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Original article
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Evaluation of Nutritive and Antioxidant Properties of Blanched Leafy Vegetables Consumed in Northern Côte d'Ivoire

Patricia D. Oulai, Lessoy T. Zoué, Sébastien L. Niamké*

Laboratoire de Biotechnologies, UFR Biosciences, Université Félix Houphouët-Boigny, 22 BP 582, Abidjan 22, Côte d'Ivoire

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The aim of this study was to evaluate the effect of steam blanching processing on the nutritive value and the antioxidant properties of five leafy vegetable species (*Amaranthus hybridus*, *Andasonia digitata*, *Ceiba patendra*, *Hibiscus sabdariffa* and *Vigna unguiculata*) that are used for sauce preparation in Northern Côte d'Ivoire. The selected leafy vegetables were subjected to blanching in pressure cooker for 15, 25 and 45 min and the physicochemical properties were determined using AOAC methods. The result of the study revealed that longer time of blanching (higher than 15 min) caused negative impact by reducing nutritive value but positive impact by reducing anti-nutrients and increasing polyphenols. The registered losses ($p<0.05$) at 15 min were as follow: ash (0.08–10.01%), proteins (0.36–12.03%), vitamin C (19.56–68.67%), carotenoids (18.91–55.48%) oxalates (3.58–21.39%) and phytates (10.51–68.02%). The average increase of polyphenols contents at 15 min of blanching was 1.61 to 30.72%. In addition, a slight increase (0.35–4.16%) of fibres content was observed in the studied blanched leafy vegetables. Furthermore, after 15 min of blanching time the residual contents ($p<0.05$) of minerals were: calcium (264.88–844.92 mg/100 g), magnesium (49.45–435.43 mg/100 g), potassium (675–1895.41 mg/100 g), iron (14.54–70.89 mg/100 g) and zinc (9.48–36.46 mg/100 g). All these results suggest that the recommended time of domestic blanching 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.

INTRODUCTION

The growing awareness in recent years of the health promoting has directed increased attention to vegetables as vital components of daily diets [Smith, 2007]. A world vegetable survey showed that 402 vegetable crops are cultivated worldwide, representing 69 families and leafy vegetables which leaves are consumed, are the most (53% of the total) often utilized [Kays, 1995]. 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 prerequisite for human development. Indeed, Obel-Lawson [2005] reported that an increased consumption of African leafy vegetables (ALVs) can have a positive effect on nutrition, health and economic wellbeing of both rural and urban populations. Socio-economic surveys conducted in various parts of Africa indicate also that ALVs are important commodities in household food and nutrition security [Mnzava, 1997]. Fresh leaves of most ALVs like vegetable amaranths (*Amaranthus*), slenderleaf (*Crotalaria brevidens*), spiderplant (*Chlorophytum comosum*), vegetable cowpeas (*Vigna*), pumpkin leaves (cucurbits) and jute mallow (*Corchorus*) contain more than 100% of the recommended daily allowances for vitamins and minerals and 40% proteins for growing children and lactating mothers [Chweya, 1985].

The high moisture content of fresh leafy vegetables renders them perishable and seasonal availability limits their utilization all around the year. Hence, there is a need to preserve this nature's store house of nutrients through proper processing techniques for safe storage with efficient nutrient retention [Gupta *et al*., 2008]. One common processing used before consumption of leafy vegetables is blanching which is a thermal treatment commonly applied to a variety of vegetables before freezing. Its primary purpose is to inactivate enzymes and destroy vegetative microbial cells, allowing stabilization and product quality retention during frozen storage [Canet, 1989]. It is usually carried out in hot water or in steam; this technique is used by indigenous people to reduce or eliminate the bitterness of the vegetables and acid components that are common in leaves. Blanching affords also a series of secondary benefits, due to its washing action, such as elimination of off-flavors that may have been formed during the time between harvesting and processing, and removal of any residual pesticides [Prestamo *et al*., 1998]. Blanching, however, has some adverse effects, such as pigment modifications, tissues softening and nutrient losses [Murcia *et al*., 1999; Oboh, 2005].

