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Effect of Two Different Drying Techniques on the Chemical Composition of *Amaranthus*

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Abstract

Amaranth (*Amaranthus*), a widely consumed green leafy vegetable in Nigeria, is valued for its rich content of micronutrients, macronutrients, phytonutrients, and potential food-toxicants. This study evaluates the impact of two common drying methods—sun-drying and oven-drying—on the chemical composition of *Amaranthus* leaves. A total of 2.5 kg of fresh *Amaranthus* leaves was procured from Watt Market in Calabar, Cross River State, Nigeria. After stalk removal, the leaves were divided into three equal portions: one left untreated as control, while the others were subjected to sun-drying and oven-drying for one month. The dried samples were pulverized, packaged in airtight containers, and stored under cool, dry conditions prior to analysis. Proximate composition, mineral content, and phytochemical screening were conducted using standard analytical techniques. Results indicated a significant reduction in moisture content from $84.30 \pm 0.1\%$ in the fresh sample to $23.70 \pm 0.1\%$ (sun-dried) and $11.30 \pm 0.1\%$ (oven-dried), thereby increasing dry matter availability.

Concentrations of ash, fibre, crude fat, crude protein, and carbohydrates were elevated in the dried samples due to moisture loss. However, notable reductions in mineral content were observed—Calcium (Ca) declined from 2.78 mg/100g in the control to 2.10 mg/100g (sun-dried) and 1.07 mg/100g (oven-dried). Heat treatment also led to a significant decrease in anti-nutrients and food-toxicants, with oven-drying showing greater efficacy. The study concludes that both sun-drying and oven-drying effectively preserve *Amaranthus* leaves, though with some loss of micronutrients. Consuming larger quantities of the dried vegetable may help offset these losses, providing essential nutrients for populations at risk of malnutrition.

Keywords: Green Leafy Vegetables; *Amaranthus*; Sun-Drying; Oven-Drying; Chemical Composition; Anti-Nutrients; Nutrient Retention

INTRODUCTION

Amaranth is a one of the edible green-leafy-vegetables. It is scientifically known as *Amaranthus*, and consist of two types, and about 70 species (Swamy, 2023). Among the 70 species are about 17 edible varieties that grow easily in many parts of the world. *Amaranthus* species were known to be native to tropical America, but now they are extensively grown in other parts of the world. Areas such as; Asia, Africa, and the Americas, have extensively grown different species of Amaranths because of their high nutritional value and ethno-pharmacological value potential. Amaranths are mainly grouped into two types based on their popular usage; leafy-Amaranths and grain-Amaranths (Andini *et al*., 2021, Swamy, 2023, and Torres *et al*., 2024).

Common Amaranths species are; *Amaranthus hybridus, Amaranthus cruentus, Amaranthus dubius, Amaranthus tricolor, Amaranthus caudatus, Amaranthus spinosus, Amaranthus viridis, Amaranthus edulis, Amaranthus lividus*, *Amaranthus retroflexus, Amaranthus deflexus, Amaranthus graecizans, Amaranthus watsonii, Amaranthus greggii, Amaranthus cannapinus, Amaranthus thunbergii, Amaranthus tuberculatus, Amaranthus floridanus*, *Amaranthus gracilis Desf.*, *Amaranthus palmeri, Amaranthus australis, Amaranthus arenicola, Amaranthus acanthochiton, Amaranthus pakai, Amaranthus blitum, Amaranthus hypochondriacus,* among others (Rachael, 2018, Velarde-Salcedo *et al*., 2019, Sharma *et al*., 2012, Andini *et al*., 2021, Grubben and Denton, 2022, Sarkar *et al*., 2022, Swamy, 2023, Jan *et al*., 2023, and Oguyi *et al*., 2024).

