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# Nutritive and antioxidant characteristics of roasted leafy vegetables consumed in Western Côte d'Ivoire (Ivory Coast)

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**Abstract:** African Leafy Vegetables (ALVs) have long been recognized as the cheapest and the most abundant potential sources of vitamins and minerals using for fighting against malnutrition. Five leafy vegetables (*Abelmoschus esculentus*, *Celosia argentea*, *Ipomea batatas*, *Manihot esculenta* and *Myrianthus arboreus*) that are used for sauce preparation in Western Côte d'Ivoire (Ivory Coast) were subjected to roasting in order to evaluate the effect of this non conventional processing method on their nutritive and antioxidant properties. This study showed that longer time (higher than 2 min) of roasting at 180-200°C caused negative impact with nutrient losses but positive impact by reducing anti-nutrients such as oxalates and phytates. The registered losses at 2 min of roasting were as follow: ash (7.47 – 36.65 %), proteins (3.04 – 32.66%), vitamin C (75 – 92.14%), carotenoids (27.34 – 81.94%), oxalates (3.84 – 10.89%) and phytates (0.45 – 15.72%). Roasting processing of the studied leafy vegetables highlighted a significant increase (2.63 to 13.83%) of polyphenols contents coupled with increasing of antioxidant activity. Moreover, after 2 min of roasting processing, the residual contents of minerals were: calcium (202.45 – 542.06 mg/100g), magnesium (123.73 – 467.43 mg/100g), potassium (1209.85 – 3796.16 mg/100g), iron (44.72 – 128.47 mg/100g) and zinc (6.35 – 40.13 mg/100g). All these results suggest that roasting processing (less than 2 min at 200°C) may be used as valuable cooking method of leafy vegetables in order to minimize nutrient losses and to contribute efficiently to the food security of Ivorian population.

**Keywords:** Antioxidant Properties, Roasting Processing, Leafy Vegetables, Nutritive Value

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## 1. Introduction

Knowledge of African Leafy Vegetables (ALVs) and their uses is crucial for the survival of many African communities because they can serve as affordable sources of micronutrients and could contribute therefore to the reduction of malnutrition [1,2,3]. African leafy vegetables are better adapted to the environment than introduced exotic vegetables and also provide low-cost quality nutrition for large parts of the population in both rural and urban areas [4]. These plants have long been recognized as the cheapest and most abundant potential sources of vitamins and minerals. The ethno-botanical studies also report information on medicinal properties of ALVs like anti-diabetic, anti-histaminic, anti-carcinogenic, hypolipidemic and antibacterial activities [5]. Many African families who depend on traditional leafy vegetables use them as available and affordable feed when they are out of the vegetable production season [6]. Many

different methods are adopted for the preservation of these leafy vegetables with sun-drying as the popular processing which removes the moisture from the food so bacteria, yeast and molds cannot grow and spoil [7]. Among the twenty hundred and seven (207) leafy vegetables widely consumed in tropical Africa, about twenty (20) species belonging to 6 botanical families, are widely consumed and cultivated by Ivorian populations [8,9]. Furthermore, ethno-botanical surveys have revealed that the consumption of these leafy vegetables is linked to cultural regions. Thus, most people in Western Côte d'Ivoire (Ivory Coast) consume through sauces preparation, leafy vegetables such as *Abelmoschus esculentus* “gombo”, *Celosia argentea* “soko”, *Ipomea batatas* “patate”, *Manihot esculenta* “manioc” and *Myrianthus arboreus* “tikliti” [9,10]. Earlier reports have highlighted the nutritive potential of these fresh leafy vegetables [11]. For these species, the

tender leaves are prepared as potherbs or as relishes, primarily to accompany starchy paste foods as cassava, maize and sorghum. These leafy vegetables may be prepared from a single species or from a combination of them. For cooking, the mature and freshly leaves are boiled in water for about 30 min in order to reduce bitter taste and then used, after discarding boiled water, for sauce preparation. In a lesser extent, blanching is also used to inactivate oxidative enzymes, destroy vegetative microbial cells, reduce or eliminate the bitterness and to remove any residual pesticides [12,13]. Even if some adverse effects such as nutrient losses have been reported by using boiling or blanching processing [14,15], there is any data on the roasting (oven-cooking) processing effect on the physicochemical and nutritive properties of leafy vegetables consumed in Western Côte d'Ivoire (Ivory Coast). Therefore, the purpose of this study is to conduct investigation on the influence of roasting on the nutritive value of these selected leafy vegetables in order to provide necessary information for their wider utilization and contribution to food security of Ivorian population.

