GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(RESEARCH ARTICLE)

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Comparative studies on the effect of processing methods on the nutritional value of *Basella alba, Talinum triangulare, Celosia argentea, Amaranthus hybridus* and *Gnetum africanum* leaves

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GSC Advanced Research and Reviews, 2021, 06(03), 044–052

Publication history: Received on 15 January 2021; revised on 22 February 2021; accepted on 28 February 2021

Article DOI: https://doi.org/10.30574/gscarr.2021.6.3.0025

Abstract

The nutritional composition of vegetables is adversely affected by the method of processing for storage or preservation. This study was designed to determine the effect of blanching, boiling, and drying on the nutritional composition of selected vegetables using standard analytical methods. Proximate analysis was carried out on the fresh and processed leaf samples. Results obtained revealed that all the vegetables analyzed contained an appreciable amount of moisture, ash, protein, fiber, carbohydrate, β-carotene, and vitamins. Results also showed that all the processing methods employed significantly reduced ($p < 0.05$) the nutritional compositions of the vegetables studied. However, drying under the shade retained more nutrients compared to the other processing methods. Drying significantly increased ($p < 0.05$) the carbohydrate and protein contents of all the leaves (79.92 % & 7.51 % respectively in *Basella alba*, 66.74 % & 12.09 % respectively in *Amaranthus hybridus*, 82.56 % & 10.07 % respectively in *Celosia argentea*, 70.77 % & 13.05 % respectively in *Gnetum africanum* and 89.12 % & 4.70 % respectively in *Talinum triangulare*) compared to blanching, boiling and the control. Thus, from the three processing methods studied, drying was the most effective processing method that retained nutrients and is, therefore, a good preservation method for the vegetables.

Keywords: Vegetables; Processing methods; Nutritional value and preservation

1. Introduction

Vegetables are edible parts of the plants and can be classified into roots (e.g. potatoes and carrots), stem (asparagus), leaf (lettuce and spinach), and fruit (tomatoes and cucumbers). Vegetables have been reported to lower blood lipids, thereby reducing the occurrences of diseases associated with the damage of the coronary artery (1). High fruit and vegetable diets have also been reported to have an ameliorating effect on several diseases including cancers, diabetes, infectious diseases, parasitic diseases, oxidative stress, cardiovascular diseases, high blood pressure (2-4). *Basella alba, Talinum triangulare, Celosia argentea, Amaranthus hybridus,* and *Gnetum africanum* are among the commonly consumed vegetables in Nigeria. These medicinal plants have been reported to possess significant amounts of nutrients and phytochemicals that are beneficial to human health and have been widely consumed in all parts of the country.

Food processing is the transformation of agricultural products into food or, of one form of food into another. This also includes the preservation and packaging of food for consumption (5). Vegetable processing is the preparation and preservation of vegetables for use by humans as food (6). Processing transforms vegetables from the perishable form

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into stable foods and it is of prime importance as it extends the shelf-life of vegetables and at the same time makes them suitable for consumption. Processing also prevents microbial growth that causes spoilage in vegetables (7). However, the major drawback of vegetable processing is the reduction in the nutritional value of these vegetables (8). The extent of nutrient reduction is largely dependent on the type of processing method employed (9).

Different processing methods have been reported to affect the nutritional compositions of vegetables, however, the effect of blanching, drying, boiling, salting, squeezing, and freezing on the nutritional compositions of vegetables commonly consumed in the northern part of Nigeria is less reported. In other to bridge the gap in knowledge, the present study evaluated the effect of different processing methods on proximate compositions and vitamin contents of *Basella alba, Talinum triangulare, Celosia argentea, Amaranthus hybridus,* and *Gnetum africanum* leaves.

2. Material and methods

2.1. Sample Collection

Amaranthus hybridus (efo tete), *Celosia argentea* (shoko), *Gnetum africanum* (okazi), and *Talinum triangulare* (Waterleaf) were purchased from Bosso Market Minna, Niger state. *Basella alba* (amunu tutu) on the other hand was obtained fresh from a garden in Bosso lowcost, Minna, Niger state. They were all identified at the Plant Biology Department, Federal University of Technology, Minna.