Swamy (2023), Andini *et al.* (2021), and Rachael (2018), reported that some species are cultivated for both their leaves and grains for food. Example of such include; *Amaranthus cruentus* and *Amaranthus caudatus*. The notably distinct Amaranth, the *Amaranthus tricolor* is known to be rich with appreciable quantity of bioactive compounds such as; antimicrobial, antimalarial, antioxidant, anti-carcinogenic, and anti-inflammatory properties. In Nigeria, the commonly grown species are popularly called *African spinach or green*, or *Efo tete* or *Shoko* by the Yorubas, *Aleho or Alaffu* by Hausas. They contain several nutrients such as; fibre, vitamins (vitamin A, vitamin C, Vitamin B6, niacin, folate), and minerals (iron, calcium, manganese, zinc, magnesium, and potassium), thiamine, riboflavin, lutein, plus carotenoids like beta-carotene, among others (Andini *et al.*, 2013, Alegbejo *et al.*, 2013, Mujaffar and Loy, 2016, Nighitha and Mathew, 2019, Andini *et al.*, 2021).

It is widely known that amaranths (*Amaranthus spp*) could be used as salad vegetables and other vegetable recipe preparations for soups, sauces, stews or porridges/pottages (Mujaffar and Loy, 2016, Sharma *et al.*, 2012). They are good alternatives to spinach and are now also used internationally as a-less-expensive option to the vegetable kale. Several researchers have over the years supported the report that Amaranth leaves have considerable high amount of; vitamins A and C, calcium, iron, fibre, as well as a very high amount of high-quality protein (Borneo and Aguirre, 2008, Rodriguez *et al.*, 2011, Alegbejo, 2013; Andini *et al.*, 2013, Gelaye, 2023).

Amaranths, just like many other commonly consumed vegetables in Nigeria, experiences postharvest losses. Its postharvest losses are a little bit higher than many other vegetables eaten in Nigeria. This is because the postharvest life of amaranth greens is often relatively short due to rapid wilting of the tender foliage compared to many other commonly consumed vegetables (Mujaffar and Loy, 2016). Therefore, there was need to preserve these vegetables from extensive spoilage. The first method ever used in its preservation was sun-drying. Drying of vegetables as a form of food preservation and/or processing happened accidentally.

Farmers in the olden days noticed that vegetables that were kept outside for several hours (for possible disposal), because they had just started wilting, stopped wilting, as they got dried. Due to this discovery, sun-drying as well as other forms/types of drying are now used extensively in food processing and preservation. Drying has also been known to add additional desirable taste to some dried vegetables. Example, many Igbos in Nigeria, prefer the taste of dried bitter leaves (*Vernonia amygdalina*) to its fresh leaves. Mepha *et al.* (2007), acknowledged the fact that leafy vegetables require special processing treatments because of their highly perishable nature, to prevent high post-harvest losses.

Udoh *et al.*, (2025), Udofia and Obizoba (2005), and AOAC (2000), noted that leafy vegetables are necessary for a balanced diet in many Nigerian homes. This is probably because they contribute extensively to the overall supply of vitamins, minerals, protein, and even fibre in many rural dwellers' homes. They also stated that it was probably because many rural dwellers do not have the financial ability to purchase and consume other food products that provide the food nutrients. Some green leafy vegetables could be consumed raw (fresh) but are usually mostly cooked before consuming. Some cooked vegetables, like Amaranth are also consumed with other major staples like rice, maize, millet, cassava, amongst others. Amaranth vegetable is also known to add variety to food menu. Varalkshmi (2015), added that Amaranths are cultivated through the year in the tropics.

Although Oguche (2011), had documented that farmers do not find green leafy vegetables production to be of advantage compared to other agricultural products. It has been confirmed through research that the production, practices, processing and marketing of vegetables, especially the commonly consumed ones such as *Telfairia occidentalis*, *Vernonia amygdalina* and *Amaranthus leaves*, could have more appeal to all. The farmers and consumers of these vegetables if enlightened on the several benefits of these vegetables, as well as the easy but less expensive methods of preserving them (sun-drying and oven-drying methods), will be highly motivated to cultivate and consume more quantities.

