10[c] | 40.00 ± 4.33[d] | 30.00 ± 0.00[e] | 60.00 ± 0.01[b] |
| **Carotenoids** | 3.38 ± 0.00[c] | 3.86 ± 0.01[b] | 5.04 ± 0.02[a] | 2.35 ± 0.09[d] | 1.55 ± 0.02[e] |
| **Polyphenols** | 135.21 ± 1.14[e] | 238.67 ± 5.25[c] | 293.08 ± 1.75[a] | 251.12 ± 0.10[b] | 136.03 ± 10.49[d] |
| **Tannins** | 70.13 ± 2.59[d] | 150.64 ± 0.00[b] | 114.28 ± 2.60[c] | 204.79 ± 1.48[a] | 69.26 ± 3.00[de] |
| **Flavonoids** | 16.40 ± 0.00[d] | 27.00 ± 0.30[ab] | 16.55 ± 0.00[c] | 27.58 ± 0.10[a] | 15.00 ± 0.01[e] |
| **Oxalates** | 780.00 ± 0.00[c] | 65.00 ± 0.00[e] | 780.00 ± 78.00[b] | 1310 ± 78.00[a] | 730.00 ± 78.00[d] |
| **Phytates** | 19.78 ± 0.01[d] | 31.99 ± 0.00[c] | 38.29 ± 1.13[b] | 86.45 ± 0.10[a] | 17.25 ± 0.00[e] |

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

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

| Minerals (mg/100g) | Leafy vegetables | | | | |
|---|---|---|---|---|---|
| | *A. digitata* | *A. hybridus* | *C. patendra* | *H. sabdariffa* | *V. unguiculata* |
| **Calcium (Ca)** | 3532.34 ± 64.00[b] | 1271.15 ± 60.00[e] | 4610 ± 70.00[a] | 1791.72 ± 24.00[d] | 3357.33 ± 70.00[c] |
| **Magnesium (Mg)** | 353.24 ± 7.69[e] | 779.74 ± 20.00[b] | 2070 ± 40.00[a] | 537.39 ± 15.00[d] | 615.84 ± 60.00[c] |
| **Phosphorus (P)** | 353.23 ± 9.70[e] | 462.80 ± 10.00[cd] | 1290 ± 30.00[a] | 472.5 ± 12.00[c] | 682.86 ± 50.00[b] |
| **Potassium (K)** | 3022.24 ± 10.92[b] | 1258.43 ± 60.00[d] | 3850 ± 120[a] | 856.8 ± 8.50[e] | 2245.91 ± 14.00[c] |
| **Sodium (Na)** | ND | ND | 1390 ± 40.00[a] | ND | ND |
| **Iron (Fe)** | 38.39 ± 6.40[c] | ND | 80.00 ± 10.00[a] | 30.87 ± 0.16[d] | 45.80 ± 0.01[b] |
| **Ca/P** | 9.99 | 2.75 | 3.57 | 3.79 | 4.92 |
| **Na/K** | - | - | 0.36 | - | - |
| **Oxalates/Ca** | 0.22 | 0.05 | 0.17 | 0.73 | 0.21 |
| **Phytates/Ca** | 0.006 | 0.02 | 0.11 | 0.05 | 0.005 |
| **Phytates/Fe** | 0.31 | - | 0.47 | 2.80 | 0.37 |

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

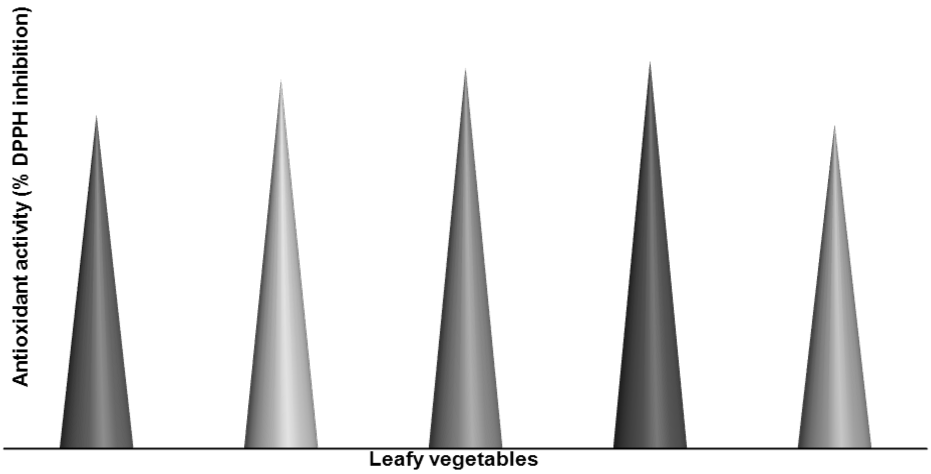


**Figure 1:** Antioxidant activity of leafy vegetables consumed in Northern Côte d'Ivoire