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Effect of Boiling on Chemicals, Phytochemicals and Nutritional Composition of *Solanum nigrum* L. Leaves Harvested in Abidjan (Côte d'Ivoire)

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Authors' contributions

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

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ABSTRACT

Aims: In tropical Africa, leafy vegetables are traditionally cooked and eaten as a relish together with a starchy staple food. The current study aimed to evaluate the influence of boiling on bioactive, proximate and antinutrients compounds in *Solanum nigrum* leaves.
Methodology: The leaves were subjected to boiling in pressure cooker for 10, 15 and 20 min and proximate composition, minerals, nutritive and anti-nutritional components were determined according to standard methods for nutritional guidelines.
Results: The result of the study revealed that longer time of boiling (higher than 10 min) caused negative impact by reducing nutritive value but positive impact by reducing anti-nutrients. The

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registered losses ($p < .05$) at 10 min were as follows: ash (12.37%), proteins (33.69%), vitamin C (11.23 mg/ 100 g), polyphenols (125.41 mg/ 100 g) Tannins (81.96 mg/ 100 g) and Flavonoids (14.03 mg/100 g). The average increase of fibers content was (39.41%). Furthermore, after 10 min of boiling time the residual contents ($p<0.05$) of minerals was: Calcium (1079±29.04 to 386±78 mg/ 100 g), Phosphorus (405..24±10-508.88±2.58 mg/ 100 g), Iron (33.48±0.93–44.50±1.23 mg / 100 g) and Magnesium (572.78±19.76–662.99±27.23 mg/ 100 g).The antinutrient composition for oxalic acid were ranged 72.61±6.29 to 223.67±6.35 mg/100 g. The different ratios sodium / potassium (<1) and oxalates/calcium (<2.5) were under the respective critical value for all boiling.

Conclusion: These results suggest that the recommended time of domestic cooking must be less than 10 min for the studied leafy vegetables in order to contribute efficiently to the nutritional requirement and to the food security of Ivorian population.

Keywords: Boiling methods; antinutrients; proximate composition; antioxidant properties; Solanum nigrum.

1. INTRODUCTION

The medicinal properties of plants have been investigated in the recent scientific developments throughout the world, due to their potency against several diseases, minor side effects and economic viability. Several compounds widely distributed among plants have been reported to exert multiple biological effects [1,2]. Traditional vegetables are valuable sources of nutrients [3], with some having important medicinal properties [4]. Leafy vegetables represent high quality nutritional sources, for the poor segment of the population especially where malnutrition is wide spread [5]. It was reported that an estimated amount of 6376 useful spontaneous African plants of which 397 are vegetables, about twenty (20) species are widely consumed and cultivated by Ivorians populations [6]. 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 [7]. *Solanum nigrum L*. is important aspects of medicinal plant resources for treatment of primary health care. The leaves of *Solanum nigrum L*. have a potential source of useful drugs due to the presence of phytochemicals and can be utilized for the treatment of many diseases and also be exploited for use in the pharmaceutical [7]. Before consumption *Solanum nigrum* post-harvest processing that can affect their nutrient contents [8]. Although most vegetables are cooked prior consumption, evidence is emerging that in vivo bioavability of many bioactive compounds enhanced as vegetables are cooked. Fresh raw plants can be prepared in various ways to eat dish. Besides, cooking gives final product pleasanter sensory characteristics, as well as being more digestible and microbiologically safer to eat [9]. Feed processing is a versatile high temperature process that may alter the nutritional value of feeds [10]. The feed process involves water, heat, and mechanical stress, all of which can impact on vitamin and carotenoid stability [11]. Traditionally, boiling, squeeze-washing, and sun-drying are practiced, and generally result from the destruction of some nutrients [12,13]. The cooking method not only affects the nutritional composition of the food, but also the level of available bioactive compound [9]. However, both positive and negative effects have been reported depending upon differences in process conditions and morphological and nutritional characteristics of vegetable species [11,14]. But there is a lack of scientific data with regard to the effect of cooking methods on their physicochemical and nutritive characteristics [15]. Moreover, a real interest for consumers is emerged since epidemiological studies have linked the dietary habits and the prevalence of certain diseases such as cancers, obesity and cardiovascular diseases [16,17]. These leafy vegetables form a part of the diets and incomes of rural and urban households by providing adequate amounts of protein, many vitamins, dietary fiber and other important nutrients which are usually in short supply in daily diets [18]. In the present study, the effect of boiling of phytochemical contents and total antioxidant capacities of *Solanum nigrum* was investigated.

2. MATERIALS AND METHODS

2.1 Materials

Solanum nigrum L. was previously authenticated by National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Côte d'Ivoire). The leaves were collected fresh and at maturity from cultivated farmlands located at Dabou (latitude 5º19′14″ North longitude: 4º22′59″West) in the District of Abidjan.

2.2 Methods

2.2.1 Preparation of raw and cooked leaves.

Leaves were put into clean and dry sample containers and transferred to the Laboratory of Food Biochemical and Tropical Products Technology (Nangui Abrogoua University, Abidjan, Côte d'Ivoire) [19] and were cooked after cleaning and washing with water [20].

2.2.2 Boiling of leaves

The boiling of leaves was carried out as described previously [21]. One (1) L of water was brought to boil in 2-L beaker. The beaker was covered to prevent water loss to evaporation. Five hundred grams of *Solanum nigrum* leave were boiled separately for 0, 10, 15 and 20 min. After cooking, the vegetables were drained, cool for a few minutes at room temperature homogenized, and. be oven-dried at 40ºC for 72 h, grounded into flour and stored in polyethylene bags for biochemical analyzes.