Among the twenty hundred and seven (207) leafy vegetables widely consumed in tropical Africa, about twenty (20) species of leafy vegetables belonging to 6 botanical families are widely consumed and cultivated by Ivorian populations [PROTA, 2004; Fondio *et al*., 2007]. Furthermore, the consumption of these leafy vegetables is linked to the region

* Corresponding Author:
y.lessoy@yahoo.fr; Tel: +(225) 08 98 67 44

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" [Fondio *et al*., 2007; Soro *et al*., 2012]. Indeed, dietary habits of these populations include culinary preparation of these leafy vegetables as follow: 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 that accompany starchy sorghum paste food commonly named "to". Earlier reports have highlighted the nutritive potential of these fresh leafy vegetables [Oulai *et al*., 2014] but there is a lack of scientific data with regards to the effect of blanching processing on their physicochemical and nutritive characteristics. Therefore, the purpose of this study is to conduct investigation on the effect of blanching 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 rinsed with deionized water and the edible portions were separated from the inedible portion. The edible portions were chopped into small pieces (500 g) and allowed to drain at ambient temperature. Each sample was divided into two lots. The first lot (raw, 250 g) was dried in an oven (Memmert, Germany) at 60°C for 72 h [Chima & Igyor, 2007]. 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 lot (250 g) was steam-blanched for 15, 25 and 45 min in a pressure cooker. The blanched samples were cooled, drained at ambient temperature and subjected to the same treatment used 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 properties

Proximate analysis

Proximate analysis was performed using the AOAC [1990] methods. The moisture content was determined by the difference of weight before and after drying the sample (10 g) in an oven (Memmert, Germany) at 105°C until constant weight. Ash fraction was determined by the incineration of dried 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 sample were weighed into separate 500 mL round bottom flasks and 100 mL of 0.25 mol/L sulphuric acid solution was added. The mixture obtained was boiled under reflux for 30 min. Thereafter, 100 mL of 0.3 mol/L sodium hydroxide solution was added and the mixture was 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 a solvent. Carbohydrates and calorific value were calculated using the following formulas [FAO, 2002]:

Carbohydrates:
100 – (% moisture + % proteins + % lipids + % ash + % fibres)
Calorific value:
(% proteins x 2.44) + (% carbohydrates x 3.57) + (% lipids x 8.37)

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

Mineral analysis

Minerals contents were determined by the ICP-MS (inductively coupled argon plasma mass spectrometer) method described by CEAEQ [2013].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 argon plasma mass spectrometer. Calibrations were performed using external standards prepared from a 1000 ppm single stock solution made up with 2% nitric acid.

Anti-nutritional factors determination

Oxalates content was determined by using the method described by Day & Underwood [1986]. One (1) g of dried powdered sample was weighed into 100 mL conical flask. A quantity of 75 mL of sulphuric acid (3 mol/L) 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 mol/L) to the end point.

Phytates contents were determined using the Wade's reagent colorimetric method [Latta & Eskin, 1980]. 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 stirrer. The mixture was centrifuged at 12,000 rpm for 40 min. An aliquot (0.5 mL) of supernatant was added with 3 mL

TABLE 1. Proximate composition of raw and blanched leafy vegetables consumed in Northern Côte d'Ivoire.