## 2. Material and Methods

### 2.1. Samples Collection

Leafy vegetables (*Abelmoschus esculentus*, *Celosia argentea*, *Ipomea batatas*, *Manihot esculenta* and *Myrianthus arboreus*) were collected fresh and at maturity from cultivated farmlands located at Dabou (latitude: 5°19'14" North; longitude: 4°22'59" West) (Abidjan District). The samples were harvested at the early stage (between one and two weeks of the appearance of the leaves). These plants were previously authenticated by the National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Ivory Coast).

### 2.2. Samples Processing

The fresh leafy vegetables were rinsed with deionized water and the edible portions were separated from the inedible portions. The edible portions were chopped into small pieces (500 g) and allowed to drain at ambient temperature. Each sample was subdivided into two parts. One part (raw, 250 g) was dried in an oven (Memmert, Germany) at 60°C for 72 h [16]. The dried leaves were ground with a laboratory crusher (Culatti, France) equipped with a 10 µm mesh sieve. Each sample was stored in a clean dry air-tight sample bottle in a refrigerator (4°C) until required for analyses. The second part (250 g) was roasted (oven-cooking) for 2, 4 and 6 min at 180-200°C. The roasted samples were cooled at ambient temperature and subjected to the same treatment (drying and gridding) using for raw samples.

### 2.3. Chemicals

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

## 2.4. Nutritive Properties

### 2.4.1. Proximate Analysis

Proximate analysis was performed using official methods [17]. The moisture content was determined by the difference of weight before and after drying fresh sample (10 g) in an oven (Memmert, Germany) at 105°C until constant weight. The dry matter content was deduced from the difference of 100 and percentage moisture. Ash fraction was determined by the incineration of dry matter sample (5 g) in a muffle furnace (Pyrolabo, France) at 550°C for 12 h. The percentage residue weight was expressed as ash content. For crude fibres, 2 g of dry matter sample were weighed into separate 500 mL round bottom flasks and 100 mL of 0.25 M sulphuric acid solution was added. The mixture obtained was boiled under reflux for 30 min. Thereafter, 100 mL of 0.3 M sodium hydroxide solution was added and the mixture were boiled again under reflux for 30 min and filtered through Whatman paper. The insoluble residue was then incinerated, and weighed for the determination of crude fibres content. Proteins were determined through the Kjeldhal method and the lipid content was determined by Soxhlet extraction using hexane as solvent. Carbohydrates content and calorific value were calculated and expressed on dry matter basis using the following formulas [18]:

Carbohydrates (dry matter basis):

$$100 - (\% \text{ proteins} + \% \text{ lipids} + \% \text{ ash} + \% \text{ fibres}) \quad (1)$$

Calorific value (dry matter basis):

$$(\% \text{ proteins} \times 2.44) + (\% \text{ carbohydrates} \times 3.57) + (\% \text{ lipids} \times 8.37) \quad (2)$$

The results of ash, fibres, proteins, lipids and carbohydrates contents were expressed on dry matter basis.

### 2.4.2. Anti-Nutritional Factors Determination

Oxalates content was performed by using a titration method [20]. One (1) g of dried powdered sample was weighed into 100 mL conical flask. A quantity of 75 mL of sulphuric acid (3 M) was added and stirred for 1 h with a magnetic stirrer. The mixture was filtered and 25 mL of the filtrate was titrated while hot against KMnO<sub>4</sub> solution (0.05 M) to the end point.

