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Research article

IMPACT OF COOKING ON NUTRITIVE AND ANTIOXIDANT CHARACTERISTICS OF LEAFY VEGETABLES CONSUMED IN NORTHERN CÔTE D'IVOIRE

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ABSTRACT: In tropical Africa where the daily diet is dominated by starchy staples, African leafy vegetables (ALVs) are the cheapest and most readily available sources of proteins, vitamins, minerals and essential amino acids. Five leafy vegetable species (*Amaranthus hybridus*, *Andasonia digitata*, *Ceiba patendra*, *Hibiscus sabdariffa* and *Vigna unguiculata*) that are used as soup condiments in Northern Côte d'Ivoire were subjected to cooking in order to evaluate the effect of this processing method on their nutritive value and antioxidant properties. The result of the study revealed that longer time of cooking (higher than 15 min) caused negative impact by reducing nutritive value but positive impact by reducing anti-nutrients such as oxalates and phytates. The registered losses at 15 min were as follow: ash (9.41 – 62.87 %), proteins (11.33 - 36.24 %), vitamin C (33.33 – 82.14 %), carotenoids (69.17 - 100%), oxalates (27.23 – 59.10%) and phytates (40.29 – 91.03%).The average reduction at 15 min of cooking was 31.30 – 56.02 % for polyphenols content. Contrary to these reductions, a slight increase of fibres content was observed in the studied cooked leafy vegetables. Furthermore after 15 min, the residual contents of minerals were: calcium (139.10 – 314.46 mg/100g), magnesium (40.55 – 344.57 mg/100g), phosphorus (120.46 – 248.93 mg/100g), potassium (177.65 – 747.28 mg/100g), iron (18.62 – 34.31 mg/100g) and zinc (7.33 – 26.33 mg/100g). All these results suggest that the recommended time of domestic cooking must be less than 15 min for the studied leafy vegetables in order to contribute efficiently to the nutritional requirement and to the food security of Ivorian population.

Keywords: Leafy vegetables, cooking processing, nutritive value, antioxidant properties.

INTRODUCTION

African Leafy Vegetables (ALVs) are considered as valuable sources of nutrients [1,2,3,4] with some having important medicinal properties [5]. Indeed, these plants are valuable sources of nutrients especially in rural areas where they substantially contribute to proteins, minerals, vitamins, fibres and other nutrients which are usually in short supply in daily diets [6]. Anti-nutrients such as nitrates, phytates, tannins and oxalates have been reported in leafy vegetables [7,2,3,4]. Anti-nutritional factor is known to interfere with metabolic processes such that growth and bioavailability of nutrients are negatively influenced [8]. Phytates and oxalates have the ability to form chelates with divalent metallic ions such as Ca, Mg, Zn and Fe to form poorly soluble compounds that are not readily absorbed from the gastrointestinal tract, thus decreasing their bioavailability [9]. In order to reduce these anti-nutritional factor contents, African leafy vegetables are usually blanched and cooked for soups preparation. Indeed, these vegetables are cooked and eaten as a relish together with a starchy staple food, usually in the form of porridge [10]. Leafy vegetable (LV) dishes may be prepared from a single plant species or from a combination of different species, and the combinations eaten vary daily [11]. Ingredients such as salt, oil, butter, groundnuts, tomato and onion are usually added while cooking African leafy vegetables in order to enhance flavor, taste, color and aesthetic appeal [12].These added ingredients also depend on availability and preference of consumers [13,14]. Several works and reports have revealed that cooking or preparation methods and period of cooking may affect the nutritional value as well as the bioavailability of many nutrients in leafy vegetables [15,16]. In Côte d'Ivoire, more than twenty (20) species of leafy vegetables belong to 6 botanical families, are consumed by populations through confectionary soups using boiling or blanched processing [17]. Furthermore, the consumption of these leafy vegetables is linked to the region and ethno-botanical studies have stated that most people in Northern Côte d'Ivoire consume indigenous green leafy vegetables such as *Amaranthus hybridus* "boronbrou", *Andasonia digitata* "baobab", *Ceiba patendra* "fromager", *Hibiscus sabdariffa* "dah" and *Vigna unguiculata* "haricot" [18,19,20].