	Ash (%)	Fibres (%)	Proteins (%)	Lipids (%)	Carbohydrates (%)	Calorific value (kcal/100 g)
			H. sabdariffa			
Raw	10.30±0.10^{a}	14.27±1.70^{a}	14.47±0.10^{a}	4.75±0.15^{b}	56.21±1.78^{a}	275.71±0.55^{a}
15 min	9.62±0.15^{b}	14.32±1.50^{a}	13.22±0.16^{b}	6.20±0.28^{a}	56.64±1.79^{a}	286.37±3.63^{a}
25 min	9.29±0.14^{c}	14.63±2.30^{a}	13.13±0.01^{b}	6.40±0.14^{a}	56.56±2.59^{a}	287.52±8.05^{a}
45 min	8.99±0.03^{c}	15.50±2.47^{a}	12.83±0.04^{b}	6.80±0.42^{a}	56.47±2.94^{a}	289.82±6.85^{a}
			A. hybridus			
Raw	8.59±1.34^{a}	17.80±0.30^{a}	13.25±0.13^{a}	2.15±0.01^{b}	58.21±1.78^{a}	305.19±7.73^{a}
15 min	7.93±0.00^{a}	17.17±0.71^{a}	13.00±0.03^{a}	2.60±0.14^{b}	59.30±0.54^{a}	265.17±3.17^{b}
25 min	7.60±0.03^{a}	17.25±0.35^{a}	12.29±0.06^{b}	3.18±0.03^{a}	59.28±0.30^{a}	269.23±1.45^{b}
45 min	6.91±1.41^{b}	17.50±1.06^{a}	12.25±0.03^{b}	3.60±0.14^{a}	59.74±2.30^{a}	273.30±9.47^{b}
			A. digitata			
Raw	10.97±0.40^{a}	12.56±0.45^{a}	18.08±0.10^{a}	2.18± 0.03^{b}	56.23±1.25^{b}	267.03±4.00^{a}
15 min	10.76±0.05^{a}	12.75±0.35^{a}	17.25±0.07^{b}	2.39±0.06^{b}	56.85±0.43^{b}	265.04±0.88^{a}
25 min	9.63±0.11^{b}	13.27±0.25^{a}	14.88±0.06^{c}	2.99±0.03^{a}	59.23±0.26^{a}	272.80±1.30^{a}
45 min	9.32±0.08^{c}	14.75±1.30^{a}	13.57±0.10^{d}	3.20±0.28^{a}	59.16±1.76^{a}	271.09±3.67^{a}
			V. unguiculata			
Raw	11.17±0.25^{a}	18.00±0.92^{a}	21.96±0.30^{a}	4.23±0.25^{c}	44.64±1.72^{a}	248.35±10.33^{a}
15 min	11.16±0.86^{a}	18.75±2.47^{a}	21.88±0.03^{a}	4.33±0.47^{c}	43.88±3.83^{a}	246.27±9.71^{a}
25 min	10.58±0.25^{b}	19.25±2.47^{a}	19.69±0.01^{b}	4.68±0.35^{b}	45.80±2.60^{a}	250.73±6.28^{a}
45 min	10.19±0.22^{b}	19.34±2.12^{a}	19.26±0.01^{b}	5.55±0.18^{a}	45.66±1.91^{a}	256.46±8.38^{a}
			C. patendra			
Raw	25.67±1.12^{a}	31.50±1.50^{a}	15.20±0.05^{a}	1.39±0.22^{d}	26.30±0.11^{a}	142.61±7.74^{c}
15 min	23.10±0 42^{a}	31.94±1.33^{a}	13.37±0.10^{b}	2.59±0.83^{c}	29.00±2.69^{a}	157.83±2.37^{b}
25 min	22.48±0.46^{b}	32.75±0.71^{a}	12.25±0.14^{c}	3.91±0.71^{b}	28.61±1.10^{a}	164.76±2.34^{a}
45 min	22.20±0.00^{b}	33.52±0.78^{a}	11.38±0.10^{d}	4.69±0.64^{a}	28.21±1.51^{a}	167.73±0.17^{a}

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

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 a standard.

Antioxidant properties

Vitamin C and carotenoids determination

Vitamin C contained in the analysed samples was determined by titration [Pongracz *et al*., 1995]. 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 were titrated to the end point with dichlorophenol-indophenol (DCPIP) 0.5 g/L.

Carotenoids were extracted and quantified following the method described by 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 a standard.

Polyphenols determination

Polyphenols were extracted and determined using Folin–Ciocalteu's reagent [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–Cio-

TABLE 2. Mineral composition of raw and blanched leafy vegetables consumed in Northern Côte d'Ivoire.