2.2.3 Proximate analysis

The methods used for sample treatment and analysis (ash, protein, lipids) were carried following standard procedures recommended by AOAC [22]. Ash was determined by gravimetric of incinerated sample, in muffle at 550ºC, total nitrogen was determined according to the Kjeldahl method and converted into protein, using factor 6.25; total lipids were extracted by the Soxhlet technique with hot solvent (hexane) and afterwards were determined by gravimetry. The total carbohydrate content was calculated by using the equation: 100-(moisture + protein + lipid +ash) [23]. Total crude fiber was determined according method described by Prosky *et al.* using sulfuric acid [24]. The caloric value of samples was calculated using the Atwater conversion factor [25].

2.2.4 Mineral analysis

Minerals were determined by American Association of Cereal Chemists method [26]. Glass and polypropylene materials were soaked in concentrated nitric acid (specific gravity = 1.41 g. cm^{-3}) for 15 min and then rinsed 3 times for distilled deionized water before use. Mineral component comprising magnesium (Mg), iron (Fe), calcium (Ca), Zinc (Zn) and phosphorus (P) were determined by atomic absorption spectrophotometry (Unicam Analytical system, Model 919, Cambridge, UK). All samples were previously subjected to dry digestion at 550°C. To dissolve the ashes, 3 mL of concentrated HCl (specific gravity = 1.19 $g.cm^{-3}$) were added, the vessel was covered with a watch glass and gently hat (~70ºC) for 3.5 h, leaving about 1 mL of liquid at the end of heating. The solution was then transferred to a 10 mL volumetric flask and brought to the volume with water. The solution was then used for individual mineral determination using spectrophotometer and flame photometer. These measurements were carried out in triplicates, for two measurements per analysis. All minerals were expressed in mg/100 g dry weight basis.

2.2.5 Anti-nutritionals compound

The method described by Day and Underwood [27] was used to determine the oxalate content of defatted leaves flours of *S. nigrum* extracts. This method consists of extracting the total oxalates (insoluble and soluble) followed by titrimetric analysis. Briefly, one gram of dried powdered and 75 mL of 1.5 N H_2SO_4 was added in 100 mL conical flask. The mixture was carefully shaken on a mechanical shaker for 1 h. Then, the solution was filtered using Whattman No.1 filter paper. A 25 mL of filtrate was titrated hot (80–90ºC) with freshly prepared 0.1 N $KMnO_4$ solution until the colour of the solution become pink persisted for 30 seconds. The results were expressed as mg/100 g dry weight.

2.2.6 Phytochemicals compounds

The phenolic compounds were extracted following the procedure described by N'Dri, et al. [28] and polyphenols content (expressed as gallic acid equivalent, mg/100 g dry weight) was determined by colorimetry, using the Folin Ciocalteu's method described by Singleton, et al. [29]. Vitamin C contained in analyzed samples was determined by titration using the method described by Pongracz, et al. [30]. The tannins assay was performed according to the method described by Bainbridge, et al. [31] using vanillin reagent. The total flavonoids content was evaluated using the method reported by Meda, et al. [32]. Antioxidant activity assay was carried out using the 2,2-diphenyl-1-pycrilhydrazyl (DPPH) spectrophotometric method [33].

2.2.7 Data analysis

Analyzes were made in triplicate and the mentioned values were the average ± standard deviation (SD). These experimental data were subjected to Analysis of Variance (ANOVA) and Duncan's multiple range test for mean separation at *P* = .05 in STATISTICA software version 7.1. The variations observed in the biochemical composition of *Solanum nigrum* leaves during cooking were examined by principal component analysis (PCA) with the STATISCA Software version 7.1.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Proximate composition

The Proximate composition of cooked and uncooked leaves of *S. nigrum* is shown in Table 1. The ash in raw leaves (17.96±0.03%) was significantly higher (*P* =.05) than those of boiled. The ash content after 10 and 20 min of boiling decreased, it ranged from 12.37±0.12%. to 9.30 ±0.42%. The lipid content was 3.22±0.06% in uncooked leaves and ranged from 5.09±0.10% to 6.36±0, 06 in boiled at 10 min and boiled at 20 min. However, the lipids content increased significantly (*P* = .05) in leaves after boiling. Total crude fibers contents were significantly different (*P* = .05) in all samples with the values of 27.62± 0.00, 39.41±0.00, 41.39±0.10 and 49.99±1.26% respectively for uncooked, boiled at 10, 15 and 20 min. The proteins content of raw and boiled samples falls between 30.33±0.39 and 34.42± 0.49%. Boiled at 20 min have presented significantly lower (*P* =.05) amounts of protein compared to the raw and the other boiled samples. However, the protein content of those others processed samples (boiled at 15 and 20 min) was significantly from boiling (16.78±0.52 to 04.02±0.79%). However, the amount of sugar varies significantly (*P* =.05) from the boiling higher (*P* =.05) than those of boiled at 10 min and raw leaves. The amount of carbohydrates of leaves was decreasing method. Calorific energy decreasing during boiling from and 233.78±0.10 to 194.01±4.43 kcal/100 g during boiling.