Earlier reports have highlighted the nutritive potential of these fresh leafy vegetables [2] but there is a lack of scientific data with regards to the effect of cooking methods on their physicochemical and nutritive characteristics. Therefore, the purpose of this study is to conduct investigation on the effect of cooking (boiling) 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 populations.

MATERIAL AND METHODS

Samples collection

Leafy vegetables (*Amaranthus hybridus*, *Andasonia digitata*, *Ceiba patendra*, *Hibiscus sabdariffa* and *Vigna unguiculata*) 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-Côte d'Ivoire).

Samples processing

The fresh leafy vegetables were destalked, washed with deionized water and allowed to drain at ambient temperature. Each sample was divided into two lots. The first lot (raw) was dried in an oven (Memmert, Germany) [21], 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 lot was cooked by using the method [22] modified as follow: 250 g of leafy vegetables were immersed in 1.5 L of boiled water in stainless steel container for 15, 25 and 45 min. The cooking solution was discarded and the boiled samples were cooled, drained at ambient temperature and subjected to the same treatment using for raw samples.

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.

Nutritive characterization

Physicochemical analysis

Ash, proteins and lipids were determined using official methods [23]. 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 following formulas [24]:

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, fibres, proteins, lipids and carbohydrates contents were expressed on dry matter basis.

Oxalates and phytates determination

Oxalates content was performed using a titration method [25]. 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 $KMnO_4$ solution (0.05 M) to the end point.

Phytates contents were determined using the Wade's reagent colorimetric method [26]. 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.

Mineral analysis

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_3 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 inductively coupled argon plasma mass spectrometer (ICP-MS). Calibrations were performed using external standards prepared from a 1000 ppm single stock solution made up with 2% nitric acid.

Antioxidant properties

Vitamin C and carotenoids determination

Vitamin C contained in analyzed samples was determined by titration [27]. 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 by using a spectrophotometric method [28]. 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.

Polyphenols determination

Polyphenols were extracted and determined using Folin–Ciocalteu's reagent [29]. 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.

Antioxidant activity

Antioxidant activity assay was carried out using the 2,2-diphenyl-1-pycrilhydrazyl (DPPH) spectrophotometric method [30]. 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]

Statistical analysis

All the analyses were performed in triplicate and data were analyzed using EXCELL and STATISTICA 7.1 (StatSoft). Values were expressed as mean ± standard deviation (SD).

RESULTS AND DISCUSSION

Nutritive properties

The proximate composition of the cooked leafy vegetables examined in this study is presented in Table 1. The ash content after 15 min of cooking ranged from 7.53 ± 0.12 % (*A. hybridus*) to 9.53 ± 0.12 % (*C. patendra* and *V. unguiculata*). These values were closed to 6.27 ± 0.12 % and 9.07 ± 0.12 % after 45 min of cooking for the same species. The decrease rate at 15 min (9.41 – 62.87 %) of ash content in the studied leafy vegetables may be a result of minerals leaching into the boiling water [31]. In spite of ash losses, the studied leafy vegetables may be considered as good sources of minerals after 15 min of cooking when compared to values obtained for cereals and tubers [32]. Cooking of all selected leafy vegetables resulted in a slight increase (1.96 – 6.34 %) in their crude fibres content at 15 min of cooking. This finding is in agreement with some reports that cooking caused increase in soluble fibres content, with corresponding decrease in insoluble fibres content [33,34]. Indeed, cooking of plant tissues alters the physical and chemical properties of plant cell walls, which affects their performance as dietary fibre [35]. The increased temperature during cooking leads to breakage of weak bonds between polysaccharides and the cleavage of glycosidic linkages, which may result in solubilization of the dietary fibres [36]. With regard to their fibres content at 15 min (13.10 – 33.50 %), adequate intake of cooked leafy vegetables could lower the risk of hypertension, constipation, diabetes, colon and breast cancer [37]. As concern proteins content, cooking processing used in this study caused 11.33 - 36.24 % reduction after 15 min. This reduced protein contents of cooked leafy vegetables could be attributed to the severity of thermal process during cooking to protein degradation [38]. The relatively low level of protein in cooked leafy vegetables necessitates supplementation with animal proteins or proteins from legumes to have an impact on protein-energy malnutrition [39]. However, 15 min cooked leaves of *H. sabdariffa*, *V. unguiculata* and *C. patendra* could be considered as non negligible sources of proteins in view to their contents (12.83 ± 0.50, 14.00 ± 0.00 and 12.25 ± 0.00%) which are higher than the minimal value (12%) recommended for protein foods [40]. The low values of lipids contents at 15 min (2.65 – 6.17 %) in the studied cooked leafy vegetables corroborate the findings of many authors which showed that leafy vegetables are poor sources of fat [41]. The estimated calorific values (206.79 – 286.54 kcal/100g) of the selected cooked leafy vegetables (15 min) compared favorably to 248.8 – 307.1 kcal/100 g reported in some Nigerian vegetables [32]. Thus, the calorific values agree with general observation that vegetables have low energy values due to their low crude fat and relatively high level of moisture [42]. This justify that cooked leafy vegetables are usually eaten as a relish together with a starchy staple food, usually in the form of porridge [10].