2.2. Reagents

The following analytical grade chemicals: sulphuric acid (Sigma-Aldrich), n-hexane (Merck KGaA Germany), hydrochloric acid (Merck KGaA Germany), boric acid (Sigma-Aldrich), sodium hydroxide (LiChrosolv, Merck KGaA Germany), acetic acid (Sigma-Aldrich), acetone (LiChrosolv, Merck KGaA Germany), 2,6–Dichlorophenolindophenol dye (Merck KGaA Germany) were used for this study.

2.3. Processing methods

Basella Alba, Talinum Triangulare, Celosia Argentea, Amaranthus Hybridus, and *Gnetum Africanum* leaves were subjected to 3 different processing methods including blanching, boiling, and drying according to the method described by Korotimi *et al.,* (10). The blanching of the leaves was done in hot water (90 – 92 °C) for 2 min while **b**oiling was conducted at 100 °C water for 25 min. For drying, the leaves were air-dried at room temperature (27 °C) for 2 weeks.

2.4. Analysis of proximate and vitamins compositions

Analysis of proximate compositions including the Moisture content, crude protein content crude lipid, crude fiber, ash content, and carbohydrate content was conducted according to the standard method of A.O.A.C. (11) as described by Tsado *et al.* (5). Vitamin C contents were analyzed using the 2,6 - Dichlorophenolindophenol (DCPIP) dye protocol as described by Onwuka, (12), while the β-carotene contents were estimated spectrophotometrically as described by Tretyakov *et al.* (13).

2.5. Statistical analysis

The data obtained were subjected to analysis of variance (ANOVA) using a statistical package for the social sciences (SPSS) version 23. Means were separated using Duncan's multiple range test (DMRT). The significant difference was accepted at $p < 0.05$.

3. Results

The proximate compositions, β-carotene and vitamin C content of *Basella alba* (amunu tutu), *Talinum triangulare* (waterleaf), *Amaranthus hybridus* (efo tete), *Celosia argentea* (shoko), and *Gnetum africanum* (okazi) are shown in Table 1 and 2. The effect of processing methods on the proximate compositions, β-carotene and vitamin C contents of *Amaranthus hybridus* is shown in Tables 3 and 4. The effect of processing methods on the proximate compositions, β-carotene and vitamin C content of *Basella alba* are shown in Tables 5 and 6. The result in both tables revealed that there were significant differences ($p < 0.05$) in the nutritional compositions of all the processed leaf samples and that of the control. The effects of the processing method on the proximate compositions, β-carotene and vitamin C content of *Celosia argentea* are shown in Table7 and 8. The result in Tables 7 and 8 revealed that there were significant differences ($p < 0.05$) in the nutritional compositions of all the processed leaf samples and that of the control. The effect of processing methods on the proximate compositions, β-carotene, and vitamin C content of *Gnetum* *africanum* is shown in Tables 9 and 10. The result in both tables revealed that there were significant differences ($p < 0.05$) in the nutritional compositions of all the processed leaf samples and that of the control. The effects of processing methods on the proximate compositions, β-carotene and vitamin C of *Talinum triangulare* is shown in Table 11 and 12. The result revealed that there were significant differences ($p < 0.05$) in the nutritional compositions of all the processed leaf samples and that of the control.

Table 1 Proximate compositions of fresh leaf samples.

Samples	Moisture Content (%)	Ash (%)	Protein (%)	Lipid (%)	Fiber (%)	Carbohydrate (%)
Amaranthus hybridus	83.40 ± 0.01 ^{a}	7.45 ± 0.03 ^{c}	3.03 ± 0.01 ^{c}	0.39 ± 0.01 ^{a}	2.09 ± 0.00 ^{b}	3.64 ± 0.03 ^{a}
Basella alba	86.46 ± 0.33 ^{b}	0.70 ± 0.31 ^{a}	1.35 ± 0.03 ^{a}	0.49 ± 0.01 ^{a}	7.52 ± 0.57 ^{c}	3.48 ± 0.02 ^{a}
Celosia argentea	84.14 ± 0.02 ^{b}	2.52 ± 0.00 ^{b}	3.49 ± 0.01 ^{c}	0.89 ± 0.01 ^{b}	1.74 ± 0.03 ^{b}	7.22 ± 0.03 ^{b}
Gnetum africanum	46.09 ± 0.37 ^{a}	8.77 ± 0.62 ^{c}	2.44 ± 0.10 ^{b}	2.02 ± 0.04 ^{c}	9.29 ± 0.61 ^{c}	31.38 ± 0.14 ^{c}
Talinum triangulare	93.03 ± 0.55 ^{c}	0.67 ± 0.01 ^{a}	1.34 ± 0.03 ^{a}	0.59 ± 0.06 ^{ab}	1.01 ± 0.03 ^{a}	3.35 ± 0.51 ^{a}

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean ± Standard Error of Mean (S.E.M) of triplicate determination.