Phytates contents were determined using the Wade's reagent colorimetric method [21]. A quantity (1 g) of dried powdered sample was mixed with 20 mL of hydrochloric acid (0.65 N) and stirred for 12 h with a magnetic. The mixture was centrifuged at 12000 rpm for 40 min. An aliquot (0.5 mL) of supernatant was added with 3 mL of Wade's reagent. The reaction mixture was incubated for 15 min and absorbance was measured at 490 nm by using a spectrophotometer (PG Instruments, England). Phytates content was estimated using a calibration curve of sodium phytate (10 mg/mL) as standard.

### 2.4.3. Mineral Analysis

Minerals contents were determined by the ICP-MS (inductively coupled argon plasma mass spectrometer) method [19]. The dried powdered samples (5 g) were burned to ashes in a muffle furnace (Pyrolabo, France). The ashes obtained were dissolved in 10 mL of HCl/HNO<sub>3</sub> and

transferred into 100 mL flasks and the volume was made up using deionized water. The mineral composition of each sample was determined using an Agilent 7500c argon plasma mass spectrometer. Calibrations were performed using external standards prepared from a 1000 ppm single stock solution made up with 2% nitric acid.

#### 2.4.4. Antioxidant Properties Evaluation

##### 2.4.4.1. Vitamin C and Carotenoids Determination

Vitamin C contained in analyzed samples was determined by titration [22]. 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.

Carotenoids were extracted and quantified following a spectrophotometric method [23]. 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  $\beta$ -carotene (1 mg/mL) as standard.

##### 2.4.4.2. Polyphenols Determination

Polyphenols were extracted and determined using Folin–Ciocalteu's reagent [24]. A quantity (1 g) of dried powdered sample was soaked in 10 mL of methanol 70% (v/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.

##### 2.4.4.3. Antioxidant Activity

Antioxidant activity assay was carried out using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) spectrophotometric method [25]. 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:

$$\text{Antioxidant activity (\%)} = 100 - \left[ \frac{\text{Abs of sample} - \text{Abs of blank}}{\text{Abs positive control}} \right] \quad (3)$$

#### 2.4.5. 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  $p < 0.05$ .

## 3. Results and Discussion

### 3.1. Nutritive Properties

The proximate composition of the roasted leafy vegetables is presented in Table 1. The described physicochemical parameters generally differ significantly ( $p < 0.05$ ) from a roasting time of a leafy vegetable to another. The ash content after 2 min of roasting ranged from  $5.72 \pm 0.93\%$  (*M. esculenta*) to  $17.59 \pm 0.09\%$  (*I. batatas*). These values were closed to  $5.48 \pm 0.15\%$  (*M. esculenta*) and  $16.18 \pm 0.57\%$  (*C. argentea*) after 6 min of roasting. The decrease rate observed at 2 min of roasting ranged from 7.47 to 36.65 % in the following order: *A. esculentus* (7.47%) > *M. arboreus* (12.10%) > *C. argentea* (20.90%) > *I. batatas* (25.33%) > *M. esculenta* (36.65%). These observed losses are lower than that (16.22 – 54.29%) reported for the same boiled leafy vegetables [26]. With regard to this minerals retention (63.35 – 92.53%), roasting processing could be advantageous for mineral quality preservation of leafy vegetables. As regards protein contents, roasting processing resulted in 3.04 to 32.66% reduction after 2 min. The lowest proteins content reduction (3.04%) was observed for *A. esculentus* while the maximum reduction of proteins content (32.66%) was noted for *M. esculenta*. The average reduction of proteins in this study is comparable to that (4 – 33%) obtained in previous report for the same boiled leafy vegetables [26]. These losses in protein contents could be attributed to the severity of thermal processing (180-200°C) which leads to protein degradation [27]. However, the studied thermal processing could enhance the digestibility of proteins by degradation of anti-nutritional factors such as tannins [28]. Roasting of the studied leafy vegetables resulted in increasing ( $p < 0.05$ ) in their crude fibres contents (4.59 – 11.48%) after 2 min of heat application. Indeed, the increased temperature leads to breakage of weak bonds between polysaccharides and the cleavage of glycosidic linkages, which makes the dietary fibres soluble [29]. Considering the fibres contents (13.59 – 32.30%) after 2 min of roasting, adequate intake (100g/day) of roasted leafy vegetables as desserts could lower the risk of constipation, diabetes, and colon cancer [30]. The relatively low values of lipids contents at 2 min of roasting (1.87 – 3.95%) for the studied leafy vegetables corroborates the findings of many authors which showed that leafy vegetables are poor sources of fat [31]. Therefore, the daily consumption of roasted leafy vegetables through soup preparation could be advantageous for the prevention of lipid disorders as obesity. In addition, the calculated calorific values (213.45 – 283.33 kcal/100g) after 2 min of roasting agrees with general observation that leafy vegetables have low energy values due to their low crude fat and relatively high level of moisture [32].

