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Vitamins and Minerals Composition of Eggplant (*Solanum macrocarpon*) and 'Ukazi' (*Gnetum africanum*) Leaves as Affected by Boiling and Steaming

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Authors' contributions

The work was carried out in collaboration between the two authors. Author GID design the study, wrote the protocol and wrote the first draft of the manuscript. Author AGM performed the statistical analysis, managed the analysis of the study and the literature searches. The authors read and approve the final manuscript.

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ABSTRACT

Aims: In relation to nutrient retention, cooking method is not a major factor considered when preparing vegetables at household level. The study evaluated the vitamin and mineral compositions of raw, boiled and steamed egg plant (*Solanum macrocarpon*) and 'ukazi' (*Gnetum africanum*) leaves.
Methodology: Freshly purchased vegetables were washed and divided into three portions. The first was pulverised raw while the second and third were pulverised after boiling and steaming, respectively. Their micro nutrients profiles were chemically determined using standard procedures. Data obtained was statistically analysed using Statistical Product for Service Solution (SPSS) version 21.0 for descriptive statistics such as means and standard deviation. Significance was accepted at $p \leq 0.05$.
Results: Micro nutrients content of eggplant were significantly ($p \leq 0.05$) higher in the raw than the steamed and boiled samples. However, no significant ($p \leq 0.05$) difference was observed in the

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vitamin B_1 content of boiled (0.19 mg/100 g) and steamed (0.16 mg/100 g) samples. Except for vitamin B_6, all the B-vitamins values of the raw and steamed 'ukazi' leaves were statistically similar. There was no significant difference in the beta carotene values of raw (587 mg/100 g), boiled (549 mg/100 g) and steamed (574 mg/100 g) samples. Mineral values of the three 'ukazi' samples were all significantly different (p=.05) and ranged from 0.28-181 mg/100 g in the raw, to 0.10-161 mg/100 g and 0.26-180 mg/100 g in the boiled and steamed samples, respectively.
Conclusion: Steaming had better micro nutrient retention than boiling. Boiling and steaming the vegetables whole (without slicing) also enhanced their nutrient retention. To improve on the intake of micro nutrients, steaming whole vegetables rather than boiling them should be advocated.

Keywords: Vegetables; vitamins; minerals; 'ukazi' leaves; eggplant leaves; boiling and steaming.

1. INTRODUCTION

Vegetables are edible parts of plants that are consumed whole or in parts, raw or cooked as part of main dish [1]. Some vegetables are used in raw form as salad, but most of them require cooking for the improvement of digestibility and palatability [2]. Vegetables contain many bioactive compounds and thus, serve as an important source of minerals, vitamins and certain hormone precursors in addition to protein and energy sources [3]. They are known to provide 80% of vitamin A and C daily requirements in diets [4]. Green vegetables are also great sources of minerals such as zinc, iron and potassium [5]. African leafy vegetables have long been, and have continued to be reported to significantly contribute to the dietary vitamin and mineral intakes of local population [6]. It is estimated that up to 2.7million lives could potentially be saved each year if fruits and vegetables consumption are sufficiently increased [7]. The health benefits of diet rich in vegetables have also been recognized and there is evidence that nutrient content of fruits and vegetables such as dietary fibre, antioxidants, vitamins and phytochemicals are associated with low risk of cardiovascular diseases [8,7].

'Ukazi' leaf (*Gnetum Africana)* belongs to the family of plant called Gnetaceae. The leaves are highly and widely consumed in Nigeria. Primarily, *G. africana* leaves are used as vegetable for soup commonly called 'Eru' soup or 'afang' soup [9]. In South East Nigeria, *G. Africana* is used for the preparation of soup and salad. The salad is often eaten as a mild laxative and its high fibre content helps to prevent constipation [10]. It is very delicious and tasty with little or no soup making ingredients such as fish or meat [11]. The leaves are cut into small strips, cooked in sauces and eaten with cassava [12]. The leaves can also be eaten raw or shredded and added to stews and porridges.

Solanum macrocarpon otherwise known as African eggplant leaf is a plant of the *Solanaceae* family. It grows in areas of high rainfall such as the tropical and humid regions of West and Central Africa, Southeast Asia, South America and the Caribbean [13]. The young leaves and fruits are cooked and consumed as vegetable [13]. The leaves are eaten as a separate dish or in sauces together with other ingredients. The taste is slightly bitter and very much liked. The characteristic bitter taste of *Solanum macrocarpon* leaves has been attributed to the presence of furostanol glycosides which is a representative class of steroidal saponins.