Table 2 β-carotene and vitamin C content of fresh leaf samples.

Samples	β-carotene (mg/100g)	Vitamin C (mg/100g)
Amaranthus hybridus	0.04 ± 0.00 ^{a}	54.34 ± 0.95 ^{a}
Basella alba	0.02 ± 0.00 ^{a}	95.01 ± 2.50 ^{b}
Celosia argentea	0.05 ± 0.00 ^{a}	53.76 ± 1.75 ^{a}
Gnetum africanum	0.18 ± 0.14 ^{b}	51.55 ± 0.77 ^{a}
Talinum triangulare	0.03 ± 0.00 ^{a}	47.89 ± 0.85 ^{a}

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean ± Standard Error of Mean (S.E.M) of triplicate determination.

Table 3 Effect of processing methods on proximate composition of *Amaranthus hybridus* (efo tete).

Processing Methods	Moisture Content (%)	Ash (%)	Protein (%)	Lipid (%)	Fiber (%)	Carbohydrate (%)
Control	83.40 ± 0.01^{b}	7.45 ± 0.03^{b}	3.03 ± 0.01^{c}	0.39 ± 0.01^{c}	2.09 ± 0.00^{d}	3.64 ± 0.03^{a}
Blanching	88.89 ± 0.00^{c}	1.87 ± 0.01^{a}	2.26 ± 0.01^{a}	0.27 ± 0.02^{b}	1.87 ± 0.11^{c}	4.84 ± 0.01^{b}
Boiling	89.88 ± 0.68^{c}	2.11 ± 0.01^{a}	2.62 ± 0.01^{b}	0.21 ± 0.00^{a}	1.40 ± 0.01^{b}	5.13 ± 0.03^{c}
Shade-drying	12.05 ± 0.03^{a}	7.40 ± 0.14^{c}	12.09 ± 0.00^{d}	0.25 ± 0.01^{b}	0.87 ± 0.01^{a}	66.74 ± 0.02^{d}

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 4 Effect of processing methods on the β-carotene and vitamin C of *Amaranthus hybridus.*

Samples	β-carotene (mg/100g)	Vitamin C (mg/100g)
Control	0.04 ± 0.00[a]	54.34 ± 0.95[a]
Boiling	0.03 ± 0.00[a]	8.25 ± 0.78[d]
Blanching	0.04 ± 0.00[a]	12.40 ± 1.40[c]
Shade drying	0.02 ± 0.00[b]	20.20 ± 0.69[b]

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 5 Effect of processing methods on proximate composition of *Basella alba (amunu tutu)*

Processing Method	Moisture Content (%)	Ash (%)	Protein (%)	Lipid (%)	Fiber (%)	Carbohydrate (%)
Control	86.46 ± 0.33[b]	0.70 ± 0.31[b]	1.35 ± 0.03[b]	0.49 ± 0.01[a]	7.52 ± 0.06[c]	3.48 ± 0.02[a]
Blanching	90.52 ± 0.62[c]	0.05 ± 0.01[a]	1.03 ± 0.02[a]	0.32 ± 0.02[b]	5.26 ± 0.50[b]	2.82 ± 0.16[a]
Boiling	93.03 ± 0.31[d]	0.06 ± 0.01[a]	0.83 ± 0.02[a]	0.23 ± 0.02[a]	2.36 ± 0.05[a]	3.49 ± 0.26[a]
Shade-drying	10.90 ± 0.91[a]	0.07 ± 0.01[a]	7.51 ± 0.26[c]	0.37 ± 0.02[b]	1.24 ± 0.03[a]	79.92 ± 0.76[b]

