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Effect of Different Drying Methods on the Mineral Composition of Three Indigenous Leafy Vegetables

Asante J.M. [a*], Amaglo N. [b] and Tandoh P.K [b]

[a] Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Ghana.
[b] Department of Horticulture, Kwame Nkrumah University of Science and Technology, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Leafy vegetables are known to contain high amounts of nutrients and phytochemicals which support growth and development in humans after consumption. Due to their high moisture content at stage of maturity, the rate of perishability is high. The objective of this study was to determine the effect of three drying techniques on the nutritional quality of three indigenous leafy vegetables. The experimental design was a 3x3 factorial arranged in Completely Randomized Design (CRD). The factors were; leafy vegetables at three levels (*Amaranthus cruentus, Celosia argentea* and *Laportea aestuans)* and drying methods at three levels (Solar, Oven and Freeze drying). Our results showed that *A. cruentus* significantly ($p < 0.05$) had the highest phosphorus (0.79 %), potassium (2.22 %) and magnesium (1.15 %) and *C. argentea* recorded the least concentrations (0.40, 1.26 and 0.61 %) respectively. The concentration of calcium was in ascending order of *A. cruentus* < *C. argentea* < *L. aestuans* with 2.04 < 2.28 < 3.03 % respectively. Iron and zinc contents were higher in *C. argentea* than *A. cruentus* and *L. aestuans*. Moreover, calcium content in freeze dried vegetables with exception of *C. argentea* increased as compared to Solar and Oven drying. Also, the

**Corresponding author: E-mail: josephinemends1@gmail.com;*

concentration of phosphorus was in ascending order of *C. argentea* < *L. aestuans* < *A. cruentus* with 0.44 < 0.60 < 1.04 % respectively for freeze drying. It can therefore be concluded that the three indigenous leafy vegetables are good sources of nutrients and these three drying techniques are for the preservation of their nutrients as well as preventing postharvest losses.

Keywords: Antioxidants; nutrients; free radicals; moisture content; phytochemicals.

1. INTRODUCTION

Vegetables are herbaceous plant parts that are consumed by both humans and other animals as result of their high nutritional and health benefits [1]. In recent times, vegetable consumption is rising gradually and this could be due to the fact that many people are now exposed to different cultures and are also acquiring proper education on the importance of vegetables [2]. Globally, there are about two hundred countries that are involved in vegetable production with 402 vegetables types comprising of 230 genera and 69 families [3,4,5]. These vegetables are normally grouped according to the parts consumed. For instance, the vegetables may be leafy, seed, root, fruit and stem [6]. Africa leafy vegetables are well known for their nutritive, economic, medicinal benefits and food security worldwide [7,8,9].

It is also worth noting that these indigenous leafy vegetables (*Amaranthus cruentus*, *Celosia argentea* and *Laportea aestuans*) also contribute to the reduction of malnutrition, and also provide significant number of antioxidants that are linked to the protection of the human body against cardiovascular and other degenerative diseases [10,11,12]. Though these African leafy vegetables are essential in many areas, high temperature in Africa caused about 30-50 % postharvest losses due to their higher moisture content and as a result, several of these African leafy vegetables are subjected to postharvest treatment techniques such as Sun drying, blanching etc. but these processing techniques may cause losses in some of the nutritional properties contain in these indigenous leafy vegetables, for instance *Amaranthus hybridis*, *Pterocarpus soyauxii, Corchorus olitorious* etc. had a significant reduction in mineral content as a result of processing techniques and the period of storage [13,14,15]. Additionally, drying also slows down the action of enzymes, but does not inactivate them because drying removes moisture, the food becomes smaller and lighter in weight. Moreover, freeze drying has been reported to be effective in reducing moisture contents and thereby extending the storage life of fruit products like banana, apples, even though little is known with usage with leafy vegetables. The consumption of these leafy vegetables, which have the highest nutritional value, will especially add to the nutritional status of poor rural and urban households in Ghana.

In Ghana these leafy vegetables are also cultivated and consumed. In spite of its benefits and usage in Ghana, there is limiting data on the impact of different drying methods on the nutritional composition. In order to address this challenge, a comprehensive research needs to be carried out to ascertain the best drying techniques among those highlighted that will ensure no or minimum losses in the nutritional quality in *Amaranthus cruentus*, *Celosia argentea*, and *Laportea aestuans* leafy vegetables. This will help to get best drying techniques for these indigenous leafy vegetables. This study was therefore aimed at determining the influence of three drying techniques on the nutritional quality of three indigenous leafy vegetables in Ghana.

The overall research objective was to determine the influence of oven, solar and freeze drying methods on the mineral compositions in *Celosia argentea, Laportea aestuans* and *Amaranthus cruentus* indigenous leafy vegetables.

2. MATERIALS AND METHODS

2.1 Study Site

The research was carried out at the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi - Ghana.

2.2 Experimental Design and Procedure

A Completely Randomized Design (CRD) with a 3 x 3 factorial design with three replications. The factors were; leafy vegetables at three levels (*Amaranthus cruentus, Celosia argentea* and *Laportea aestuans)* and drying methods at three levels (Solar, Oven and Freeze drying). Seeds of

Amaranthus cruentus, *Celosia argentea* and *Laportea aestuans* were obtained from a vegetable farmer at Ahodwo, Kumasi - Ghana. Broadcasting method was used to nurse the seeds. The seedlings were then transplanted onto the experimental field at the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The transplanted seedlings were watered when necessary until it was matured.