The effect of cooking time on oxalates and phytates contents is depicted in figure 1. Levels losses at 15 min for oxalates and phytates were 27.23 – 59.10 % and 40.29 – 91.03 %, respectively. These levels at 45 min were 32.30 – 74.24% and 51.30 – 97.06%, respectively. The reduction of oxalates and phytates during cooking of leafy vegetables may be advantageous for improving the health status of consumers. Indeed, oxalates and phytates are anti-nutrients which chelate divalent cations such as calcium, magnesium, zinc and iron, thereby reducing their bioavailability [43]. Therefore, cooking of leafy vegetables appears as a detoxification procedure by removing these anti-nutritional factors [44]. Mineral composition of cooked leafy vegetables used in this study is shown in table 2. The residual contents of minerals after 15 min of cooking were: calcium (139.10 – 314.46 mg/100g), magnesium (40.55 – 344.57 mg/100g), phosphorus (120.46 – 248.93 mg/100g), potassium (177.65 – 747.28 mg/100g), iron (18.62 – 34.31 mg/100g) and zinc (7.33 – 26.33 mg/100g). These observed reductions may be due to leaching of the mineral compounds into the boiling water [45]. Considering, the recommended dietary allowance (RDA) for minerals [46]: calcium (1000 mg/day), phosphorus (800 mg/day), magnesium (400 mg/day), iron (8 mg/day) and zinc (6 mg/day), consumption of 15 min cooked leafy vegetables could cover at least 50% RDA. Calcium and phosphorus are associated for growth and maintenance of bones, teeth and muscles [47]. As concern magnesium, this mineral is known to prevent cardiomyopathy, muscle degeneration, growth retardation, congenital malformations and bleeding disorders [48]. Iron plays important role in prevention of anemia which affects more than one million people worldwide [49]. To predict the bioavailability of calcium and iron, anti-nutrients to nutrients ratios of cooked leafy vegetables were calculated (Table 3). The calculated [phytates]/[Ca] ratios in all the species were below the critical level of 2.5 whatever the cooking time. This critical value is known to impair calcium bioavailability [50]. It was also observed that the calculated [phytates]/[Fe] ratios of *V. unguiculata* and *H. sabdariffa* at 15 min cooking time were also below the critical level of 0.4 which is known to impair iron bioavailability [51].

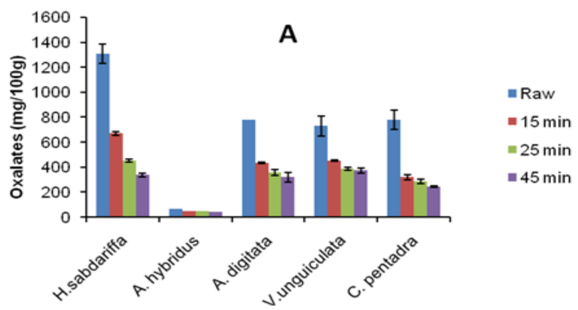
Table 1: Proximate composition of raw and cooked leafy vegetables consumed in Northern Côte d'Ivoire