The impact of roasting on anti-nutritional factors (oxalates

and phytates) contents is depicted in figure 1. The observed losses at 2 min of roasting were 3.84 – 10.89 % and 0.45 – 15.72% for oxalates and phytates, respectively. Considering oxalates and phytates contents, the maximum reduction values (10.89 and 15.72%) after 2 min of roasting were observed for *A. esculentus*. These reductions in oxalates and phytates contents during roasting are lower than that (19.63 – 67.47%) of boiled leafy vegetables consumed in Western Côte d'Ivoire [26]. Oxalates and phytates are anti-nutrients which chelate divalent cations such as calcium, magnesium, zinc and iron thereby reducing their bioavailability [33]. In order to reduce considerably their oxalates and phytates contents, roasted leafy vegetables may be soaked before using as desserts.

### 3.2. Mineral Composition

Mineral composition of the studied roasted leafy vegetables is shown in table 2. The residual contents of minerals after 2 min of roasting were significantly different ( $p < 0.05$ ): calcium (202.45 – 542.06 mg/100g), magnesium (123.73 – 467.43 mg/100g), potassium (1209.85 – 3796.16 mg/100g), iron (44.72 – 128.47 mg/100g) and zinc (6.35 – 40.13 mg/100g).

Compared to the values of raw and boiled leafy vegetables [26], these observed reductions may be due to the losses of ashes. With regard to these residual values, powdered roasted leafy vegetables could be recommended as food complement in porridges preparation for target populations as infants, pregnant woman and old people in order to cover mineral requirements. Indeed, the standard mineral requirements for human are: calcium (1000 mg/day); magnesium (400 mg/day), iron (8 mg/day) and zinc (6 mg/day) [34]. Calcium and phosphorus play important role in growth and maintenance of bones, teeth and muscles [35]. As regards magnesium, this mineral is known to prevent muscle degeneration, growth retardation, congenital malformations and bleeding disorders [36]. Iron plays important role in prevention of anemia while zinc is important for vitamin A and vitamin E metabolisms [37,34]. In order to predict the bioavailability of calcium and iron, anti-nutrients to nutrients ratios of roasted leafy vegetables were calculated (Table 3). The calculated [phytates]/[Ca] ratio in all the roasted species were below the critical level of 2.5 which is known to impair calcium bioavailability [38].