Kiremire *et al.* (2010) and Udoh *et al.*, (2025) added that although traditional food processing or preservation methods (sun drying, oven-drying) reduces food nutrients, it is still recommended. This is because it can still furnish one with the necessary food nutrients if the dried vegetables are consumed in many quantities, as well as reduce antinutrients and food toxicants. Similarly, Aletor and Abiodun (2013) reported nutrient loss after drying of Amaranth vegetable. Hence, there is crucial need for regular enlightenment program for farmers and consumers if mal-nutrition is meant to be tackled the way it ought to be, especially in rural communities that at risk of mal-nutrition.

MATERIALS AND METHODS

Several materials and methods were employed depending on the different analyses' requirements. The several steps carried out, and analyses done were:

Collection and identification of the plant materials

Only disease-free plant material of *Amaranthus* leaves were purchased from Watt-Market in Calabar, Cross River State, Nigeria.

Study area/design

This research study analyses were done in the Biochemistry Department, University of Calabar, Calabar, Cross-River, Nigeria. This was done to determine the effect of two different, but commonly used drying methods on the chemical composition of *Amaranthus* leaves.

Preparation/Cleaning of plant materials

Amaranthus leaves were washed, after being stalks-picked to rid it of dirt and sand. The leaves were afterwards shared into three portions. Two portions got treated (sun-dried and oven- dried) for one month. The remaining portion of the leaves was not treated, and it serves as control (fresh sample). The samples that were dried were pulverized using electric blender to a fine powder. The pulverized samples got packaged in different airtight-containers and kept in a cool dry place until it was time for its analyses.

Laboratory analysis of dried samples

The dried *Amaranthus* leaves were analysed using three different laboratory-analyses; proximate composition, elemental composition and phytochemical composition screening which were subjected to different standard-analytical-methods.

Proximate composition analysis

Proximate composition of the sun-dried and oven-dried samples were done using standard methods documented by the Association of the Official Analytical Chemists (AOAC).

Brief Breakdown of analyses carried out:

i. ***Moisture content determination*** (AOAC, 2000)

The two grams of each pulverised dried samples of *Amaranthus* leaves were put into different dried measured moisture dish. It was afterwards placed in an air oven at 70^{0}C, to further dry it to a constant weight. Weight loss after cooling in the desiccator for about 65 minutes was equated as moisture content.

ii. ***Ash determination*** (AOAC, 2000)

Two grams of each of *Amaranthus* leaves samples that were pulverised were weighed correctly and were put inside a porcelain-crucible whose weight was known. The porcelain-crucible were covered with its contents, and they were ignited for 24-hours at 525^{0}C. The estimation of the ash content were done by weighing the ash in the crucible. Ash estimation was done thrice for each sample.

Calculation

Ash (% dry weight) = Weight of ash in grams × 100

Weight of sample

iii. ***Crude-Protein content estimation using total Nitrogen (Macro Kjeldahl method)*** (AOAC, 2000)

A gram of each pulverised dried samples was put into different digestion-flasks in triplicate. A 96% anhydrous sodium sulphate along with 3.5% copper sulphate catalyst mixture were introduced into the samples. The samples got digested afterwards using concentrated sulphuric acid. The digestion flasks got cooled, and their sides were rinsed with de-ionized water. Digestion was continued for an extra one hour. The digestions obtained were transferred into a distillation apparatus. An approximate value of 10ml de-ionized water and 15ml of 45% sodium hydroxide was what were used for the distillation. Ammonia released were made to steam-distilled into a 10ml of 5% boric acid solution, which contained 4 drops of methyl-red-methylene-blue indicator. Distillation was continued until a volume of 20ml in the receiving flask was reached. Ammonium borate complex that was produced was diluted to 50ml. This was titrated with 0.02N HCl until a pink end point was reached. In a similar manner, a blank distillation determination was done, just that there was sample omission in the digestion flask.