	Ash (%)	Fibres (%)	Proteins (%)	Lipids (%)	Carbohydrates (%)	Calorific energy (kcal/100g)
H. sabdariffa						
Raw	10.30±0.10	14.27±1.70	14.47± 0.1	4.75±0.15	56.21± 1.78	275.71±0.55
15 min	9.33± 0.12	14.55± 2.78	12.83± 0.5	6.17± 0.29	57.50± 2.43	286.85±4.80
25 min	9.07± 0.12	15.1± 0.88	11.37±0.00	8.40± 0.17	56.61± 2.84	300.16±8.68
45 min	8.43± 0.06	16.87± 1.14	10.5± 0.00	8.67± 0.12	55.53± 1.03	296.41±4.34
A. hybridus						
Raw	8.59± 1.34	17.80±0.30	13.25±0.13	2.15 ± 0.01	58.21±1.78	305.19±7.73
15 min	7.53± 0.12	17.27± 0.25	11.37±0.00	3.44± 0.11	60.39±0.15	272.11±0.99
25 min	6.78± 0.17	17.77± 0.23	9.62± 0.00	3.87± 0.06	61.96±0.15	277.05±1.01
45 min	6.27± 0.12	18.27± 0.31	8.75± 0.00	3.97± 0.03	62.75± 0.22	278.58±0.92
A. digitata						
Raw	10.97±0.4	12.56± 0.45	18.08±0.10	2.18± 0.03	56.23±1.25	267.03±4.00
15 min	9.27± 0.23	13.10± 0.17	11.96±0.51	2.65± 0.05	63.03± 0.53	276.34±0.28
25 min	9.13± 0.12	14.67± 0.15	10.21±0.51	4.78± 0.08	61.22± 0.43	283.43±1.28
45 min	9.13± 0.12	15.53± 0.92	9.91± 0.51	5.25± 0.23	60.17±1.33	282.92±4.95
V. unguiculata						
Raw	11.17±0.25	18.00±0.92	21.96±0.30	4.23 ±0.25	44.64 ± 1.72	248.35±10.33
15 min	9.53± 0.12	19.17± 0.01	14.00±0.00	6.07± 0.12	51.23± 0.15	267.84±1.02
25 min	7.4± 0.35	20.17±0.29	12.25±0.00	7.43± 0.04	52.43± 0.32	279.23±1.33
45 min	7.27±0.23	20.49±0.29	11.37±0.00	7.67± 0.12	53.53± 0.36	283.1± 2.09
C. patendra						
Raw	25.67±1.12	31.50±1.50	15.20±0.05	1.39 ± 0.22	26.30 ± 0.11	142.61 ± 7.74
15 min	9.53 ± 0.12	33.5± 0.87	12.25±0.00	4.17± 0.29	39.78± 0.57	206.79± 3.53
25 min	9.33± 0.12	34.27± 0.64	11.37±0.00	5.23± 0.06	40.56± 0.84	216.36± 2.81
45 min	9.07± 0.12	35.33± 3.06	10.5± 0.00	5.30± 0.10	39.8± 3.04	212.07±10.05

Data are expressed as means ± SD (n=3).

Table 2: Mineral composition (mg/100g) of raw and cooked leafy vegetables consumed in Northern Côte d'Ivoire