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 6 Effect of processing methods on the β-carotene and vitamin C content of *Basella alba* (amunu tutu)

Samples	β-carotene (mg/100g)	Vitamin C (mg/100g)
Control	0.02 ± 0.00[c]	95.01 ± 2.50[c]
Boiling	0.01 ± 0.00[b]	21.63 ± 1.00[a]
Blanching	0.01 ± 0.00[b]	24.83 ± 0.78[a]
Shade-drying	0.00 ± 0.00[a]	73.07 ± 1.48[b]

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 7 Effect of processing methods on the proximate composition of *Celosia argentea* (shoko)

Processing methods	Moisture Content (%)	Ash (%)	Protein (%)	Lipid (%)	Fiber (%)	Carbohydrate (%)
Control	84.14 ± 0.02[b]	2.52 ± 0.00[c]	3.49 ± 0.00[b]	0.89 ± 0.01[c]	1.74 ± 0.03[c]	7.22 ± 0.03[b]
Blanching	88.19 ± 0.75[c]	1.77±0.07[a]	1.78±0.09[a]	0.54±0.07[a]	1.45 ± 0.00[b]	6.27 ± 0.66[b]
Boiling	91.22 ± 0.58[d]	1.89 ± 0.07[ab]	2.97 ± 0.12[b]	0.42 ± 0.05[a]	1.30 ± 0.06[b]	2.20 ± 0.41[a]
Shade-drying	3.85 ± 0.10[a]	2.01 ± 0.82[b]	10.07 ± 0.36[c]	0.70 ± 0.29[b]	0.81 ± 0.04[a]	82.56 ± 0.43[c]

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 8 Effect of processing methods on the β-carotene and vitamin C content of *Celosia argentea* (shoko)

Samples	β-carotene (mg/100g)	Vitamin C (mg/100g)
Control	0.05 ± 0.00[a]	53.76 ± 1.75[a]
Boiling	0.04 ± 0.00[b]	28.70 ± 0.57[d]
Blanching	0.02 ± 0.00[c]	33.06 ± 0.73[c]
Shade-drying	0.01 ± 0.00[d]	43.35 ± 1.59[b]

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 9 Effect of processing methods on proximate composition of *Gnetum africanum* (okazi)

Processing methods	Moisture Content (%)	Ash (%)	Protein (%)	Lipid (%)	Fiber (%)	Carbohydrate (%)
Control	46.09 ± 0.37^{b}	8.77 ±0 .62^{c}	2.44 ± 0.10^{b}	2.02 ± 0.04^{c}	9.29 ± 0.61^{c}	31.38 ± 0.14^{a}
Blanching	49.55 ± 1.06^{c}	3.82 ± 0.30^{a}	1.34 ± 0.19^{a}	1.41 ± 0.05^{b}	7.08 ± 0.39^{b}	36.81 ± 1.53^{b}
Boiling	52.23 ± 0.27^{d}	7.18 ± 0.16^{b}	2.06 ± 0.21^{a}	0.67 ± 0.76^{a}	6.01 ± 0.35^{ab}	31.86 ± 0.90^{a}
Shade drying	1.87 ± 0.04^{a}	7.60 ± 0.56^{c}	13.05 ± 0.35^{c}	1.51 ± 0.09^{b}	5.20 ± 0.13^{a}	70.77 ± 1.11^{c}

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 10 Effect of processing methods on the β-carotene and vitamin C content of *Gnetum africanum.*

Samples	β-carotene (mg/100g)	Vitamin C (mg/100g)
Control	0.18 ± 0.14^{b}	51.55 ± 0.77^{d}
Boiling	0.02 ± 0.00^{a}	22.15 ± 1.59^{a}
Blanching	0.03 ± 0.00^{a}	28.51 ± 0.75^{b}
Shade drying	0.00 ± 0.00^{a}	36.23 ± 1.20^{c}

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 11 Effect of processing methods on proximate composition of *Talinum triangulare* (Waterleaf)