Mineral	Ca	Mg	P	K	Fe	Na	Zn
H. sabdariffa							
Raw	402.21±0.55^{a}	295.93±0.41^{a}	407.59±0.00^{a}	816.19±1.12^{a}	102.08±0.14^{a}	23.46±0.03^{a}	26.06±0.04^{a}
15 min	272.61±5.30^{b}	64.51±1.32^{b}	213.47±8.76^{b}	698.45±4.28^{b}	30.59±0.12^{b}	22.31±0.09^{a}	9.85±0.20^{b}
25 min	270.64±5.53^{c}	59.34±0.24^{c}	189.16±3.87^{c}	647.88±2.63^{c}	26.66±0.52^{c}	21.15±0.43^{a}	9.70±0.04^{b}
45 min	255.25±1.03^{d}	59.08±1.15^{c}	183.47±0.74^{c}	528.88±1.27^{d}	25.84±0.53^{c}	18.34±0.36^{b}	9.20±0.18^{c}
A. hybridus							
Raw	932.60±0.55^{a}	497.75±0.49^{a}	368.69±0.00^{a}	1989.32±2.12^{a}	77.88±0.05^{a}	94.39±0.04^{a}	31.73±0.04^{a}
15 min	844.92±0.00^{b}	435.43±1.76^{b}	366.18±0.82^{a}	1895.41±7.65^{b}	70.89±0.00^{b}	94.38±0.00^{a}	30.01±0.12^{a}
25 min	830.30±3.35^{c}	387.91±0.00^{c}	343.36±7.00^{b}	1501.63±0.00^{c}	66.49±0.27^{c}	94.31±0.38^{a}	24.86±0.00^{b}
45 min	702.57±4.38^{d}	292.49±9.69^{d}	241.40±0.00^{c}	1005.65±2.23^{d}	46.36±9.46^{d}	61.70±2.59^{b}	18.49±3.77^{c}
A. digitata							
Raw	496.26±2.20^{a}	264.36±1.17^{a}	761.63±0.00^{a}	1856.90±8.23^{a}	106.27±0.47^{a}	37.13±0.12^{a}	22.61±0.10^{a}
15 min	445.81±1.98^{b}	49.45±0.45^{b}	174.99±0.78^{b}	1469.25±1.10^{b}	14.54±0.06^{b}	36.91±0.25^{a}	12.25±0.08^{b}
25 min	408.99±3.73^{c}	48.75±0.34^{b}	94.66±0.86^{c}	1355.82±2.37^{c}	14.41±0.10^{b}	33.49±0.31^{b}	11.79±0.05^{b}
45 min	401.78±2.76^{c}	45.08±0.20^{c}	38.79±0.27^{d}	1119.30±4.96^{d}	13.47±0.12^{c}	28.27±0.13^{c}	11.68±0.11^{b}
V. unguiculata							
Raw	439.54±0.56^{a}	341.34±0.18^{a}	309.04±0.00^{a}	718.11±0.91^{a}	91.45±0.12^{a}	33.32±0.02^{a}	40.83±0.04^{a}
15 min	424.71±2.64^{b}	265.18± 0.33^{b}	295.80±2.89^{a}	675.00±0.84^{b}	54.92±0.07^{b}	21.74±1.52^{b}	36.46±0.05^{b}
25 min	423.30±0.53^{b}	209.60±4.41^{c}	289.63±0.36^{b}	566.82±9.56^{c}	45.62±3.18^{c}	20.55±0.43^{b}	24.03±0.51^{c}
45 min	402.33±8.46^{c}	208.14±4.53^{c}	148.86±1.94^{b}	477.64±1.04^{d}	41.68±0.88^{c}	15.15±0.02^{c}	20.81±1.45^{d}
C. patendra							
Raw	997.02±0.55^{a}	773.55±0.43^{a}	570.85±2.11^{a}	1585.58±0.87^{a}	219.84±0.12^{a}	42.69±0.02^{a}	35.68±0.02^{a}
15 min	264.88±7.86^{b}	136.09±0.00^{b}	145.76±3.45^{b}	921.92±0.00^{b}	20.60±0.38^{b}	26.73±0.49^{b}	9.48±0.17^{b}
25 min	258.28±0.00^{b}	106.08±2.20^{c}	89.86±0.00^{c}	787.84±4.47^{c}	19.81±0.00^{b}	18.32±0.38^{c}	8.45±0.00^{c}
45 min	240.21±4.99^{c}	104.51±1.92^{c}	74.36±0.79^{d}	694.08±4.42^{d}	17.36±0.36^{c}	15.55±0.00^{d}	7.57±0.16^{d}

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

calteu'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 a standard.