3.1.2 Mineral composition

The results of the evaluation of total minerals in raw and boiled leaves are shown in Table 2. Minerals content decreased significantly (*P* =.05) compared to fresh forms after the boiling. Calcium content in uncooked leaves (1687.65 ± 78 mg / 100 g) was significantly lower (*P* =.05) than those of boiled. The Magnesium content was 1008.22 ± 20.72 mg / 100 g in uncooked leaves and decreasing from 662.99 ± 27.23 to 572.78 ± 5.36 mg / 100 g by increasing the degree of boiling. The Phosphorus content after 15 min of boiling decreased significantly (*P* = .05) compared to the fresh leaves and ranged from 423.71±15.12 to 405.24±10 mg / 100 g (boiled at 20 min). The Iron content after 10 min of boiling decreased significantly (*P* = .05) compared to the fresh leaves and ranged from 33.48±0.93 mg / 100 g to 44.50±1.23 mg / 100 g (boiled at 10 min). The Zinc contents were significantly different (*P* = .05) in all samples with the values of 25.14±1.80 mg / 100 g, 18.90 ± 0.10 mg / 100 g, 17.07 ± 0.02 mg / 100 g and 11.12 ± 0.08 mg / 100 g respectively for uncooked, boiled at 10 min, 15 min and 20 min. The computed molar ratios of oxalate/calcium were lower than 2.5. All the samples analyzed Na / K molar ratio less than 1.

3.1.3 Phytochemical properties

The Phytochemical properties composition of the boiled and uncooked leaves was presented in Table 3. The phytochemical properties parameters generally differ significantly ($p < 0.05$) from boiled to fresh leaves. Vitamin C contents after 10 min of boiling decreased significantly (*P* = .05) compared with the fresh leaves and ranged from 11.23 ± 0.00% to 9.90±0.00% (boiled at 20 min). Total polyphenols content was decreased significantly (*P* = .05) from all boiled samples with the values of 240.98±3.00, 125.41±0.94, 93.64±0.92 and 86.11±0.5 mg/100 g respectively for uncooked, boiled at 10, 15 and 20 min. The tannins content after 10 min of boiling decreased significantly (*P* = .05) compared to the fresh leaves and ranged from 157.45±2.73 to 73.82±1.22 mg / 100 g (boiled at 20 min). The Flavonoids content was 16.46±0.34 mg / 100 in uncooked leaves and which recorded 10.19±0, 46 mg / 100 (boiled at 20 min) and 14.03±0.21 mg / 100 g (boiled at 10 min). However, the tannins content decreased significantly (*P* = .05) in leaves after boiling. The antioxidant activity was decreased significantly (*P* =.05) from all boiled samples and ranged from 95.05±0.50% to 76.34±0.92%.

3.1.4 Principal component analysis.

Principal component analysis (PCA) performed on proximate, minerals and phytochemical of cooked and uncooked leaves is illustrated in Fig. 1. This analysis showed two axes (axis 1 and 2) explaining the essential variability revealed by the nine (09) proximate, and phytochemical variables. The first and the second PCs described 97.79 and 06.10% of the variance respectively. Leaves from *Solanum nigrum* cooked during 10 min (SN10) and uncooked were located at the left of the score plot, while those cooked during 15 min (SN15) and 20 min (SN20) had positive score in the first principal component (PC1) (Fig. 1). *Solanum nigrum* fresh leaves (SN00) and SN 20 had a large positive score, whereas SN 15 and SN10 had a negative score in PC2 (Fig. 1). The projection on the components CP1 and CP2 showed that SN 00 and SN 10 were characterized by Vitamin C, Polyphenols, Antioxydant activity, ash, Proteins, oxalate and Phytic acid contents. SN 15 and SN 20 were characterized by high Crude fibers and lipid contents (Fig. 2).

3.2 Discussion

Food processing may affect the functionality and nutritional quality of the food products [34]. Also, it leads to beneficial transformations, compound degradation, or nutrient loss [35]. The effect of boiling on proximate composition of *Solanum nigrum* leaves is given in Table 1. The physicochemical parameters generally differed significantly (P = .05) according to boiling time. The ash content of fresh *Solanum nigrum* (17,96 ±0,03%) is significantly higher than those of *Corchorus olitorus* and *Hibiscus sabdariffa* which are 7.00±0.00% and 9.14±0.02% respectively [22]. These high values show that *Solanum nigrum* leaves are higher in mineral content. After boiling, the reduction of ash content up to 28.73% in boiled at 10 min to 52.22% in boiled at 20 min may be due to leaching of mineral compounds into the boiling water [36].

Table 1. Proximate composition of *Solanum nigrum* leaves during boiling

Parameters	Times of cooking			
	Raw	10 min	15 min	20 min
Ash (%)	17.96±0.03^{a}	12.37±0.12^{b}	10.68±0.33^{c}	9.30±0.42^{d}
Crude fibres (%)	27.62±0.00^{e}	39.41±0.00^{d}	41.39±0.10^{c}	49.99±1.26^{b}
Lipids (%)	3.22±0.06^{e}	5.09±0.10^{d}	5.71±0.06^{c}	6.36±0.06^{b}
Proteins (%)	34.42±0.49^{a}	33.69±0.03^{a}	31.06±0.29^{b}	30.33±0.39^{bc}
Carbohydrates (%)	16.78±0.52^{a}	09.40±0.13^{b}	09.15±0.49^{b}	04.02±0.79^{c}
Calorific energy (kcal/100) g)	233.78±0.10^{a}	218.33±0.19^{b}	212.29±1.14^{c}	194.64±4.43^{d}

Data are represented as Means ± SD (n = 3). Means in the lines with no common superscript differ significantly (P = .05)