	Ca	Mg	P	K	Fe	Na	Zn
H.sabdariffa							
Raw	402.21± 0.55	295.93± 0.41	407.59 ± 0.00	816.19 ± 1.12	102.08±0.14	23.46±0.03	26.06±0.04
15 min	139.10± 9.54	40.55 ± 0.58	167.60 ± 1.72	527.15 ± 2.10	21.46 ± 0.60	12.15±0.00	7.60 ± 0.10
25 min	113.03± 2.61	28.71 ± 1.14	132.19 ± 6.26	523.34 ± 1.88	13.61 ± 0.54	11.00±0.40	5.20 ± 0.00
45 min	94.00 ± 5.87	25.27 ± 2.76	107.90 ± 7.70	507.49 ± 6.95	10.12 ± 0.22	9.34 ± 0.30	4.50 ± 0.10
A.hybridus							
Raw	932.6 ± 0.55	497.75± 0.49	368.69 ± 0.00	1989.32±2.12	77.88 ± 0.05	94.3 ±0.04	31.73±0.04
15 min	141.25±6.24	344.57± 5.73	241.26 ± 6.36	635.53 ± 9.16	20.89 ± 0.00	44.35±0.00	20.50±0.10
25 min	119.36± 4.68	327.32± 8.82	232.22±18.98	467.82 ± 3.51	16.20 ± 0.20	24.55±0.18	14.80±0.00
45 min	64.62 ± 0.27	279.34± 2.08	185.59 ±27.59	349.24 ± 1.44	10.23 ± 0.36	11.70±0.59	12.30±0.75
A. digitata							
Raw	496.26± 2.20	264.36± 1.17	761.63 ± 0.00	1856.90± 8.23	106.27 ±0.47	37.13±0.12	22.61±0.10
15 min	314.46± 3.96	239.28± 4.10	126.30 ± 2.98	682.62 ± 4.42	26.15 ± 0.27	16.35±0.20	10.22±0.05
25 min	261.57± 9.69	218.64± 6.74	70.68 ± 6.17	616.65 ± 2.23	17.39 ± 0.13	13.49±0.21	9.54 ± 0.01
45 min	153.17± 2.79	202.02± 3.66	30.27 ± 2.74	498.17 ± 4.59	7.29 ± 0.10	8.33 ± 0.10	5.60 ± 0.01
V.unguiculata							
Raw	439.54± 0.56	341.34± 0.18	309.04 ± 0.00	718.11 ± 0.91	91.45 ± 0.12	33.32±0.02	40.83±0.04
15 min	280.82± 4.80	244.16± 1.25	248.93 ± 9.06	177.65 ± 3.83	34.31 ± 1.91	11.53±0.45	26.33±0.05
25 min	205.02± 1.02	205.52± 2.60	139.66 ± 2.46	127.84 ± 6.28	22.94 ± 2.96	10.25±0.40	14.00±0.55
45 min	112.31± 3.99	195.16± 2.81	91.72 ± 1.36	97.39 ± 2.54	21.81 ± 1.45	7.10 ± 0.02	10.30±0.45
C. patendra							
Raw	997.02± 0.55	773.55± 0.43	570.85 ± 2.11	1585.58± 0.87	219.84± 0.12	42.69±0.02	35.68±0.02
15 min	225.89± 7.45	131.08± 7.33	120.46 ± 3.36	747.28 ± 9.56	18.62 ± 0.67	25.22±0.40	7.33 ± 0.10
25 min	174.78± 4.55	108.91± 6.18	62.43 ± 2.12	643.77 ± 1.99	14.38 ± 0.59	18.00±0.20	6.45 ± 0.00
45 min	154.71± 7.96	93.14 ± 6.28	31.27 ± 3.91	595.90 ± 8.12	12.58 ± 0.07	12.25±0.00	4.50 ± 0.10



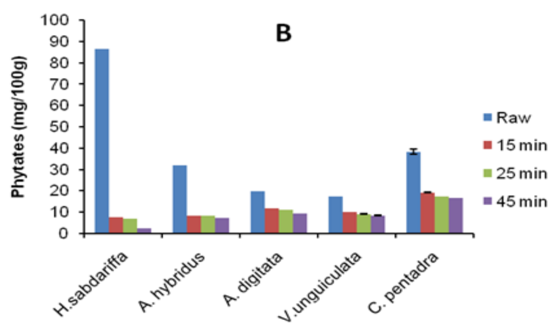


Figure 1: Effect of cooking time on oxalates (A) and phytates (B) contents of leafy vegetables consumed in Northern Côte d'Ivoire

Table 3: Anti-nutritional factors/mineral ratios of raw and cooked leafy vegetables consumed in Northern Côte d'Ivoire