Many foods are cooked before they are eaten and vitamin and mineral levels tend to decrease as food is cooked [14]. Most vitamins are sensitive to heat and water. Water-soluble vitamins, especially most of the B vitamins and vitamin C, leach into the cooking water. Some minerals are also lost in water, but their retention is higher than vitamins. Hence, vegetables are mainly prepared at home on the basis of convenience and taste preference rather than retention of nutrient and health-promoting compounds [15]. It is also known that cooking induces significant changes in chemical composition thus, affecting the bioavailability and content of chemo preventive compounds in vegetables [16]. Cooking methods have been shown to affect the contents of nutrient and health-promoting compounds such as vitamin C, carotenoids, polyphenols and glucosinolates in broccoli [17,18,19]. Nutrient data are frequently lacking for cooked foods. It has been observed that majority of the available nutritional information is based on uncooked and unprepared food [14]. However, the nutritional content of ingredients typically changes according to the method of food storage and preparation.

Steaming and boiling are common ways of cooking vegetables and these have been shown to affect the mineral and vitamin contents of vegetables [20]. It is, therefore, important to choose a cooking method that leads to optimal nutrient retention and bioavailability [21]. Earlier studies on the nutritional composition of cooked vegetables often dealt with a single and chopped vegetable [21], or few nutrients [22]. A more integrated analysis of nutritional properties of vegetables particularly when cooked whole is needed to gain insight into the effect of cooking. In this study, the effect of cooking methods (boiling and steaming) on the micronutrient profile of two vegetables (*Gnetum africana* and *Solanum macrocarpon*), selected on the basis of their popularity in the traditional cuisine of South-eastern Nigerians, was evaluated.

2. MATERIALS AND METHODS

2.1 Study Design

Quasi experimental design was adopted in the study.

2.2 Materials

The materials used in this study included fresh leaves of eggplant (*Solanum macrocarpon*) and 'ukazi' (*Gnetum africanum*)

2.3 Sample Procurement

The vegetables were purchased from three different sellers at Ogige market in Nsukka Local Government Area of Enugu State, Nigeria.

2.4 Sample Preparation

Leaves of eggplant (*Solanum macrocarpon*) and 'ukazi' (*Gnetum africanum*) bought from three sellers were, respectively, mixed together. Three hundred grams (300 g) of each vegetable was weighed out into three portions and washed after the inedible portions were removed. The first portion was boiled, the second steamed while the third was left raw (the control). Eggplant leaves were boiled for 10 minutes while 'ukazi' leaves were boiled for 12 minutes ('ukazi leaves being coarser required more boiling time before they became tender). All steaming was done for 5 minutes and all the vegetables were cooked whole. Cooking was done with moderate heat at 100°C using a gas range, 1000 cm^3 of water and a tightly covered pot/steamer measuring 9.05 by 4.8 inches. All the samples (the boiled, steamed and raw vegetables) were subsequently pulverised, packaged in tightly covered plastic container, packed with ice bag and sent for chemical analysis. Water was drained from the boiled samples using a colander before pulverising. The chemical analysis was carried out in an analytical laboratory at Ibadan, Oyo State, Nigeria. All the samples were prepared in the Food and Nutrition Laboratory, Department of Home Science and Management, University of Nigeria, Nsukka, Enugu State, Nigeria.

2.5 Chemical Analysis

The vitamins (B_1, B_2. B_3, B_6, B_9, B_{12} and ascorbic acid), beta carotene and minerals (sodium, potassium, magnesium, phosphorous, calcium, iron, zinc and copper) were analysed according to the official methods of analysis described by the Association of Official Analytical Chemists [23]. Vitamins and beta-carotene were determined using spectrophotometer (Cecil A20 model, Cecil Instrument Ltd., Cambridge, United Kingdom) method. Ascorbic acid values were obtained by titration method. Mineral elements (magnesium, copper, iron, and zinc) were determined using the Atomic Absorption Spectrophotometer (Buck 200). Phosphorus was determined using the vanadomolybdate method while calcium, potassium and sodium were determined using flame photometer.