Table 2. Mineral composition of *Solanum nigrum* leaves during boiling

Minerals	Times of cooking			
(mg/100)	Raw	10 min	15 min	20 min
Calcium (Ca)	1687.65±78^{a}	1386.56±9.92^{b}	1201.34±20.83^{c}	1079.83±29.04^{d}
Magnesium (Mg)	1008.22±20.72^{a}	662.99±27.23^{a}	627.38±19.76^{a}	572.78±5.36^{a}
Phosphorus (P)	549.39±24.28^{a}	508.88±2.58^{a}	423.71±15.12^{b}	405.24±10^{b}
Iron (Fe)	55.07±2.07^{a}	44.50±1.23^{b}	40.59±1.07^{c}	33.48±0.93^{d}
Na/K	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.00
Oxalates/Ca	0.13±0.01	0.10±0.01	0.10±0.01	0.08±0.01

Data are represented as Means ± SD (n = 3). Means in the lines with no common superscript differ significantly (P = .05)

Table 3. Nutritive and antioxidant properties of *Solanum nigrum* leaves during boiling

Minerals	Times of cooking			
(mg/100 g)	R aw	10 min	15 min	20 min
Vitamin C	33.51±01^{a}	11.23±0.00^{b}	9.97±0.00^{d}	9.90±0.00^{d}
Polyphenols	240.98±3.00^{a}	125.41±0.94^{b}	93.64±0.92^{c}	86.11±0.5^{d}
Tannins	157.45±2.73^{a}	81.96±0.32^{b}	75.13±0.48^{d}	73.82±1.22^{d}
Flavonoids	16.46±0.34^{a}	14.03±0.21^{b}	10.96±1.37^{c}	10.19±0.46^{c}
Antioxydant activity (%)	98.21±2.00^{a}	95.05±0.50^{b}	92.34±1.31^{c}	76.34±0.92^{d}

Data are represented as Means ± SD (n = 3). Means in the lines with no common superscript differ significantly (P = .05)

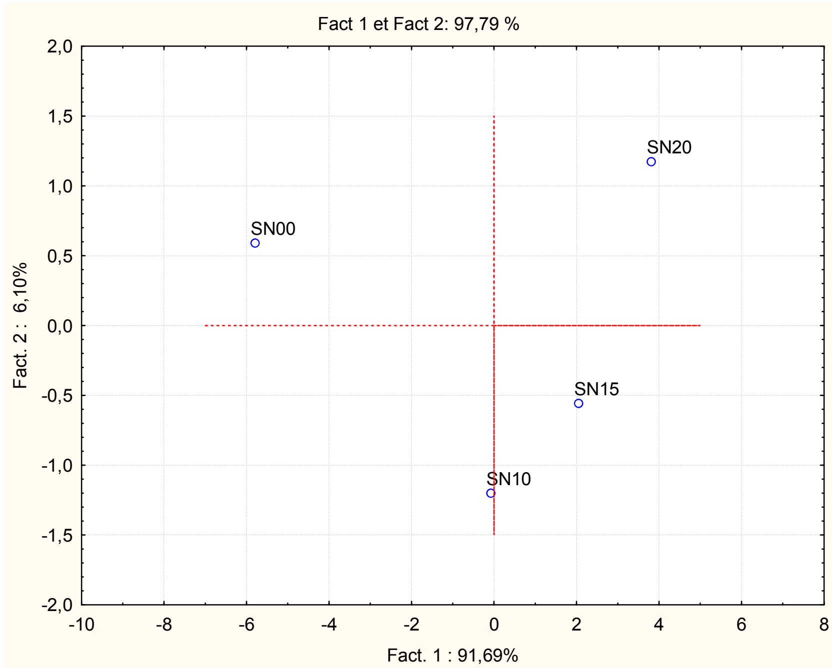

Fig. 1. Sample plot of principal components 1 and 2 of leaves from raw and cooked of *Solanum nigrum* leaves

SN 00: Solanum nigrum fresh; SN 10: Solanum nigrum leaves cooked in water during 10 min; SN 15: Solanum nigrum leaves cooked in water during 15 min; SN 20: Solanum nigrum leaves cooked in water during 20 min