The percentage (D/W) of nitrogen found in the sample was calculated as stated below:

$$\frac{\text{ml of HCl (sample)} - \text{ml of HCl (blank)} \times 14 \times 100}{\text{Wt. of sample in gm} \times 1000}$$

1g = 1000mg (was used to offset the titre values that are in millilitres)

The crude-protein was estimated by multiplying the percentage nitrogen by the factor of 6.25.

Crude-Protein = Percentage of nitrogen × 6.25

iv. ***Crude-Fat content (Petroleum ether extract)*** (AOAC, 2000)

Accurately weighed five grams of each pulverised samples were treated in a continuous Soxhlet extractor with petroleum ether extraction. The fat content was obtained after the defatting period, through ether evaporation, leaving behind the lipid extract, which was determined by weight. The determination was done in triplicate.

Calculation

$$\text{Petroleum ether extract (\% dry weight)} = \frac{\text{Weight of extract (g)}}{\text{Weight of dry sample}} \times 100$$

v. ***Crude-Fibre content***

The fat-free material weighing 3.50g obtained for each pulverised dried samples for crude-fibre determination, were involved in 1.25% sulphuric acid with 1.25% sodium hydroxide extraction digestion following its standard procedure. The residue obtained after digestion were dried at a temperature of 105^{0}C, and the weight noted. Incineration at 550^{0}C followed to convert it to ash.

The weight loss was considered as the crude-fibre content. This analysis was done in triplicate.

$$\text{\% Crude-fibre content} = \frac{\text{Weight of ash in crucible after ignition}}{\text{Weight of sample}} \times 100$$

vii. ***Carbohydrate content***

Each pulverised samples Carbohydrate content was obtained by the addition of the obtained values for moisture content, crude-protein, crude-fat, total ash and crude-fibre, then the result subtracted from 100g.

2. ***Estimation of Mineral Elements***

i. Estimation of Calcium (AOAC, 2000)

Calcium was reacted to an acidic state. This was done by digesting 2.0g of each pulverised dried sample in a 25ml concentrated sulphuric acid with 5ml per-chloric acid mixture. The dilutions for each of the pulverised samples was done as aliquots. They were subjected afterwards to flame photometry. For each sample, the calcium content was measured at 626nm on the photometry. A prepared calibration curve of standard solutions of calcium carbonate was used to obtain calcium concentration.

ii. ***Estimation of Phosphorus (Molybdovanadate Method)*** (AOAC, 2000)

Phosphorus estimation was carried out with a portion from the calcium determination acidic digest. Suitable aliquots were taken and was reacted with molybdovanadate reagent to obtain a phosphor-molybdovanadate with a pink-colour complex. Colour developed was quantified with the aid of a colorimeter at 400nm. A standard curve that was prepared with potassium hydrogen phosphate (KH_2PO_4) was used to phosphorus concentration.

3. ***Estimation of Antinutrients***

i. ***Estimation of Phytates*** (Finglas *et al.*, 2014)

About 5g of each dried sample was extracted to obtain phytic acid using 0.5N hydrochloric acid. The extracted phytic acid for each were precipitated to obtain ferric phytate using ferric chloride. Sodium hydroxide was used to further react ferric phytate to convert it to sodium phytate. The phosphorus content of each sample got quantified colorimetrically after the addition of molybdate colour development solution at 620nm.

ii. ***Estimation of Hydrogen Cyanide content*** (AOAC, 2000)

Eight grams of Cyanide content of each sample got released after soaking it in water for about 4 hours. The liberated cyanide present in the water were extracted through a steam distillation directed into a 20ml 2.5% NaOH, with 8ml 6N ammonium hydroxide alongside 2ml 5% potassium iodine was added. They were titrated with 0.02N silver nitrate to give a faint, yet permanent turbidity.