Antioxidant activity

Antioxidant activity assay was carried out using the 2,2-diphenyl-1-pycrilhydrazyl (DPPH) spectrophotometric method [Choi *et al*., 2002]. About 1 mL of 0.3 mmol/L 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). Differences between means were evaluated by Duncan's test. Statistical significant difference was stated at $p<0.05$.

RESULTS AND DISCUSSION

Proximate composition of the selected leafy vegetables is presented in Table 1. The physicochemical parameters generally differed significantly ($p<0.05$) from a blanching

TABLE 3. Anti-nutritional factors/mineral ratios of raw and blanched leafy vegetables consumed in Northern Côte d'Ivoire.

	Phytates/Ca	Phytates/Fe	Oxalates/Ca
	H. sabdariffa		
Raw	0.21±0.01^{a}	0.85±0.10^{a}	3.26±0.10^{a}
15 min	0.10±0.01^{b}	0.90±0.01^{a}	0.10±0.00^{b}
25 min	0.03±0.00^{c}	0.29±0.01^{b}	0.03±0.00^{c}
45 min	0.01±0.00^{c}	0.10±0.01^{c}	0.01±0.00^{c}
	A. hybridus		
Raw	0.03±0.00^{a}	0.41±0.01^{a}	0.07±0.00^{a}
15 min	0.01±0.00^{a}	0.15±0.01^{b}	0.01±0.00^{a}
25 min	0.01±0.00^{a}	0.15±0.01^{b}	0.01±0.00^{a}
45 min	0.01±0.00^{a}	0.16±0.01^{b}	0.01±0.00^{a}
	A. digitata		
Raw	0.04±0.00^{a}	0.19±0.01^{d}	1.57±0.01^{a}
15 min	0.04±0.00^{a}	1.22±0.01^{a}	0.04±0.00^{b}
25 min	0.03±0.00^{a}	0.94±0.01^{b}	0.03±0.00^{b}
45 min	0.02±0.00^{a}	0.69±0.01^{c}	0.02±0.00^{b}
	V. unguiculata		
Raw	0.04±0.00^{a}	0.19±0.01^{b}	1.66±0.10^{a}
15 min	0.03±0.00^{a}	0.23±0.01^{a}	0.03±0.00^{b}
25 min	0.02±0.00^{a}	0.23±0.01^{a}	0.02±0.00^{b}
45 min	0.02±0.00^{a}	0.22±0.01^{a}	0.02±0.00^{b}
	C. patendra		
Raw	0.04±0.00^{b}	0.17±0.01^{c}	0.78±0.01^{a}
15 min	0.09±0.00^{a}	1.12±0.01^{a}	0.09±0.00^{b}
25 min	0.07±0.00^{a}	0.95±0.01^{b}	0.07±0.00^{b}
45 min	0.07±0.00^{a}	1.02±0.10^{b}	0.07±0.00^{b}

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

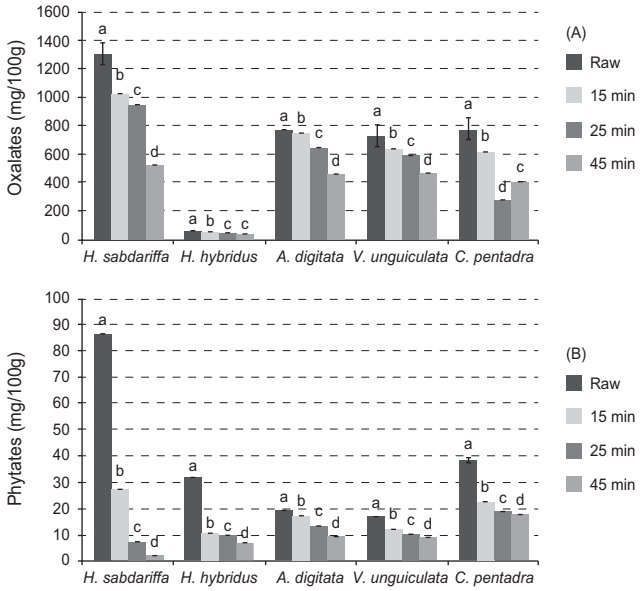

FIGURE 1. Oxalates (A) and phytates (B) contents of raw and blanched leafy vegetables consumed in Northern Côte d'Ivoire.