**Table 1.** Proximate composition of raw and roasted leafy vegetables consumed in Western Côte d'Ivoire.

	Ash (%)	Fibres (%)	Proteins (%)	Lipids (%)	Carbohydrates (%)	Energy (kcal /100g)
<i>A. esculentus</i>						
Raw	11.90 ± 0.10a	15.66 ± 0.05b	9.19 ± 0.15a	3.38 ± 1.59a	59.87 ± 1.90a	264.44 ± 2.51b
2 min	11.01 ± 0.13a	16.38 ± 0.53a	8.91 ± 0.00a	3.38 ± 0.00a	60.34 ± 0.53a	280.10 ± 1.90a
4 min	10.18 ± 0.35b	16.33 ± 0.53a	8.90 ± 0.92a	3.89 ± 0.00a	60.70 ± 1.45a	283.37 ± 2.93a
6 min	9.96 ± 0.64b	16.75 ± 0.35a	8.53 ± 0.91a	3.22 ± 0.00a	61.54 ± 1.56a	282.92 ± 0.23a
<i>M. esculenta</i>						
Raw	9.03 ± 2.12a	26.23 ± 0.31a	23.39 ± 0.71a	4.09 ± 0.02b	37.27 ± 3.16b	224.35 ± 5.67a
2 min	5.72 ± 0.93b	26.00 ± 0.54a	15.75 ± 1.86b	3.95 ± 0.00b	48.58 ± 1.68 a	229.68 ± 1.52a
4 min	5.57 ± 0.17b	28.00 ± 0.41b	15.75 ± 0.00b	3.66 ± 0.00c	47.02 ± 1.56a	229.35 ± 5.56a
6 min	5.48 ± 0.15b	28.11 ± 0.56b	15.03 ± 0.93b	4.59 ± 0.00a	46.79 ± 1.48a	228.09 ± 3.04a
<i>I. batatas</i>						
Raw	23.56 ± 2.13a	21.50 ± 0.82b	15.52 ± 0.40a	2.63 ± 0.06c	36.79 ± 3.41b	232.91 ± 5.78b
2 min	17.59 ± 0.09b	23.00 ± 0.50a	13.53 ± 0.91b	3.52 ± 0.00a	42.36 ± 1.41a	240.13 ± 1.90a
4 min	17.53 ± 0.13b	23.75 ± 0.50a	13.18 ± 0.95b	3.01 ± 0.00b	42.53 ± 1.55a	243.37 ± 2.93a
6 min	16.01 ± 0.09c	24.12 ± 0.54a	13.22 ± 1.95b	3.55 ± 0.00a	43.10 ± 1.41a	245.92 ± 0.23a
<i>C. argentea</i>						
Raw	22.10 ± 0.75a	30.83 ± 1.61b	9.77 ± 0.10a	1.79 ± 0.20b	35.52 ± 0.60b	165.62 ± 6.40b
2 min	17.48 ± 0.68b	32.30 ± 0.97b	9.14 ± 0.11a	1.87 ± 0.00b	39.21 ± 1.85a	213.45 ± 3.88a
4 min	15.38 ± 0.00d	32.31 ± 0.10b	9.10 ± 0.93a	2.50 ± 0.00a	40.71 ± 1.02a	219.41 ± 2.81a
6 min	16.18 ± 0.57c	34.80 ± 0.51a	7.06 ± 0.00b	2.57 ± 0.00a	39.39 ± 3.51a	217.99 ± 2.55a
<i>M. arboreus</i>						
Raw	11.73 ± 0.76a	12.19 ± 0.73b	16.95 ± 0.05a	1.47 ± 0.02d	56.70 ± 1.74b	259.5 ± 5.26c
2 min	10.31 ± 0.54b	13.59 ± 1.99a	13.96 ± 0.00b	1.90 ± 0.00c	60.24 ± 1.99a	283.33 ± 7.11a
4 min	9.94 ± 0.08b	13.86 ± 1.92a	13.79 ± 1.36b	2.31 ± 0.00b	60.10 ± 0.55a	280.86 ± 5.30a
6 min	9.45 ± 1.63b	14.75 ± 1.06a	13.78 ± 0.25b	3.43 ± 0.00a	58.59 ± 0.81a	275.31 ± 3.49b

Data are represented as Means ± SD (n = 3). Means in the column with no common letter differ significantly ( $p < 0.05$ ) for each leafy vegetable.