The fiber content in boiled leaves increased significantly (*P* = .05) compared those of the raw leaves as mentioned by Slavin, et al. [37] and Lintas, et al. [38] where boiling caused decrease soluble fiber and increase insoluble fiber content. Indeed, increased temperature during cooking leads to breakage of weak bonds between polysaccharides and the cleavage of glyosidic linkages, which may result in solubilization of the low molecular weight carbohydrate from the thermal degradation [39]. Therefore, the adequate intake of leafy may be advantageous since high fibers content of foods help in digestion, prevention of colon and breast cancer and in the treatment of diseases such as obesity, diabetes and gastrointestinal disorders [38]. Fat content of boiled samples was significantly (*P* = .05) higher than uncooked samples. This increased in fat content may be attributed to the increase activity of lipolytic enzymes which produced more free fatty acid [40]. However, high contents of lipid in human diet are principal sources of obesity and other related diseases. Dietary fat composition can interfere in the development of obesity due to the specific roles of some fatty acids that have different metabolic activities, which can alter both fat oxidations and deposition rates, resulting from changes in body weight and/or composition [41]. Talking about the protein content, a significant decrease (*P* = .05) was registered for boiling at 10 min, 15 min, 20 min compared for uncooked leaves. This reduced protein content could be attributed to the severity of thermal process during boiling for leads to protein degradation [42]. The total carbohydrate (Table 1) showed that the amount of sugar varies significantly (*P* = 0.05) from processing method. The amount of carbohydrate of boiled leaves, significantly ($p<0.05$) decreased during boiling compared to the control. As previously mentioned, this can be related to the Maillard reaction, as carbohydrates (reducing sugar) are also substrates of no enzymatic browning [43]. The estimated calorific values (194.01–233.78 kcal/100 g) of the cooked leafy vegetables (10 min) compared favorably to 248.8 – 307.1 kcal/100 g reported on some Ivoirian vegetables [44]. 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 [45]. This justifies that cooked leafy vegetables are usually eaten as a relish together with a starchy staple food, usually in the form of porridge [46]. The effect of boiling on mineral composition of *Solanum nigrum* leaves is given in Table 2. The residual contents of minerals after 10 min of cooking were: calcium (1386.56–1079.83 mg/100 g), phosphorus (508.88–405.24 mg/100 g), Magnesium (662.99–572.78 mg/100 g) and Iron (44.50-33.48 mg/100 g). These reductions may be due to leaching of the mineral compound into the boiling water [47]. With regard to these values, the consumption of 10 min boiled leaves of *Solanum nigrum* could cover all the standard mineral requirements for human. Indeed, these standard requirements are: Calcium (1000 mg/day); Magnesium (400 mg/day) and Iron (8 mg/day) [48]. The presence of these minerals in African leafy vegetables is also beneficial, due to their direct relationship with hypertension in humans. This may be the reason why the plant is used to prevent and control high blood pressure [49]. They are implicated in several body functions such as enzymatic reactions, energy production, transmission of nerve impulses, and multiple biological reactions [50]. Magnesium is known to prevent cardiomyopathy, muscle degeneration, growth retardation, alopecia, dermatitis, immunologic dysfunction, gonadal atrophy, impaired spermatogenesis, congenital malformations and bleeding disorders [51]. Iron plays numerous biochemical roles to the body, including oxygen blinding of haemoglobin and acting as an important catalytic center in many enzymes as the cytochrome oxidase. Thus, the selected leaves of this study could be recommended to diets of reducing anaemia which affects more than one million people worldwide [52]. The species analyzed in this study showed appreciable levels of potassium. Sodium and potassium are involved in membrane and cellular exchange, thus contribution to the regulation of plasma volume, acid-base balance and muscle contraction. In addition, the sodium/potassium ratio for all fresh leafy vegetables studied being less than one, this would mean that they could use in diet of

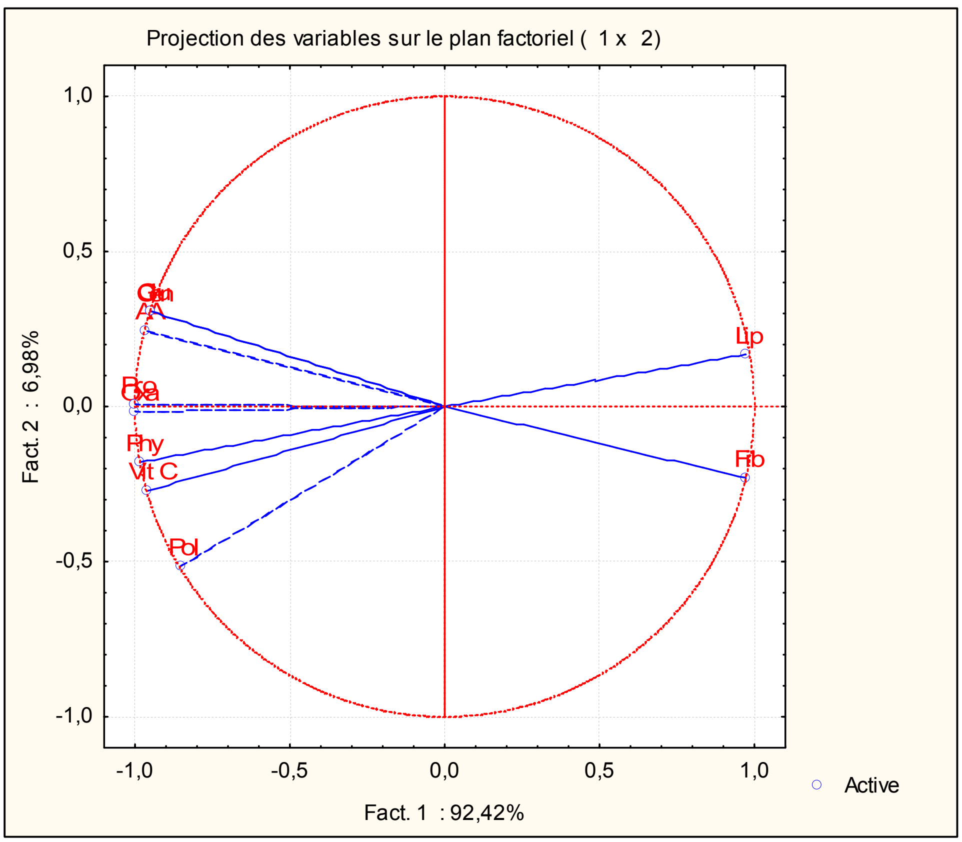

Fig. 2. Circle of correlation of proximate, minerals, phytochemical properties of leaves from fresh and cooked of leaves of *Solanum nigrum* on axis 1 and 2