Processing methods	Moisture Content (%)	Ash (%)	Protein (%)	Lipid (%)	Fiber (%)	Carbohydrate (%)
Control	93.03 ± 0.55^{b}	0.67 ± 0.01^{d}	1.34 ± 0.03^{b}	0.59 ± 0.06^{b}	1.01 ± 0.03^{c}	3.35 ± 0.51^{b}
Blanching	94.78 ± 0.29^{c}	0.33 ± 0.02^{b}	0.62 ± 0.05^{a}	0.53 ± 0.04^{b}	0.92 ± 0.15^{a}	2.54 ± 0.23^{ab}
Boiling	95.59 ± 0.29^{c}	0.10 ± 0.02^{a}	1.05 ± 0.08^{c}	0.24 ± 0.03^{a}	0.74 ± 0.06^{b}	2.28 ± 0.27^{a}
Shade-drying	5.07 ± 0.03^{a}	0.51 ± 0.03^{c}	4.70 ± 0.09^{d}	0.46 ± 0.17^{c}	0.14 ± 0.03^{d}	89.12 ± 0.25^{c}

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

Table 12 Effect of processing methods on the β-carotene and vitamin C content of *Talinum triangulare.*

Samples	β-carotene (mg/100g)	Vitamin C (mg/100g)
Control	0.03 ± 0.00^{c}	47.89 ± 0.85^{d}
Boiling	0.00 ± 0.00^{a}	19.72 ± 0.66^{a}
Blanching	0.00 ± 0.00^{a}	27.83 ± 1.49^{b}
Shade-drying	0.02 ± 0.00^{b}	35.02 ± 0.75^{c}

Different superscripts along a column are significantly different (p≤0.05). Values are represented as mean± SEM of triplicate determination.

4. Discussion

The results in Table.1 revealed that all the fresh leaf samples contained an appreciable amount of nutrients (ash, protein, fiber, and carbohydrate). This result corresponds with Fadi *et al.,* (14) who reported the presence of moisture, ash, protein, fiber, and carbohydrate in *Amaranthus hybridus*, *Basella alba*, *Celosia argentea*, *Gnetum africanum* and *Talinum triangulare*. The results in Table.2 also showed that all the fresh leaf samples contained β-carotene and vitamin C. This result is consistent with Fadi *et al.,* (14) who also reported that β-carotene and vitamin C are present in *Amaranthus* *hybridus*, *Basella alba*, *Celosia argentea*, *Gnetum africanum,* and *Talinum triangulare*. Thus, they are good sources of nutrients, vitamins, and minerals.

The results presented in Table 3 are in agreement with Korotimi *et al.,* (10) who reported that boiling and blanching increased the moisture content of *Amanranthus hybridus*. This increase in moisture content may be attributed to the disruption of cell walls and membranes allowing water to fill spaces in the vegetables. The dried samples will thus favor longer shelf-life with the less microbial attack. Tsado *et al.,* (5) also reported a decrease in ash content of *Amanranthus hybridus*. Reduction in ash content may be a result of minerals leaching out of the leaves during processing. The protein contents obtained in this study are in agreement with Reid *et al.,* (15) who reported that dried leaf samples had higher protein content compared to other processed leaf samples. Reid *et al.,* (15) similarly stated decreased lipid content for processed *Amanranthus hybridus* leaf samples. The decrease in the lipid content might be due to the breakdown of lipid into glycerol and fatty acids. The decreased fiber content in this study is also in agreement with Tsado *et al.,* (5) who reported a similar decrease in fiber contents of processed *Amanranthus hybridus* leaf samples. He added that the decrement in the fiber content was due to the disruption of the cell wall of the vegetable. Also, the increased carbohydrate content of *Amanranthus hybridus* leaves as observed in this study is consistent with Diez & Alvarez, (16) who recorded higher carbohydrate content for dried leaf samples and attributed it to a decrease in moisture content, which led to the high concentration of the nutrients.

The result obtained in Table4 is consistent with James & Kuipers, (17) who reported that blanching and boiling brought about a decrease in the β-carotene content of *Amaranthus hybridus* leaves. Oboh, (18) also recorded reduced vitamin C content for *Amaranthus hybridus* leaves. He stated that reduction in vitamin C content can be attributed to the fact that it is water-soluble and at the same time not heat stable. It, therefore, means that the processing method affected the nutritional compositions of *Amaranthus hybridus*. Out of the processing techniques employed in this study, drying is the best processing method for retaining the nutrients in *Amaranthus hybridus* leaves. The result in Table.5 showed the moisture content of fresh leaf samples dried under the shade (10.90 ± 0.91) was significantly lowered ($p < 0.05$) while those of blanched leaf samples (90.52 ± 0.62) and boiled leaf samples (93.03 ± 0.31) were significantly increased. This means that blanching and boiling increased the moisture content of *Basella alba* leaves beyond that of the control leaf samples (86.46 ± 0.33) while the drying method drastically decreased it.