**Table 2.** Mineral composition (mg/100g) of raw and roasted leafy vegetables consumed in Western Côte d'Ivoire.

	Ca	Mg	P	K	Fe	Na	Zn
<i>A. esculentus</i>							
Raw	468.45 ± 0.55a	364.11 ± 0.43a	671.50 ± 0.79a	1844.25 ± 8.22a	130.95 ± 0.15a	35.76 ± 0.04a	41.45 ± 0.04a
2 min	448.98 ± 5.15b	282.39 ± 2.91b	280.53 ± 2.90b	1480.52 ± 5.29b	48.28 ± 0.50b	27.93 ± 0.29b	40.13 ± 0.48a
4 min	402.34 ± 3.48c	280.39 ± 7.66b	278.07 ± 7.73b	1330.77 ± 4.06c	45.18 ± 1.48c	24.93 ± 0.94c	39.77 ± 1.15b
6 min	401.86 ± 4.63c	260.92 ± 2.96c	272.06 ± 3.51b	1320.64 ± 8.49c	36.35 ± 2.80d	17.84 ± 1.38d	38.39 ± 1.91b
<i>M. esculenta</i>							
Raw	296.66 ± 0.46a	229.45 ± 0.35a	759.81 ± 1.18a	2306.09 ± 3.61a	48.69 ± 0.07a	18.30 ± 0.02a	45.48 ± 0.31a
2 min	202.45 ± 3.70b	123.73 ± 2.59b	263.94 ± 4.93b	1917.1 ± 5.65b	46.75 ± 3.44a	12.01 ± 3.66b	23.73 ± 3.95b
4 min	201.42 ± 2.98b	119.87 ± 3.56b	241.05 ± 7.15c	1071.49 ± 3.79c	42.85 ± 1.57b	8.28 ± 1.13c	21.15 ± 0.72b

	Ca	Mg	P	K	Fe	Na	Zn
6 min	198.87±5.93c	110.13±3.26c	224.36±7.17d	1050.8 ± 8.50d	42.86±1.43b	5.98 ± 0.92d	19.85±0.70c
<i>I. batatas</i>							
Raw	898.83±0.53a	501.75±0.30a	494.76±0.29a	1377.81±0.22a	53.54±0.03a	404.30±3.62a	30.10±0.01a
2 min	256.81±3.11b	149.49±1.74b	182.04±2.21b	1209.85±9.51b	44.72±1.75b	70.29 ± 0.85b	6.35 ± 0.07b
4 min	246.67±4.34b	139.65±2.36c	174.26±2.94c	1122.77±7.43c	42.80± 2.50b	52.25 ± 0.88c	4.29 ± 0.07b
6 min	235.48±2.70c	123.13±1.41d	170.39±1.96c	1056.75±9.02d	38.75±1.13c	20.40 ± 0.23d	4.15±0.14b
<i>C. argentea</i>							
Raw	788.02±0.50a	981.31±0.62a	650.37±0.41a	4987.15±3.19a	285.31±0.18a	42.26 ± 0.02a	62.01±0.03a
2 min	542.06±2.05b	467.43±8.15b	384.56±4.93b	3796.16±7.42b	128.47±4.99b	40.78 ± 2.74a	24.68±0.96b
4 min	499.13±1.60c	431.56±1.39c	274.64±5.06c	3448.92±1.07c	118.12±0.37c	34.42± 0.14b	22.18±0.08c
6 min	394.15±0.03d	419.67±0.01d	260.57±2.61d	3067.20±1.20d	93.78 ± 1.50d	25.56±2.50c	20.48±0.01d
<i>M. arboreus</i>							
Raw	436.64±0.52a	354.23±0.42a	283.19±0.34a	2350.58±2.83a	79.54 ± 0.09a	20.83 ± 0.02a	75.20±0.09a
2 min	326.40±7.25b	263.50±3.92b	175.19±9.26b	1648.94±7.12b	72.40±5.41b	16.70±2.47b	27.00±1.43b
4 min	278.98±2.38c	215.23±1.84c	160.10±1.87c	1253.61±1.70c	70.50 ± 0.67b	11.58 ± 0.44c	22.36±0.19c
6 min	224.83±6.14d	203.40±3.60d	153.01±1.39d	1071.74±7.45d	63.43±3.27c	9.70 ± 6.78d	20.38±3.46d

Data are represented as Means ± SD (n = 3). Means in the column with no common letter differ significantly (p<0.05) for each leafy vegetable.