Vit c: Total vitamin C, Pol: Total polyphenols, Phy: phytic acid, AA: antioxidant activity, Cen: Total ash, Fib: Total fibers, Pro: Crude protein; Lip: Crude fat, Oxa: Total oxalate hypertensive individuals [53]. The effect of cooking time on oxalates contents is depicted in Table 2. Levels losses at 10 min and 20 min for oxalates (140.87- 91.64 mg / 100 g) could be advantageous for improving the health status of boiled leafy vegetables consumers. Indeed, oxalate is anti-nutrients which chelate divalent cations such as calcium, magnesium, zinc and iron, thereby reducing their bioavailability [54]. Therefore, cooking of leafy vegetables appears as a detoxification procedure by removing these anti-nutritional factors [55]. To predict the bioavailability of calcium, the calculated oxalates/Ca ratios molar ratios in the cooked and uncooked leaves were below the critical level of 2.5 known to impair calcium bioavailability [56]. The effect of boiling on nutritive and antioxidant properties of *Solanum nigrum* leaves is given in Table 3. A significant reduction vitamin C (11.23 mg / 100 g) was highlighted at 10 min during boiling processing. These values support the results obtained for other studies which indicate losses up to 66% in cooked vegetables [57]. 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 agriculture organization [58]. The predominant polyphenols of *Solanum nigrum* leaves were tannins followed by flavonoids. The less negative effect of boiling on total phenolics notably tannins (47.95–53.12%) and flavonoids (14.76-38.09%) can be attributed to the water-soluble compounds leaching into the cooking water as well as the breakdown of these compounds during cooking [59,60]. The decrease of total polyphenols contents (47.96-64.27%) could be the consequence of a destruction of the cellular structure during cooking. The cells swell and explode in the presence of an excess of water during the cooking then releasing their contents [61]. Indeed, the losses of polyphenols contents decrease of the polyphenolic compounds content and overall antioxidant activity could be due to leaching or heat ability of specific flavonoids [62, 63]. DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging ability of raw and boiled leaves samples are shown in Fig. 1. In comparison to raw leaves of all boiled leaves, studied showed significantly (P=.05) lower free radicals scavenging ability. When vegetables are submitted to cooking processes, in one hand, variations appear in their antioxidant activity or scavenger capacity [64]. On the other hand, the DPPH assay and total antioxidant capacity assay of leafy vegetable extracts are correlated with the total phenolic content [65]. The principal component analysis illustratively divided the uncooked, cooked at 10 min and cooked at 15 min, cooked at 20 min according to the assessed parameters. Only those cooked at 10 min had good contents.

4. CONCLUSION

This study indicate that boiling time has determined effect on the levels of phytochemicals, bioactive components and antioxidant capacities of *Solanum nigrum* leaves. Boiling caused the loss of nutrients, this might be due to leaching during heat application. It was not a significant reduction of nutrient and anti-nutrients content of leaves after boiling. This is probably because the antinutrients are heating labile. Nevertheless, the losses in anti-nutrients (oxalates) might have asserted a beneficial effect on bioavailability of minerals like iron and calcium. Thus, the study suggests time of domestic cooking must be less than 10 min for the studied leafy vegetables in order to the nutritional requirement and to the food security of Ivorian population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kumar A, Kota S, Veena KM, Rao JPK, Laxmikanth C, Prashh S, Prabhu RV, Tashika KR, Pratima S, Shaul H. Areca nut and its effects on the human body. Am J Oral Medicine Radiol. 2015;2(1):10-14.
2. Rao GB, Rao PR, Murty P, Rao ES, Madhukiran P, Rao TM. Investigation on regional variation in total phenolic, alkaloid content and in vitro antioxidant activity of Leucas aspera. Internat J Pharmace Sci Res. 2011;2(10):2699-703.
3. Yang RY, Keding GB. Nutritional contributions of important African indigenous vegetables. In: Shackleton C.M., Pasquini M.W., Drescher A.W. (eds), African indigenous vegetables in urban agriculture. Earthscan, London. 2009;105-143.
4. Hilou A, Nacoulma OG, Guiguemde, In vivo antimalarial activities of extract from Amaranthus spinosus L., Boerhaavia erecta L. J. Ethnopharmacol. 2006; 103:236-40.