Data are represented as Means ± SD (n=3). Means with no common letter (a, b, c, d) differ significantly ($p<0.05$) for each leafy vegetable.

time of a leafy vegetable to another. The ash content after 15 min of blanching ranged from 7.93±0.00% (*A. hybridus*) to 23.10±0.42% (*C. patendra*) with a decrease rate at 15 min ranged from 0.08 to 10.01%. After 15 min of blanching, the ash losses increased in the order: *V. unguiculata* (0.08%) > *A. digitata* (1.91%) > *H. sabdariffa* (6.60%) > *A. hybridus* (7.68%) > *C. patendra* (10.01%). As concerns protein contents, blanching processing caused 0.36 to 12.03% reduction after 15 min. These protein losses increased in the order: *V. unguiculata* (0.36%) > *A. hybridus* (1.88%) > *A. digitata* (4.59%) > *H. sabdariffa* (8.64%) > *C. patendra* (12.03%). This reduced protein content could be attributed to the severity of thermal process during blanching which leads to protein degradation [Lund, 1997]. The ash and protein content losses are lower than that (9.78–28.0%) reported for 15 min cooked Nigerian leafy vegetables [Lola, 2009]. This fact could be explained by the agronomic cultural conditions and the period of leafy vegetables harvesting. In spite of the ash losses levels, the studied leafy vegetables may be considered as good sources of minerals when compared to values obtained for cereals and tubers [Antia *et al*., 2006]. Moreover, the leaves of *Vigna unguiculata* revealed the higher retention (99.70–99.92%) of ash and proteins after 15 min of blanching. All selected leafy vegetables highlighted a slight increase ($p>0.05$) in their crude fibres content (0.35–4.16%) at 15 min of blanching. Indeed, the increased temperature during blanching leads to breakage of weak bonds between polysaccharides and the cleavage of glycosidic linkages, which may result in solubilization of the dietary fibres [Svanberg *et al*., 1997]. With regard to their fibres content at 15 min (12.75–31.94%), adequate intake of blanched leafy vegetables could lower the risk of constipation, diabetes, colon and breast cancer [Ishida *et al*., 2000]. The relatively low values of lipids contents at 15 min of blanching (2.39–6.20%) corroborate the findings of many authors which showed that leafy vegetables are poor sources of fat [Ejoh *et al*., 1996]. The estimated calorific values agreed with general observation that vegetables have low energy values due to their low crude fat and relatively high level of moisture [Sobowale *et al*., 2011].

Mineral composition of blanched leafy vegetables used in this study is shown in Table 2. The residual contents of minerals after 15 min of blanching were significantly different ($p<0.05$): calcium (264.88–844.92 mg/100 g), magnesium (49.45–435.43 mg/100 g), potassium (675–1895.41 mg/100 g), iron (14.54–70.89 mg/100 g) and zinc (9.48––36.46 mg/100 g). With regard to these values, the consumption of 15 min blanched leafy vegetables could cover at least 50% of the standard mineral requirements for human. Indeed, these standard requirements are: calcium (1000 mg/