(1.0ml of 0.02N $AgNO_3$ = 1.08mg HCN)

iii. ***Estimation of Total Oxalates*** (Dye, 1956)

In a 200ml distilled water and 6N hydrogen chloride at 37^0C were five grams of each sample digested separately. Calcium chloride as calcium oxalate was used to precipitate the oxalate. The obtained oxalate was then washed with 25% sulphuric acid and dissolved in 100ml water. It was afterwards titrated against 0.05N potassium permanganate to a purple end point that remained for about 15 seconds.

1.0ml $KMnO_4$ = 2.20mg oxalate

iv. ***Estimation of Soluble Oxalates*** (Dye, 1956)

In a 200ml distilled water and 6N hydrogen chloride, 5g of each sample was digested at 90^0C for approximately 4 hours. The digest was further analysed using the same procedure explained in total oxalate.

1.00ml $KMnO_4$ = 2.20mg oxalate

Data/Statistical analysis

All the obtained data in this study, were expressed as the mean ± standard error of the three (3) replicates done. The data were also analysed using analysis of variance (ANOVA). The associations between variables were considered statistically significant at p-values less than, or equal to 0.05, $p \leq 0.05$.

RESULTS

The results that were obtained from the proximate composition, elemental composition and phytochemical screening analyses of the fresh, sun-dried and oven-dried samples of *Amaranthus* leaves are shown in Tables 1 to 5. Proximate composition analyses of fresh, sun-dried and oven-dried *Amaranthus* leaves samples analysed are placed in Table 1. This study showed drastic reduction of moisture in the dried samples, thereby increasing their dry matter. Ash content was observed to be very high in the dried leaves analysed compared to the control. In this study, the ash content obtained was from 2.40 ± 0.01 to 12.50 ± 0.02, with the oven-dried sample having the highest value. Protein content increased for sun dried leaves (4.67 ± 0.02) but decreased for oven-dried heat treatment from 4.42 ± 0.02 (control) to 3.63 ± 0.2. On the other hand, lipid content increased significantly in all dried samples analysed, and fibre content also had significantly higher value from 0.98 ± 0.01 to 1.61 ± 0.01. Whereas for carbohydrates, there was an exponential increase from 7.58 ± 0.02 to 68.84 ± 0.02.

The elemental composition of *Amaranthus* leaves' fresh, sun-dried and oven-dried samples are presented in Table 2. Great loss in the treated samples were observed compared to the control. This points to the fact that drying vegetables do not increase availability of minerals like some food nutrients discussed earlier. Table 3 shows the percentage loss in elemental composition of *Amaranthus*. About 40 to 70% mineral contents loss was observed, mostly in oven-dried samples. Phytochemical screening of the fresh, sun-dried and oven-dried *Amaranthus* leaves samples are shown in Table 4. Anti-nutrients and food toxicants present in *Amaranthus* leaves were reduced upon application of heat, especially in most of the oven dried samples. Hence, application of intense heat (oven drying) to *Amaranthus* removed a great percentage of available anti-nutrients and food toxicants than mild heat treatment, like sun drying.

In the phytochemicals quantitative analysis of *Amaranthus* leaves (Table 5), it was observed that phytic acid was higher than the other phytochemicals present. Phytic acid value obtained was 1.80 ± 0.02 for control, 1.63 ± 0.02 for sun dried samples and 1.60 ± 0.02 for oven dried samples. Whereas the least phytochemical present in the analysed *Amaranthus* leaves was hydrocyanic acid with values from 0.13 ± 0.02 to 0.09 ± 0.01 (control to oven dried samples).