5. Nnamani CV, Oselebe H, Agbatutu. Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State, Nigeria. Afr. J. Biotechnol. 2009;8:2321-324.
6. Fondio L, Kouamé C, N'zi JC, Mahyao A, Agbo E, Djidji AH. Survey of indigenous leafy vegetable in the urban and periurban areas of Côte d'Ivoire. Acta Hortic. 2007;752:287-89.
7. Elhag RAM, El-Badwi SMA, Bakhiet AO, Galal M. Hepatoprotective activity of Solanum nigrum extracts on chemically induced liver damage in rats. J. Vet. Med. Anim. Health. 2011;3(4):45-50.
8. Oboh G. Effect of some post-harvest treatments on the nutritional properties. Pak. J. Nutr. 2011;4(4):226–30.
9. Kao PJ, Chiu YS, Tsou MJ. Effect of Chinese domestic cooking method on the carotenoid's composition of vegetables in Taiwan LWT. Foods Scien Technol. 2012;46:485-92.
10. Camire ME, Camire A, Krumhar K. Chemical and nutritional changes in foods during extrusion. Crit. Rev. Food Sci. Nutr. 1990;29:35–57.
11. Rodriguez-Amaya DB. Changes in carotenoids during processing and storage of foods. Arch. Latinoam. Nutr. 1999; 49:38–47.
12. Ejoh RA, Djuikwo VN, Gouado I, Mbofung CM. Effect of the method of processing and preservation on some quality parameters of three non-conventional leafy vegetables. Pak. J. Nutr. 2007;6(2):128-33. Doi:10.3923/pjn.2007.128.133
13. Judprasong K, Charoenkiatkul S, Sungpuag P, Vasa-nachitt K, Nakjamanong Y. Total and soluble oxalate contents in thai vegetables, cereal grains and legume seeds and their changes after cooking. J. Food Compost. Anal. 2006; 19(4):340-47.
14. Nnamani CV, Oselebe H, Agbatutu A. Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State, Nigeria. Afr. J. Biotechnol. 2009;8:2321-324.
15. Zoro AF, Zoué LT, Bédikou ME, Kra SA, Niamké SL. Effect of cooking on nutritive and antioxidant characteristics of leafy vegetables consumed in Western Côte d'Ivoire. Archives of Applied Science Research. 2014;6(4):114-23.
16. Wong SP, Leong LP, Koh JHW. Antioxidant activities of aqueous extracts of selected plants. Food Chem. 2006;99: 775-78.
17. Li M, Fan Y, Zhang X, Hou W, Tang Z. Fruit and vegetable intake and risk of type 2 diabetes mellitus: meta-analysis of prospective cohort studies. BMJ Open. 2014;4:e005497.
Available:http://dx.doi.org/10.1136/bmjopen-201 4-005497
18. Mohammed MI, Sharif N. Mineral composition of some leafy vegetables consumed in Kano, Nigeria. NJBAS. 2008;19:208-211.
19. Dogni KD, N'Dri YD, Kouassi KN, N'Guessan AG. Evaluation of nutritive value of two traditional African vegetables (Corchorus olitorus and Hibiscus sabdariffa) commonly consumed in Côte d'Ivoire. Int. J. Biochem. Res. Rev. 2018; 23(4):1-8.
DOI: 10.9734/IJBCRR/2018/43796
20. Jiménez-monreal AM, Garcia-diz L, Martinez-tomé M, Mariscal EM, Amurcia M. Influence of cooking methods on antioxidant activity of vegetables. J. of Food Sci. 2009;74:97-103.
21. Parkouda C, Korotimi T, Savadogo A, Fatoumata B, Kamga R, Traoré Y. Effect of processing methods on the nutritional content of three traditional vegetables leaves: Amaranth, black nightshade and jute mallow. Food Sci. Nutr. 2009;5:1139–144.
22. Association of Official Analytical Chemists (AOAC). Official methods of analysis. 15th ed.; Association of Official Analytical Chemists: Washington, DC, USA; 1990.
23. FAO. Carbohydrates in human nutrition. Report of a joint FAO/WHO expert consultation. FAO Food and Nutrition Rome. 1998;66.
24. Prosky L, Asp NG, Schweizer TF, Vries JW, Furda I. Determination of insoluble, soluble, and total dietary fiber in foods and food products: Inter laboratory study. J. Assoc. Off. Anal. Chem. 1988;71:1017-023.
25. Atwater W, Rosa EA. New respiratory calorimeter and the conservation of energy in human body. Phys. Rev. 1899;9:214–51.
26. American Association of Cereal Chemists (AACC). Official method 40-70.01: elements by atomic absorption spectrophotometry. In approved methods of the american association of cereal

chemists, 11th ed.; AACC International: St. Paul, MN, USA; 1999.
27. Day RA, Underwood AL. quantitative analysis. 5th ed. Prentice Hall Publication: London, UK. 1986;1–701.
28. N'Dri D, Mazzeo T, Zaupa M, Ferracane R, Fogliano V, Pellegrini N. Effect of cooking on the total antioxidant capacity and phenolic profile of some whole-meal African cereals. J. Sci. Food Agric. 2013; 93:29-36.
Available:https://doi.org/10.1002/jsfa.5837
29. Singleton VL, Orthofer R, Lamuela-Raventos. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol. 1999;299:152-78.
30. Pongracz G, Weiser H, Matzinger D. Tocopherols-Antioxydant. Fat Sci. Technol. 1971;97:90-104.
31. Bainbridge Z, Tomlins K, Westby A. Methods for assessing quality character-ristic of non-grains starch (Part 3. Laboratory Methods); Natural Ressources Institute: Chathom, UK; 1996.
32. Meda A, Laien CE, Romito M, Millogo J, Nacoulma OG. Determination of total phenolic, flavonoid and proline contents in Burkina Faso honeys as well as well as their radical scavenging activity. Food Chem. 2005;91:571–77.
33. Choi CW, Kim SC, Hwang SS, Choi BK, Ahn HJ, Lee MZ, Park SH, Kim SK. Antioxydant activity and free radical scavenging capacity between Korean medicinal plant and flavonoids by assay guided comparison. Plant Sci. 2002; 163:1161-168.
34. Omenna EC, Olanipekun Otudouso VB. Effect of the traditional cooking methods (boiling and roasting) on nutritional profile of quality protein maize. J. Food Nutr. Sci. 2016;4(2):34-40.
Available:http://dx.doi.org/10.11648/j.jfns.20160402.12
35. Essack H, Odhav B, John JMJJ. Screening of traditional South African leafy vegetables for specific anti-nutritional factors before and after processing. Campinas. 2017;37(3):462-71.
Available:http://dx.doi.org/10.1590/1678-457X.20416
36. Ishida H, Suzuno H, Sugiyama N, Innami S, Todokoro T. Maekawa A. Nutritional evaluation of chemical component of leaves stalks and stems of sweet potatoes (*Ipomea batatas*). Food Chem. 2000;68: 359-67.
37. Slavin JL. Dietary fiber and body weight. J Am. Die. Ass. 1987;87:1164-168.
38. Lintas C. Cappelloni M. Dietary fiber, resistant starch and in vitro starch digestibility of cereal meals. Food Sci. Nutr. 1998;42:117–24.
39. Svanberg, SSM, Nyman EMG, Andersson L, Nilsson R. Effects of boiling and storage on dietary fiber and digestible carbohydrates in various cultivars of carrots. J. Sci. Food Agric. 1997;73:245–54.
40. Chukwuma EO, Taiwo OO, Udouso VB. Effect of the traditional cooking methods (boiling and roasting) on the nutritional profile of quality protein Maize. Food. Nutr. Sci. 2016,4(2).
Available:http://www.sciencepublishinggroup.com/j/jfns
41. Coelho DF, Pereira-Lancha LO, Chaves DS, Diwan D, Ferraz R, Campos-Ferraz PL, Poortmans JR, Lancha AHJ. Effect of high-fat diets on body composition, lipid metabolism and insulin sensitivity and the role of exercise on these parameters. Brazilian. J. Med. Biol. Res. 2011;44:966-72.
42. Patricia D, Oulai, L, T. Zoué, Sébastien Niamké L. Evaluation of Nutritive and Antioxidant Properties of Blanched Leafy Vegetables Consumed in Northern Côte d'Ivoire. J. Food Nutr. Sci. 2015;65(1):31–38.
43. Tenyang N, Ponka R, Tiencheu B, Djikeng FT, Azmeera T, Karuna MSL. Womeni HM. Effect of bioling and roasting on proximate composition, lipid oxidation, fatty acid profile and mineral content of two sesame varieties commercialized and consumed in Far-North region of Cameroon. Food Chem. 2017;221:1308-316.
Available:http://doi.org/10.1016/j.foodchem.2016.11.025
44. Antia BS, Akpan EJ, Okon PA, Umoren IU. Nutritive and anti-nutritive evaluation of sweet potatoes (Ipomea batatas) leaves. Pak. J. Nutr. 2006;5(2):166–68.
45. Pinheiro SHM, Stringheta PC, Cardoso BSC, Cordeiro ARM. Carotenoid retention and vitamin A value in carrot Daucus carota L. prepared by food service. Food Chem. 1998;61:145–51.
46. Andersen LT, Thilsted SH, Nielsen BB, Rangasamy S. Food and nutrient intakes among pregnant women in rural Tamil