2.6 Statistical Analysis

Data obtained was statistically analysed using Statistical Product for Service Solution (SPSS) version 21.0 for descriptive statistics such as means and standard deviations. Analysis of Variance (ANOVA) was used to compare the means while Duncan's multiple range tests was used to separate the means. Significance was accepted at ($p \leq 0.05$).

3. RESULTS

Table 1 presents the result of the vitamin composition of raw, boiled and steamed eggplant leaves. It shows that the raw had the highest vitamin values followed by the steamed while the boiled had the least. Vitamin values for the three samples were also significantly different ($p \leq 0.05$). For vitamin B_1 however, no significant difference was observed between the raw (0.19 mg/100 g) and steamed (0.16 mg/100 g) values. In the boiled and steamed samples, percentage losses in vitamins and beta carotene content ranged from 4.48 to 46.67 and 0.00 to 15.79%, respectively.

Table 2 shows the result of the mineral composition of raw, boiled and steamed eggplant (*Solanum macrocarpon*) leaves. It was observed that the raw samples had the highest mineral values followed by the steamed samples while the boiled samples had the least. Mineral values for the three samples were all significantly different ($p \leq 0.05$). Percentage loss in zinc was the highest in the boiled (35.29%) and steamed (17.64%) samples when compared to other minerals.

Table 3 shows the result of vitamins composition of raw, boiled and steamed 'ukazi' (*Gnetum africanum*) leaves. The raw sample had the highest vitamins values followed by the steamed sample while the boiled sample had the least. Except for vitamin B_6, all the B-vitamins values of the raw and steamed samples were statistically similar at $p \leq 0.05$). There was no significant difference in the beta carotene values of raw (587 mg/100 g), boiled (549 mg/100 g) and steamed (574 mg/100 g) samples at $p \leq .05$. Up to 55.88% loss was observed in the vitamin B_2 content of the boiled sample when compared to the raw.

Table 4 reveals the result of mineral compositions of raw, boiled and steamed 'ukazi' (*Gnetum africanum*) leaves. The raw sample had the highest values followed by the steamed sample while the boiled sample had the least. Mineral values for the three samples were all significantly different ($p \leq 0.05$). In the steamed sample, percentage loss in all the mineral was below 10%.

Table 1. Vitamins and beta carotene composition of raw, boiled and steamed eggplant leaves

Vitamins/100 g	Raw	Boiled	%Losses	Steamed	% Losses
Vitamin B_1 (mg)	0.19^{b} ±0.02	0.10^{a} ± 0.01	44.37	0.16^{b} ± 0.02	15.79
Vitamin B_2 (mg)	0.27^{c} ± 0.01	0.15^{a} ± 0.02	44.44	0.23^{b} ± 0.02	8.22
Vitamin B_3 (mg)	0.73^{c} ± 0.02	0.48^{a} ± 0.03	34.25	0.67^{b} ± 0.02	8.23
Vitamin B_6 (mg)	0.15^{c} ± 0.01	0.08^{a} ± 0.02	46.67	0.12^{b} ± 0.0	20
Vitamin $_{B12}$ (mg)	0.02^{b} ± 0.00	0.01^{a} ± 0.00	50	0.02^{c} ± 0.00	0.00
Total Ascorbic Acids (mg)	24.70^{c} ± 0.02	21.90^{a} ± 003	11.34	22.57^{b} ±0.02	8.62
Total Folate (µg)	23.76^{c} ± 0.02	19.90^{a} ±0.02	16.25	21.47^{b} ± 0.02	9.64
Beta Carotene (µg)	558.00^{c} ±0.10	533.00^{a} ±0.25	4.48	550.00^{b}±0.15	1.43

Results are mean values of triplicate analysis and the values with different superscripts in the same rows are significant at p≤ 0.05

Table 2. Minerals composition of raw, boiled and steamed eggplant leaves (*Solanum macrocarpon*)