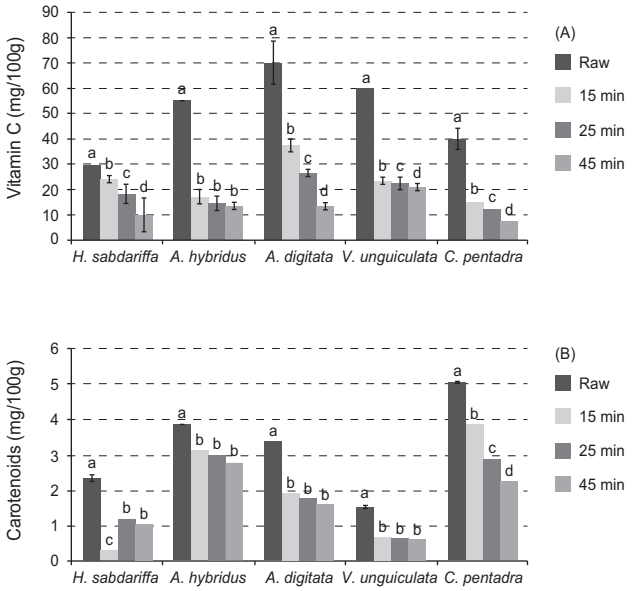

FIGURE 2. Vitamin C (A) and carotenoids (B) contents of raw and blanched leafy vegetables consumed in Northern Côte d'Ivoire.

Data are represented as Means ± SD (n=3). Means with no common letter (a, b, c, d) differ significantly ($p<0.05$) for each leafy vegetable.

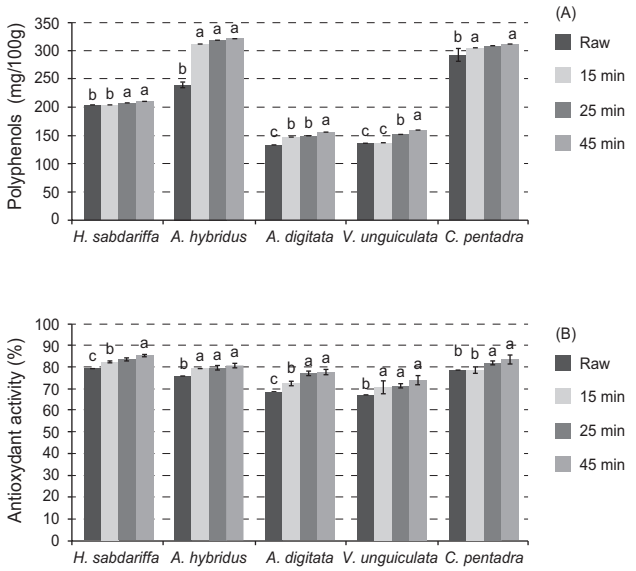

FIGURE 3. Polyphenols contents (A) and antioxidant activity (B) of raw and blanched leafy vegetables consumed in Northern Côte d'Ivoire.

Data are represented as Means ± SD (n=3). Means with no common letter (a, b, c, d) differ significantly ($p<0.05$) for each leafy vegetable.

day); magnesium (400 mg/day), iron (8 mg/day) and zinc (6 mg/day) [FAO, 2004]. Calcium and phosphorus play an important role in growth and maintenance of bones, teeth and muscles [Turan *et al*., 2003]. As concerns magnesium, this mineral is known to prevent cardiomyopathy, muscle degeneration, growth retardation, congenital malformations and bleeding disorders [Chaturvedi *et al*., 2004]. Iron plays an important role in the prevention of anemia while zinc is important for vitamin A and vitamin E metabolism [Martorell & Trowbridge, 2002; FAO, 2004]. To predict the bioavailability of calcium and iron, anti-nutrients to nutrients ratios of blanched leafy vegetables were calculated (Table 3). The calculated [phytates]/[Ca] and [oxalates]/[Ca] ratios in all the blanched species were below the critical level of 2.5 which is known to impair calcium bioavailability [Hassan *et al*., 2007; Umar *et al*., 2007].

The effect of blanching on anti-nutritional factors (oxalates and phytates) contents is depicted in Figure 1. The losses ($p<0.05$) at 15 min were 3.58–21.39% and 10.51–68.02% for oxalates and phytates, respectively. Oxalates losses increased in the order: *A. digitata* (3.59%) > *A. hybridus* (8.33%) > *V. unguiculata* (11.87%) > *C. patendra* (20.70%) > *H. sabdariffa* (21.39%) while phytates losses increased in the order: *A. digitata* (10.51%) > *V. unguiculata* (26.89%) > *C. patendra* (39.85%) > *A. hybridus* (65.89%) > *H. sabdariffa* (68.02%). These percentage losses are similar to those (7–56%) of phytates obtained for blanched leafy vegetables from Thailand [Samsub *et al*., 2008]. The reductions in oxalates and phytates contents during blanching 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 [Sandberg, 2002]. In view of the highest oxalates and phytates losses (21.39 and 68.02%) of *Hibiscus sabdariffa* leaves, blanching processing may appear as a detoxification procedure by removing these anti-nutritional factors [Ekop & Eddy, 2005].