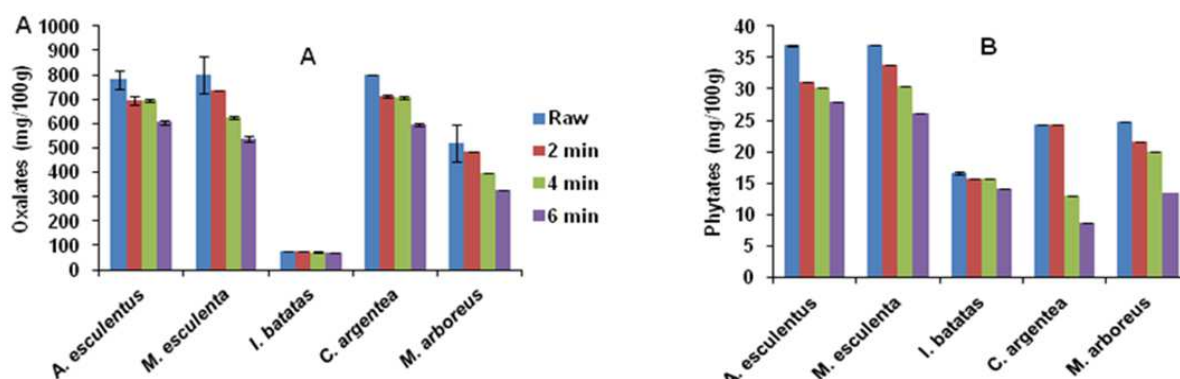


Figure 1. Oxalate (A) and phytate (B) contents of raw and roasted leafy vegetables consumed in Western Côte d'Ivoire.

Table 3. Anti-nutritional factors/mineral ratios of raw and roasted leafy vegetables consumed in Western Côte d'Ivoire.

	Phytates/Ca	Phytates/Fe	Oxalates/Ca
<i>A. esculentus</i>			
Raw	0.07	0.28	1.66
2 min	0.10	1.04	1.56
4 min	0.08	0.74	1.37
6 min	0.07	0.67	1.22
<i>M. esculenta</i>			
Raw	0.12	0.75	2.69
2 min	0.36	1.30	3.64
4 min	0.32	1.25	3.15
6 min	0.28	1.06	2.71
<i>I. batatas</i>			
Raw	0.01	0.31	0.08
2 min	0.14	0.26	2.41
4 min	0.13	0.24	1.84
6 min	0.14	0.34	1.72
<i>C. argentea</i>			
Raw	0.03	0.08	1.01
2 min	0.06	0.26	1.50
4 min	0.02	0.11	1.43
6 min	0.01	0.10	1.35
<i>M. arboreus</i>			
Raw	0.05	0.31	1.19
2 min	0.20	0.64	1.48
4 min	0.22	0.80	1.41
6 min	0.13	0.46	1.01