Table 1: Proximate Composition of Fresh, Sun dried and Oven dried *Amaranthus* leaves (%)

S/N	Name of sample	Moisture	Ash	Crude Protein	Crude Fat	Fibre	Carbohydrates
1	Fresh *Amaranthus* leaves	84.30 ± 0.1	2.40 ±0.01	4.42 ±0.02	0.20 ± 0.2	1.10 ± 0.1	7.58 ± 0.02
2	Sun dried *Amaranthus* leaves	23.70 ± 0.1	12.81 ±0.01	4.67 ± 0.2	0.33 ±0.02	2.51 ±0.02	55.98 ±0.02
3	Oven dried *Amaranthus* leaves	11.30 ± 0.1	12.50 ±0.02	3.63 ± 0.2	0.63 ± 0.1	3.10 ±0.01	68.84 ±0.02

Each value represents mean of 3 determinants ± SD

Table 2: Elemental Composition of Fresh, Sun dried and Oven dried *Amaranthus* leaves (mg/100g Dry matter)

S/N	Name of sample	Na	P	K	Ca	Mg	Fe	Cu	Zn
1	Fresh *Amaranthus* leaves	6.40	2.10	5.10	2.78	2.70	0.12	0.11	0.04
2	Sun dried *Amaranthus* leaves	5.90	0.64	4.29	2.10	1.45	0.05	0.04	0.02
3	Oven dried *Amaranthus* leaves	3.41	0.06	2.98	1.07	0.65	0.01	0.02	0.01

Table 3: Percentage Loss in Elemental Composition of Processed Sample (Sun dried and Oven dried) *Amaranthus* leaves (%)

S/N	Name of sample	Na	P	K	Ca	Mg	Fe	Cu	Zn
1	Sun dried *Amaranthus* leaves	7.81	69.52	15.88	15.88	46.30	58.33	63.64	50.00
2	Oven dried *Amaranthus* leaves	46.72	97.14	41.57	61.51	75.93	91.67	81.82	75.00

Table 4: Results of Phytochemical Screening of Fresh, Sun dried and Oven dried *Amaranthus* leaves

S/N	Chemical constituents	Fresh *Amaranthus* Leaves		Sun dried *Amaranthus* leaves		Oven dried *Amaranthus* Leaves	
		Ethanol extract	Aqueous extract	Ethanol extract	Aqueous extract	Ethanol extract	Aqueous extract
1	Alkaloids	+	+	-	-	-	-
2	Cyanogenic Glycosides (Hydrocyanic acid)	++	+	++	+	+	+
3	Saponins	-	++	++	+	-	+
4	Tannins	+	-	-	-	-	-
5	Flavonoids	+	-	-	-	-	-
6	Oxalates	+	+	+	++	+	+
7	Phytic acid	+++	++	++	+	+	+
8	Phlobatanins	-	-	-	-	-	-
9	Anthroquinons	-	-	-	-	-	-
10	Hydroxymethyl anthraquinons	-	-	-	-	-	-

Key

Presence	+
Presence in excess	++
Presence in much excess	+++
Absent	-

Table 5: Results of Quantitative Analysis of Prominent Phytochemicals in Fresh, Sun dried and Oven dried *Amaranthus* leaves

Sample	Phytic acid (mg/g)	Hydrocyanic acid (mg/g)	Saponins (mg/g)	Total Oxalates (mg/g)	Soluble Oxalates (mg/g)
Fresh *Amaranthus* leaves	1.80±0.02	0.13±0.02	1.79±0.01	1.70±0.01	0.41±0.02
Sun dried *Amaranthus* leaves	1.63±0.01	0.11±0.02	1.66±0.02	1.65±0.02	0.37±0.01
Oven dried *Amaranthus* leaves	1.60±0.02	0.09±0.01	1.62±0.02	1.60±0.01	0.33±0.01

DISCUSSION

Amaranths are vegetables that consist of about 70 species that are scientifically known as *Amaranthus*. Amaranths just like other vegetables need to be consumed regularly, as they are good sources of micronutrients when consumed regularly in much quantity. Amaranth vegetable is a highly perishable food product. Therefore, for Amaranths (like other vegetables) to be available all year round, it entails special processing treatment to preserve them, in order to avoid great post-harvest loses. Drying is one of the simplest and affordable means of preserving it. Drying, just like other vegetable processing methods has some effects on the chemical composition of vegetables being processed (Udoh *et al*., 2025). Moisture for all dried samples in this study reduced drastically, whereas values for crude-protein (except for its oven-dried sample), ash, crude-fat, fibre and carbohydrates of the dried vegetables were much higher than that of their control as observed in this study (Table 1).