Blanching of the studied leafy vegetables also resulted in a decrease of carotenoids and vitamin C contents (Figure 2). For carotenoids, losses at 15 min were estimated to 18.91 to 55.48%. Carotenoids losses increased in the order: *A. hybridus* (18.91%) > *C. patendra* (23.41%) > *H. sabdariffa* (33.61%) > *A. digitata* (43.19%) > *V. unguiculata* (55.48%). The decrease in carotenoids contents could be attributed to the oxidation and isomerization of β-carotene [Speek *et al*., 1986]. Carotenoids are considered as sources of provitamin A in plants and their amount determines their bioavailability in a human diet [Rodriguez-Amaya, 2001]. Therefore, consumption of blanched leafy with fat added, could contribute significantly to improving the vitamin A status of children [Takyi, 1999]. For vitamin C content, a significant reduction (19.56–68.67%) was highlighted at 15 min during blanching processing (Figure 2). Vitamin C losses increased in the order: *H. sabdariffa* (19.57%) > *A. digitata* (46.58%) > *V. unguiculata* (61.13%) > *C. patendra* (62.5%) > *A. hybridus* (68.67%). This decrease in vitamin C is lower than that (60–90%) reported for blanched Indian leafy vegetables [Gupta *et al*., 2008] but agrees with earlier findings of Oboh [2005] on some Nigerian vegetables who reported 47.5–82.4% loss in vitamin C content during blanching. It is important to note that ascorbic acid is a heat-labile and water-soluble antioxidant that promotes absorption of soluble iron by chelating or by maintaining the iron in the reduced form [Yamaguchi *et al*., 2001]. With regard to the decrease of vitamin C, consumption of blanched leafy vegetables may be supplemented with other sources of vitamin C such as tropical fruits to cover the daily demand for humans (40 mg/day) as recommended by the Food Agriculture Organization [FAO, 2004]. The significant reduction of antioxidants components such

as carotenoids and vitamin C in the studied leafy vegetables could also be due to the preliminary oven-drying treatment used. Indeed, higher temperatures affect negatively carotenoids and vitamin C by leading to their partial destruction [Rice-Evans & Miller, 1995]. This justifies the traditional practices which consist in drying leafy vegetables at ambient temperature in order to preserve their antioxidant properties. The effect of blanching on polyphenols content and antioxidant activity of the selected leafy vegetables is depicted in Figure 3. It was observed a high increase of polyphenols contents varying from 1.61 to 30.72%. The percent gain in the total phenol content during blanching may be due to the breakdown of tough cell walls and release of phenolic compounds trapped in the fibres of green leafy vegetables [Oboh & Rocha, 2007]. This result agrees with earlier report by Dewanto *et al*. [2002], where ferulic acid, a phenolic component found in the cell wall of grains such as corn, wheat and oats, doubled after 10 min of blanching. The content in polyphenols which is linked to the antioxidant activity of the studied blanched leafy vegetables could be advantageous for lower cellular oxidative stress, which has been implicated in the pathogenesis of various neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis [Rice-Evans & Miller, 1995; Amic *et al*., 2003].

CONCLUSION

African leafy vegetables (ALVs) contain significant levels of nutrients that are essential for human health. The result of this study revealed that blanching at 15, 25 and 45 min decreased considerably the nutritional value of these leafy vegetables. Nevertheless, the losses in anti-nutrients (oxalates, phytates) might have asserted a beneficial effect on the bioavailability of minerals like calcium, iron and zinc. Thus, the study suggests that the recommended time of domestic blanching 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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