	Phytates/Ca	Phytates/Fe	Oxalates/Ca
H. sabdariffa			
Raw	0.21	0.85	3.25
15 min	0.05	0.36	4.82
25 min	0.06	0.50	3.99
45 min	0.03	0.25	3.58
A. hybridus			
Raw	0.03	0.41	0.07
15 min	0.06	0.40	0.33
25 min	0.07	0.50	0.38
45 min	0.11	0.72	0.68
A. digitata			
Raw	0.04	0.18	1.57
15 min	0.04	0.45	1.38
25 min	0.04	0.64	1.37
45 min	0.06	1.27	2.08
V. unguiculata			
Raw	0.04	0.19	1.66
15 min	0.03	0.29	1.62
25 min	0.04	0.39	1.89
45 min	0.07	0.38	3.33
C. patendra			
Raw	0.04	0.17	0.78
15 min	0.08	1.03	1.41
25 min	0.09	1.19	1.64
45 min	0.11	1.33	1.58

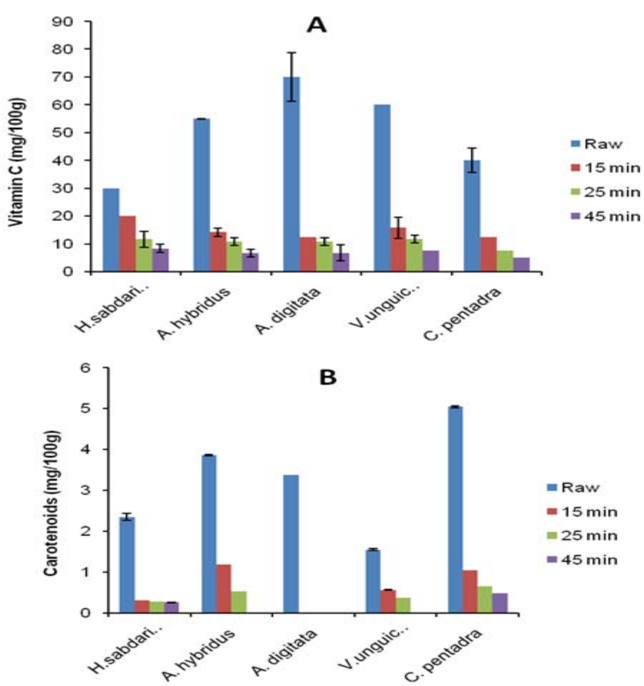


Figure 2: Effect of cooking time on vitamin C (A) and carotenoids (B) contents of leafy vegetables consumed in Northern Côte d'Ivoire