The results of the present study is also consistent with the reports of Korotimi *et al.* (10), Tsado *et al.* (5), Reid *et al.* (15), and Diez and Alvarez, (16) reported a similar decrease in the ash, lipid and fiber content of *Basella alba*. They also reported a similar increment in the carbohydrate and protein contents of leaf samples dried under the shade. They added that an increase in moisture content during processing may be attributed to the disruption of cell walls and membranes allowing water to fill spaces in the vegetables. The decrease in ash content may be a result of minerals leaching out of the leaves during processing. The decrease in the lipid content might be due to the breakdown of lipid into glycerol and fatty acids. The reduction in the fiber content was due to the disruption of the cell wall of the vegetable. The increase in carbohydrate content of *Basella alba* leaves could be attributed to a decrease in moisture content, which led to the high concentration of the nutrients.

Babajide *et al.,* (19) and Igwemmar *et al.,* (20) also reported that blanching and boiling brought about a decrease in the β-carotene and vitamin C content of *Basella alba.* The reduction in vitamin C content could be attributed to the fact that it is water-soluble and also heat-labile. It, therefore, means that the processing method affected the nutritional composition of *Basella alba* leaves. However, drying is the best processing method for retaining the nutrients. In addition, it reduces microbial attack, has a longer shelf life, and thus is a preservation method for these leaves.

The result in Table 4.8 corresponds with Bamidele *et al.* (21) who reported an increase in the moisture content of boiled and blanched *Celosia argentea* leaves. The moisture content increased due to the movement of water which filled spaces in the vegetables after the disruption of the cell wall by heat. The dried samples decreased in moisture content due to the loss of water from the cell wall of the vegetable. This will thus favor longer shelf-life with a less microbial attack. Tsado *et al.,* (5) also reported a decrease in the ash content of *Celosia argentea* leaves. The reduction in ash content may be a result of minerals leaching out of the leaves during processing. The protein contents obtained in this study are in agreement with Okewole *et al.,* (22) who reported that dried leaf samples had higher protein content compared to other processed leaf samples. Srivastav *et al.,* (23) also stated a decrease in the lipid content for processed *Celosia argentea* leaf samples. The decrease in the lipid content might be due to the breakdown of lipid into glycerol and fatty acids. The decreased fiber content in this study corresponds with Tsado *et al.* (5) who reported a similar decrease in the fiber contents of processed *Celosia argentea* leaf samples. He also added that decrement in the fiber content was due to the disruption of the cell wall of the vegetable. The increase in carbohydrate content of *Celosia argentea* leaves as observed in this study is in agreement with Verma & Demla (24) who recorded higher carbohydrate content for dried leaf samples and attributed it to a decrease in moisture content, which led to the high concentration of the nutrients.

The result in Table 8 corresponds with Babajide *et al.,* (19) who reported that processing methods decreased the β-carotene and vitamin C contents of*Celosia argentea* leaves. They reported that reduction in vitamin C content can be attributed to the fact that it is water-soluble and at the same time not stable to heat. This implies that the processing method affected the nutritional compositions of *Celosia argentea* leaves. However, out of all the processing techniques employed, the drying method is the best processing method for retaining the nutrients. Drying reduces microbial attack, has a longer shelf life, and thus is a preservation method for *Celosia argentea* leaf. The result in Table 9 showed that the moisture content of boiled leaf samples (52.23 ± 0.27) was significantly higher ($p < 0.05$) than that of the blanched (49.55 ± 1.06), control leaf samples (46.09 ± 0.37), and fresh leaf samples dried under the shade (1.87 ± 0.04). However, fresh leaf samples dried under the shade (1.87 ± 0.04) had the lowest moisture content for *Gnetum africanum* leaves.