Minerals (mg/100 g)	Raw	Boiled	% Losses	Steamed	% Losses
Sodium	16.60^{c}±0.02	13.80^{a}±0.01	16.87	15.40^{b}±0.02	7.23
Potassium	175.00^{c}±0.02	164.00^{a}±0.02	6.29	168.00^{b}±0.02	4.00
Phosphoros	25.48^{c}±0.02	21.77^{a}±0.01	14.56	23.54^{b}±0.02	7.61
Calcium	31.24^{c}±0.02	27.69^{a}±0.02	11.36	29.56^{b}±0.02	5.38
Iron	1.16^{b}±0.01	1.06^{a}±0.03	8.62	1.12^{b}±0.03	3.45
Zinc	0.17^{c}±0.01	0.11^{a}±0.02	35.29	0.14^{b}±0.01	17.64
Copper	31.06^{c}±0.02	28.74^{a}±0.02	7.47	29.69^{b}±0.02	4.41

Results are mean values of triplicate analysis and the values with different superscripts in the same rows are significant at p ≤ 0.05

Table 3. Vitamins and beta carotene composition of raw, boiled and steamed 'ukazi' (*Gnetum africanum*) leaves

Vitamins/100 g	Raw	Boiled	% Losses	Steamed	% Losses
Vitamin B_1 (mg)	0.24^{b} ±0.02	0.12^{a} ± 0.01	50	0.21^{b} ± 0.03	12.5
Vitamin B_2 (mg)	0.34^{c} ± 0.02	0.15^{a} ± 0.02	55.88	0.31^{b} ± 0.03	8.82
Vitamin B_3 (mg	0.79^{c} ± 0.02	0.54^{a} ± 0.02	31.65	0.76^{b} ± 0.02	3.80
Vitamin B_6 (mg)	0.02^{c} ± 0.00	0.01^{a} ± 0.00	50	0.02^{b} ± 0.00	0.00
Total Ascorbic Acids (mg)	27.20^{c} ± 0.02	23.47^{a} ± 0.03	13.71	25.40^{b} ±0.00	6.61
Total Folate (µg)	26.16^{c} ± 0.02	20.80^{a} ±0.02	20.49	24.90^{b} ± 0.02	4.82
Beta Carotene (µg)	587.00^{c} ±5.60	549.00^{a} ±37.27	6.47	574^{b}±0.2	2.21

Results are mean values of triplicate analysis and the values with different superscripts in the same rows are significant at p ≤ 0.05

Table 4. Mineral compositions of raw, boiled and steamed 'ukazi' (*Gnetum africanum*) leaves

Minerals(mg/100 g)	Raw	Boiled	% Losses	Steamed	% Losses
Sodium	17.15^{c}±0.02	12.90^{a}±0.01	24.78	16.01^{b}±0.02	6.64
Potassium	181.00^{c}±0.02	161.00^{a}±0.03	11.05	180.00^{b}±0.02	0.55
Magnesium	12.23^{c}±0.26	6.93^{a}±0.02	43.35	11.60^{b}±0.05	5.15
Phosphorus	29.47^{c}±0.02	20.90^{a}±0.01	29.08	27.21^{b}±0.02	7.67
Calcium	34.22^{c}±0.02	26.56^{a}±0.02	22.38	33.86^{b}±0.02	1.05
Iron	1.31^{b}±0.03	1.00^{a}±0.04	23.66	1.24^{b}±0.02	5.34
Zinc	0.28^{c}±0.02	0.10^{a}±0.01	64.29	0.26^{b}±0.02	7.14
Copper	36.54^{c}±0.02	27.90^{a}±0.02	23.64	34.31^{b}±0.02	6.10

Results are mean values of triplicate analysis and the values with different superscripts in the same rows are significant at $p \leq 0.05$

4. DISCUSSION

The micronutrients compositions of the vegetables were generally higher in the raw than the boiled and steamed samples. The fact that raw vegetables are of higher nutritional value than cooked ones have been documented by several researchers [21,22,24,25]. It seems that raw vegetables are more beneficial to consume than when cooked. However, cooking of vegetables is important to soften the matrix of cells and increase extractability of nutrients [26] while destroying anti-nutritional factors as well as halting spoilage process [27]. According to Lopez et al. [28] the reason for the decrease as shown in the vitamin content may be due to the susceptibility of vitamins to oxidation and heat leading to destruction and degradation. It was observed that the reduction in vitamin content was more in the boiled than steamed samples. For instance, the vitamin values of the steamed eggplant and 'ukazi' leaves were statistically higher ($p \leq 0.05$) than their boiled counterpart. According to previous studies [29,30], steaming is considered as one of the healthiest methods of preparing food as it helps vegetables retain nutrients. The higher vitamin loss of the boiled vegetables was attributed to leaching of vitamins into the boiling water. This finding is also in line with the study by Coila, [31] who reported that some vitamins such as B vitamins and vitamin C are water soluble and are destroyed when submerged in water.