### 3.3. Antioxidant Properties

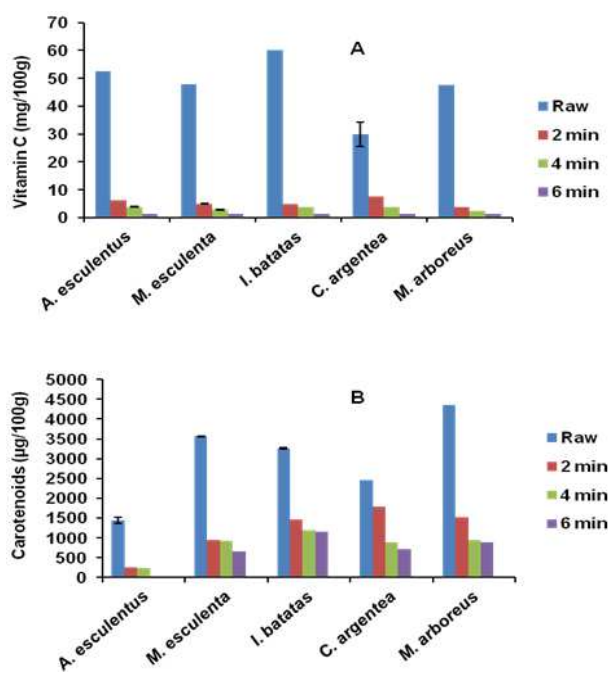
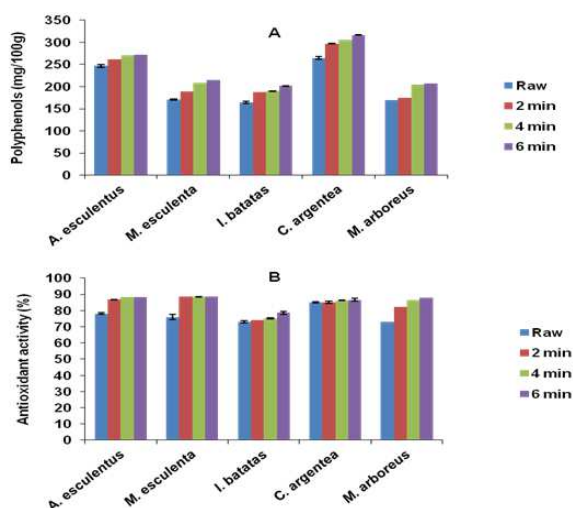


Figure 2. Vitamin C (A) and carotenoid (B) contents of raw and roasted leafy vegetables consumed in Western Côte d'Ivoire



**Figure 3.** Polyphenol contents (A) and antioxidant activity (B) of raw and roasted leafy vegetables consumed in Western Côte d'Ivoire

Roasting also resulted in decrease of carotenoids and vitamin C contents in the studied leafy vegetables (Figure 2). For carotenoids, losses at 2 min ranged from 27.37% (*C. argentea*) to 81.94% (*A. esculentus*). These losses are slightly lower than those (87 – 100%) obtained for the same boiled leafy vegetables [26]. The decrease of total carotenoids could be attributed to the oxidation and isomerization of  $\beta$ -carotene [39]. For vitamin C content, a significant reduction (75 – 92.14%) was highlighted after 2 min during roasting processing (Figure 2). The reduction of vitamin C in this study was lower than that (50 – 84%) obtained for boiling processing [26]. This decrease in vitamin C could be attributed to the fact that vitamin C is not stable at high temperature [40]. With regard to the vitamin C decrease, consumption of roasted leafy vegetables may be supplemented with other sources of vitamin C such as tropical fruits to cover the daily need for humans (40 mg/day) as recommended by food agriculture organization [34].

The effect of roasting on polyphenols content and antioxidant activity of the selected leafy vegetables is depicted in figure 3. It was observed a relatively high increase of polyphenols contents varying from 2.63 to 13.83%. The percent gain in the total phenols contents during blanching may be due to the release of phenolic compounds trapped in the fibres of leafy vegetables [41]. Therefore, consumption of drinks prepared with powdered roasted leafy vegetables could be advantageous for lower cellular ageing process in human body because polyphenols are known for their antioxidant and scavenging properties [42,43].

## 4. Conclusion

Leafy vegetables used for sauce preparation that accompany starchy foods in Western Côte d'Ivoire highlighted a potential of nutrients that are essential for human health. The aim of this work was to investigate the impact of roasting processing on the nutritive and antioxidant properties of these leafy vegetables. The results obtained showed that

roasting processing decreases to a lesser extent the contents of proteins, minerals, vitamin C, carotenoids, and anti-nutritional factors (oxalates and phytates) but increases their antioxidant activity. The reduction of anti-nutritional factors and the increase of polyphenols content might have a beneficial effect on health consumers. In order to contribute efficiently to the nutritional requirement and to the food security of Ivoirian population, the recommended time of roasting leafy vegetables must be less than 2 min. However, roasting processing must be compared with other cooking methods as blanching and boiling in the same experiment conditions. In addition, sensorial analysis of roasted leafy vegetables must be performed in order to appreciate their palatability.

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