Nadu, South India. Public Health Nutr. 2003;6:131-137.
47. Lola A. The effect of boiling on the nutrients and anti-nutrients in two non-conventional vegetables. Pak. J. Nutr. 2009;8:1430–433.
48. FAO. Human vitamin and mineral requirements. FAO Ed. 2004;361.
49. James NR. Volatile components of green walnut husks. J. Agric. Food. Chem. 2000; 48:2858–861.
Available:https://doi.Org/10.1021/jf000288b
50. Steinberg FM, Bearden MM, Keen CL. Cocoa and chocolate flavonoids: Implications for cardiovascular health. J. Am. Diet. Assoc. 2003;103:215–23.
51. Trowbridge F, Martorell M. Forging effective strategies to combat iron deficiency. Summary and recommendations. J. Nutr. 2002;85:875-80.
52. Chaturvedi VC, Shrivastava R, Upreti RK. Viral infections and trace elements: A complex trace element. Curr. Sci. 2004;87: 1536-554.
53. Ehile EJS, Kouassi KN, Kouamé AC, N'Dri YD, Amani NG. Nutritional composition of five spontaneous wild plant used as human foods in Cote d'Ivoire areas (west Africa), a potential role in househloid food security. Pak. J. Nutr. 2018;17:171-78.
Available:Httd//dx
DOI:10.3923/pjn.2018.171.178
54. Sandberg AS. Bioavailability of minerals in legumes. Brit. J. Nutr. 2002;88:281-85.
55. Ekop AS, Eddy NO. Comparative Studies of the level of toxicants in the seed of Indian almond (*Terminalia catappa*) and African walnut (*Coula edulis*). J. Agri Food Chem. 2005;2:74-76.
56. Hassan LG, Umar KJ, Umar Z. Antinutritive factors in *Tribulus terrestris* (Linn) leaves and predicted calcium and zinc bioavailability. J. Trop. Biosci. 2007;7:33-36.
57. Oboh G. Effect of blanching on the antioxidant properties of some tropical green leafy vegetables. LWT – Food Sci. Technol. 2005;38:513–517.
58. FAO. Human vitamin and mineral requirements. FAO Ed. 2004;361.
59. Raffaella P, Mattia R, Giuliana V. Effect of steaming and boiling on the antioxidant properties and biogenic amines content in green bean (Phaseolus vulgaris) varieties of different colours. Hindawi J. Food. Qual. 2017;1-8.
60. Crozier A, Lean MEJ, McDonald MS, Black C. Quantitative analysis of the flavonoid content of commercial tomatoes, onions, lettuce, and celery. J. Agric. Food Chem. 1997;45(3):590–95.
61. Abusin SAE, Hassan AB, Babiker EE. Nutritional evaluation of cooked Faba bean (Vicia Faba L.) and white bean (Phaseolus Vulgaris L.) cultivars. Australian Journal of Basic and Applied Sciences. 2009;3(3): 2484-490.
62. Kalt W. Effects of production and processing factors on major fruit and vegetable antioxidants. J. Food Sci. 2005; 70:11–19.
Available:https://doi.org/10.1111/j.1365-2621.2005.tb9053.x
63. Yamaguchi T, Mizobuchi, T, Kajikawa R, Kawashima H, Miyabe F, Terao J, Takamura H, Matoba T. Radical scavenging activity of vegetables and the effect of cooking on their activity. Food Sci Technol Res. 2001;7:250–57.
64. Miglio C, Chiavaro EA, Fogliano V, Pellegrini N. Effects of different cooking methods on nutritional and physic-chemical characteristics of selected vegetables. J. Agric. Food Chem. 2008;56: 139–47.
[CrossRef] [PubMed]
65. Prasanna KD, Gunathilake P, Somathilaka RKKD, Vasantha RHP. Effect of different cooking methods on polyphenols, carotenoids and antioxidant activities of selected edible leaves. Antioxidants. 2018; 117.

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