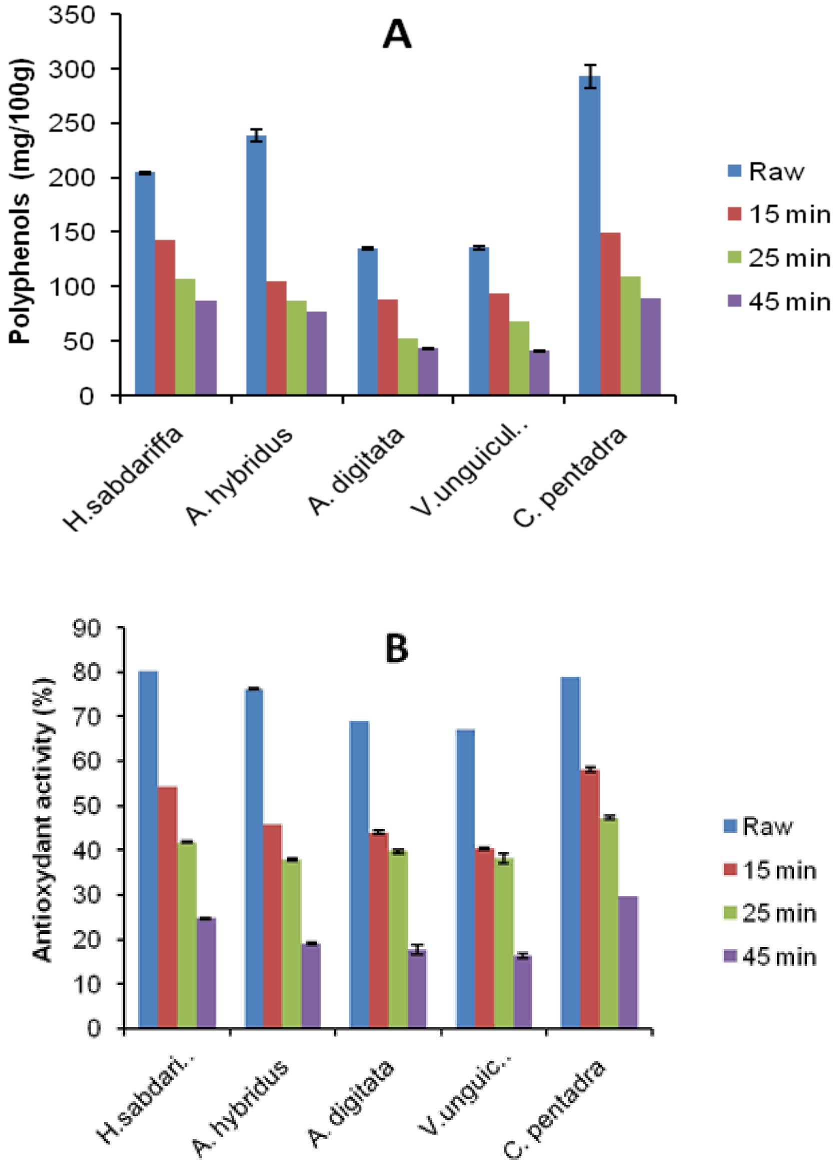


Figure 3: Effect of cooking time on polyphenols content (A) and antioxidant activity (B) of leafy vegetables consumed in Northern Côte d'Ivoire

Antioxidant properties

Cooking resulted in higher decrease of carotenoids and vitamin C contents in the studied leafy vegetables (Figure 2). For carotenoids, losses at 15 min were estimated from 69.17 to 100%. The decrease in the concentration of the total carotenoids observed during cooking could be attributed to wilting and damage of the leaf tissues which resulted in leaching. Also, excessive activity of lipoxygenase enzyme in the initial (warming) stages of cooking, oxidation and isomerization of β-carotene might account for the decrease in their concentration [52]. Carotenoids are considered as sources of provitamin A in plants and their amount determine their bioavailability in human diet [28]. Therefore, increased intake of cooked leafy with fat added, contributed significantly to improving the vitamin A status in children [53]. For vitamin C content, a significant reduction (33.33 – 82.14 %) was highlighted at 15 min during cooking processing (Figure 2). These values support the results obtained for other studies which indicate losses up to 66 % in cooked vegetables [54]. It 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 [55]. With regard to the drastic decrease of vitamin C during cooking, consumption of cooked 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 and agriculture organization [46]. The effect of cooking on polyphenols content and antioxidant activity of the selected leafy vegetables is depicted in figure 3.

Losses of polyphenols contents at 15 min of cooking were 31.30 – 56.02 %. The decrease of the polyphenolic compounds content and overall antioxidant activity could be due to leaching or heat lability of specific flavonoids [56]. Indeed, flavonoids such as myricetin, quercetin, kaempferol, isorhamnetin and luteolin have been reported in leafy vegetables [57]. The negative impact of cooking on polyphenols content may affect the medicinal potentialities of leafy vegetables previously underlined [5]. Therefore, other processing methods such as blanching, drying, roasting and microwaving of leafy vegetables should be used to limit or avoid losses of polyphenols by leaching as observed during cooking.

CONCLUSION

African leafy vegetables (ALVs) contain significant levels of nutrients that are essential for human health. The result of this study revealed that leafy vegetables consumed in Northern Côte d'Ivoire contain appreciable amount of minerals, polyphenols and anti-nutrients. Cooking at 15, 25 and 45 minutes decreased considerably the nutritional value of these leafy vegetables. Nevertheless, the losses in anti-nutrients (oxalates, phytates) might have asserted a beneficial effect on bioavailability of minerals like iron and calcium. Thus, the study suggests that the recommended time of domestic cooking must be less than 15 min for the studied leafy vegetables in order to contribute efficiently to the nutritional requirement and to the food security of Ivorian population.

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