The result in Table 10 showed that the β-carotene and vitamin C contents of the control (0.18 ± 0.14 and 51.55 ± 0.77 respectively) are significantly higher ($p < 0.05$) than that of the blanched (0.03 ± 0.00 and 28.51 ± 1.59 respectively), boiled (0.02 ± 0.00 and 22.15 ± 0.75 respectively) and fresh leaf samples dried under the shade (0.00 ± 0.00 and 36.23 ± 1.20 respectively). The results obtained are in agreement with Fadi *et al.,* (14), Udeh *et al.,* (25), Igwemmar *et al.,* (20), and Reid *et al.,* (15), who reported a similar decrease in the ash, lipid, and fiber content of *Gnetum afircanum* leaves. They also reported a similar increment in the carbohydrate and protein contents of leaf samples dried under the shade. They stated that the decrease in the moisture content of fresh leaf samples dried under the shade was due to evaporation. They added that the decrease in the ash content of blanched and boiled leaf samples may be attributed to the flow of minerals from the leaves into the processing water. The decrement in the lipid content during processing might be due to the breakdown of lipid into glycerol and fatty acids. The decrease in the fiber content was due to the disruption of the cell wall of the vegetable. They also stated that the increase in carbohydrate content of *Gnetum africanum* leaves could be attributed to the fact that as moisture content decreased there was an accumulation of carbohydrate content in the leaves.

James & Kuipers*,* (17) also reported that blanching and boiling decreased the β-carotene and vitamin C contents of *Gnetum afircanum* leaves. They reported that the reduction in vitamin C content could be attributed to the fact that it is water-soluble and also cannot withstand high temperatures. It, therefore, implies that the processing methods altered the nutritional compositions of *Gnetum africanum.* However, out of all the processing methods employed in this study, drying retained more nutrients in *Gnetum africanum* leaves than others. It is also the best preservation method.

The result in Table 12 also showed that the β-carotene and vitamin C contents of the control (0.03 ± 0.00 and 47.89 ± 0.85 respectively) are significantly higher ($p < 0.05$) than that of the blanched (0.00 ± 0.00 and 27.83 ± 1.49 respectively) leaf samples and fresh leaf samples dried under the shade (0.02 ± 0.00 and 35.02 ± 0.75 respectively). However, the boiled leaf samples had the lowest β-carotene and vitamin C content (0.00 ± 0.00 and 19.72 ± 0.66 respectively) as seen in Table 12. No β-carotene content was recorded for boiled and blanched leaf samples. The result in Table 11 is in agreement with Ikewuchi*et al.,* (26), Idris *et al.,* (27), and Joshua *et al.,* (28) who reported a decline in the ash, lipid, and fiber contents of *Talinum triangulare*. They also reported a similar increase in the carbohydrate and protein contents of leaf samples dried under the shade. They stated that the decrease in the moisture content of fresh leaf samples dried under the shade may be due to the evaporation of water molecules from the leaves. This will favor longer shelf-life due to reduced microbial attack. The reduction in ash content can be attributed to minerals leaching out of the leaves during processing. The reduction in the fiber content may be attributed to the disruption of the cell wall of the vegetable. An increase in carbohydrate content of *Talinum triangulare* leaves could be due to a decrease in moisture content, which resulted in a high concentration of the nutrients. Gunathilake *et al,* (29) also reported that blanching and boiling brought about a reduction in the β-carotene content and vitamin C content of *Talinum triangulare* leaves. The reduction in vitamin C content may be due to the fact that it is water-soluble. It, therefore, means that the processing method affected the nutritional compositions of *Talinum triangulare* leaves. However, drying is the best processing method for retaining the nutrients. In addition, it reduces microbial attack, has a longer shelf life, and thus the best preservation method for this leaf.

5. Conclusion

Amaranthus hybridus, *Basella alba*, *Celosia argentea*, *Gnetum africanum* and *Talinum triangulare* vegetables are rich in vital nutrients such as protein, vitamin C, β-carotene, carbohydrate, and dietary fiber required for human health and well-being. From the three processing methods studied, drying was found to be the most effective processing method that retains nutrients and is therefore a good preservation method for the vegetables.

Compliance with ethical standards

Acknowledgments

We would like to appreciate the entire staff of Biochemistry Department, Federal University of Technology Minna, for their kind assistance.

Disclosure of conflict of interest

All author declared no conflict of interest is exist.

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