Oguche (2011) and Udoh *et al*., (2025) documented that vegetables that are dried, experienced great moisture loss, varying nutrient loss, as well as reduced phytochemicals (antinutrients/food toxicants) compared to its fresh untreated vegetables. He further added that flavonoids and tannin amount in vegetables that are dried are lower in value than the fresh vegetables. Morris and Burrows (2004), on the other hand confirmed that drying increases dry matter. They also reported that increased dry matter help in increasing the availability of nutrients, and aid in better digestion. Whereas Gallali *et al*., (2000) is of the opinion that ash content gives insight on total mineral-element and can also be used to estimate the level of sand contamination from the environment of the analysed item.

The elemental composition values in this study are lower in dried vegetables than fresh vegetables (Table 2). This observation confirms the report made by Chweya and Eyzaguirre (1999). Also, this study findings gives insight to the fact that vegetables need to be consumed in very large amounts for one to have enough micronutrients that are embedded in them. This is because vegetable processing by heat treatment leads to great micronutrient loss, and most edible vegetables are mostly either cooked or fried before consumption. Nahapetian and Bassir (1975), had stated that potassium that are in its ion form (K^+) are the most important cation of a living cell. Another important mineral in a living cell is calcium. According to Ladan *et al.* (1996), potassium and calcium are essential for teeth, bone, and muscles development, as well as the metabolism of Vitamin D. Zinc is another mineral that experienced great loss (Table 2), whereas zinc in sufficient amount is vital for good immune system (Bhaskaram, 2002).

Other researchers such as Chausmer (1998), stated that zinc is needed for the secretion of insulin, while Hwang *et al.* (2002), added that its secretion aid in vitamin A release from the liver, and Boron *et al.* (1988) observed that it acts as an enzyme. The percentage loss of minerals (Table 3) showed that the average loss of minerals in dried vegetables is about 40 to 70%. Tables 4 and 5, presents the observed antinutrients and food toxicants present in Amaranth vegetable. It further shows the reduction of the available antinutrients and food toxicants upon heat treatment of the *Amaranthus* leaves. This aspect of heat treatment is a good one, as antinutrients and food toxicants are inhibitors of some nutrients, thereby hindering good health. The effect of antinutrients and food toxicants could be obvious if they are present in the leaves in very large quantities, and the leaves are regularly consumed in much quantity, especially raw.

Hence, preserving vegetables by heat application (drying of vegetables) is inevitable, even when it reduces the minerals and vitamins values of processed vegetables. This is because drying vegetables also help in the reduction of food toxicants and anti-nutrients in the processed vegetables (Udoh *et al.*, 2025). It also makes macronutrients present in vegetables more available. Therefore, for all year-round supply of macronutrients, especially among young children in communities at risk of malnutrition, drying of vegetables such as Amaranth is advised.

CONCLUSION

This research findings, especially the results of statistical analysis recorded great nutrient loss due to drying. This imply that for vegetable to be fully utilised for the provision of micronutrients, they must be consumed regularly in much quantity. Farmers and consumers are advised to cultivate more vegetables during the period that they grow well (during light rains), and preserve the excess vegetables during the time that they are abundant. This will ensure that there is constant supply of vegetables, especially in homes that vegetables are the main or only source of macronutrients or micronutrients in their diet.

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Authors' Roles/Participation in the Authorship of the Manuscript:

i. **Mary Athanasius Udoh (Corresponding Author):** substantial contributions to the conception and design of the work, acquisition of data, analysis and interpretation of data, drafting the work, final approval of the version to be published.

ii. **Musbau Adekunle Yahaya**: acquisition of data, analysis and interpretation of data, final approval of the version to be published.

iii. **Abimbola Gbenga Olayemi**: acquisition of data, analysis and interpretation of data, final approval of the version to be published.

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