The B vitamin values for the two vegetables ranged from 0.014 to 0.79 mg/100 g. This result agrees with the work of Osum et al. [32] who reported trace level of vitamin B_1 in blanched extracts of Vitex domiana leaves. The ascorbic acid value of the boiled vegetables (21.90 to 23.47 mg/100 g) was comparable to the value (19.22 mg/100 g) obtained by Ogbadoyi et al. [33] after boiling *Amaranthus cruentus* for five minutes. However, the result disagrees with the vitamin C value (1.21 mg/100 g) reported [21] after two minutes of blanching Amaranth leaves. This result is not in line with that of Migilo *et al*. [26] who found out that boiling surprisingly had a lower detrimental effect on ascorbic acid concentration of carrot. The highest ascorbic acid loss (about 14%) was seen in boiled 'ukazi' leaves. Keshinro and Ketiku [34] reported an 80.3% loss of vitamin C from parboiling for 5 minutes, which increased to 91.5% after final cooking for another 5 minutes. Boiling vegetables whole (without slicing/chopping) as was done in the study drastically enhanced its nutrient retention particularly vitamin C (ascorbic acid).

Total folate reduced significantly in the boiled and steamed vegetables compared to the raw. Though Dang et al. [35] have observed that heat denatures most vegetables Mc Killop et al. [36] reported no significant loss of folate in spinach and broccoli after steaming for five and ten minutes, respectively.

The beta carotene content of the cooked vegetables revealed that steaming is a better cooking method for its retention. This result agrees with that of Bongoni et al. [37] whose findings showed that steaming retained more beta carotene in carrots when compared to boiling. Other studies have reported that up to 5 to 78% of beta carotene was degraded when vegetables were prepared using different cooking methods. Masrizal et al. [15] demonstrated that spinach and swamp cabbage retained 57 to 79% and 65 to 80% of beta carotene after boiling and frying respectively. The higher beta carotene retention (93 to 95% for boiled and 97-98% for steamed samples) could be due to the fact that the vegetables were cooked whole thereby minimizing the effects of leaching and oxidation. The beta carotene values (533 to 587 mg/100 g) of the boiled vegetables were all lower than that

of washed bitter leaves boiled for twelve minutes (603.67 mg/100 g) as reported by Davidson et al. [38]. 'Ukazi' leaves had higher beta carotene (549 to 587 mg/100 g) and ascorbic acids (23.47 to 27.20 mg/100 g) when compared to eggplant leaves. This vegetable is, therefore, a cheap and rich source of these substances which are powerful antioxidants that could be effective in combating degenerative diseases like breast cancer [39,40].

The mineral contents of the vegetables were higher in the raw than cooked samples. This could be attributed to the susceptibility of minerals to heat which led to their destruction as discussed by Lopez et al. [28]. The lower mineral values observed in the boiled samples was due to leaching of mineral into the boiling water [41]. This finding is in line with the report of Oladunmoye et al. [42] who observed significant reduction in the mineral concentration of blanched and boiled tender and matured cassava leaves. Ogbadoyi et al. [33] also found a significant reduction in the level of all mineral elements in boiled *Amaranthus cruentus*. Mepba et al. [20] also discovered that blanching and boiling caused significant loss in the mineral content of some selected vegetables.

The high retention of some micronutrient observed in this study was attributed to the fact that the vegetables were cooked whole (not chopped) which prevented the nutrients from leaching into the boiling water. Tumwet et al. [21] also found out that most nutrients were retained when vegetables were boiled for only five minutes without discarding the water used.

5. CONCLUSION AND RECOMMENDATION

Boiling and steaming, as cooking methods, substantially reduced the micro nutrient compositions of the vegetables which were attributed to leaching (for boiling method), oxidation and heat. Steamed vegetables had better micro nutrient retention than the boiled. It was, therefore, recommended that for maximum nutrient retention, vegetables should be washed and steamed whole for five to twelve minutes depending on their coarseness. Also, the tender vegetable should be mashed before its incorporation into dishes. However, where this is not possible, stewing (simmering in a liquid medium) rather than boiling should be used so that they can be consumed along with the liquid medium used in their preparation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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