2.3 Sample Collection

Amaranthus cruentus, *Celosia argentea* and *Laportea aestuans* leaves were harvested from the experimental field after one month of planting into an A4 brown envelope.

2.3.1 Preparation of sample and drying

Matured harvested leaves of the leafy vegetables were washed thoroughly under running water to get rid of foreign particles and air dried under the shade. The samples were divided into two. One group (fresh leaves) was sent to the soil science laboratory at the Department of Crop and Soil Sciences, KNUST for the analysis of mineral compositions whiles the other group was subjected to three postharvest treatment procedure (Oven drying, Solar drying and Freeze drying) after which mineral contents were analyzed at the laboratory.

The leaves of the three leafy vegetables were subjected to Oven, Solar and Freeze drying methods. The Oven and Solar drying of the samples were done at the Department of Horticulture, KNUST, whereas the freeze drying was done at the Council for Scientific and Industrial Research (CSIR) - Crop Research Institutes (CRI), Kumasi - Ghana.

2.3.2 Solar drying method

To determine the effect of solar drying on the three indigenous leafy vegetables, 100 grams each of the fresh indigenous leafy vegetables were weighed and triplicated, and then put into an A4 brown envelopes before subjecting to solar box dryer which was completed after 5 days (mean temperature and relative humidity of 33.4 ^{o}C and 84.5 % respectively was recorded using micro sensor) until a consistent weight was achieved. Afterwards, the dried samples were sent to the laboratory for mineral composition analysis [16].

2.3.3 Oven drying method

To evaluate the effect of oven drying on the three indigenous leafy vegetables, 100 grams each of the fresh leafy vegetables were weighed and triplicated and put into an A4 brown paper envelopes and totally dried out in a Magtech oven at 60°C for 72 hours. Immediately after drying, the samples were sent to the laboratory for the analysis of mineral component [16].

2.3.4 Freeze drying method

To ascertain the effect of freeze drying on *A. cruentus*, *C. argentae* and *L. aestuans* leafy vegetables, 100 grams each of the fresh leafy vegetables were weighed and triplicated and freeze dried in the Heto PowerDry LL 3000 Freeze Dryer for 15 hours. Afterwards, the dried samples were sent to the soil science laboratory for the analysis of mineral contents.

2.4 Data Collection

The mineral constituents contained in the fresh and dried samples of each leafy vegetable was analyzed using the Association of Official Analytical Chemists (AOAC) method, to determine phosphorus (P), calcium (Ca), potassium (K), iron (Fe), and magnesium (Mg) (AOAC, 1990).

One gram of the sample weighed was burnt to ashes in the furnace for four to five hours, the ash sample was then dissolved with 10 ml of aqua regia solution. It was then transferred to 100 ml volumetric flask. Afterwards, it was transferred into a reagent bottle.

2.4.1 Phosphorus (P) concentration determination

5 ml of the digest of each sample was measured and put into 50 ml volumetric flasks. 10 ml of vanadomolybdate was then added to each sample and the volumes of the 50 ml volumetric flasks filled with distilled water. The flask content was thoroughly mixed by shaking and kept for 30 minutes. A yellow colour which developed was read at 430 nm wavelength on a spectrophotometer. Percentage transmittance was recorded and the absorbance level was determined. The phosphorus content was then determined using a standard curve developed from a standard phosphorus solution [17].

2.4.2 Calcium (Ca) concentration determination

10 ml of the extract was measured into 100 ml Erlenmeyer flask. Afterwards, 10 ml of 10 % potassium hydroxide solution was added followed by 1 ml of 30 % triethanolamine to the flask. Then, 3 drops of 10 % potassium cyanide and few drops of Eriochrome Black T indicator solution were added. The mixture was shaken to ensure homogeneity. Afterwards, the mixture was titrated with 0.02 N EDTA solutions from a red to blue end point.

Calcium (mg) = Titre value of EDTA x 0.4008

$$\%\ \text{Calcium} = \frac{\text{Calcium (mg) x 100}}{\text{Sample weight x volume}}$$

2.4.3 Potassium (K) concentration determination

The concentrations of potassium present in the three indigenous leafy vegetables were determined using the method of Flame Photometry. The air-acetylene flame was used to measure the emissions of the potassium after diluting the digest. Afterwards, a curve of calibration was drawn for concentration against potassium emission and was compared to that of a standard solution [17].

2.4.4 Iron (Fe) and zinc (Zn) concentration determination

Portion of standard sample was pipetted into test cylinders and absorbance estimated at 248 nm utilizing air-acetylene fire. In order to determine the iron concentration, absorbance curve of calibration was then drawn against the iron concentration [17].

2.4.5 Magnesium (Mg) concentration determination

10 ml of the extract of each leafy vegetable was measured into a conical flask for magnesium. Then 10 ml of ammonia buffer solution was added to the flask for magnesium. 1ml of triethanolamine solution was added to the flask and three drops of potassium cyanide was added. Eriochrome Black T was added to the flask respectively to magnesium and titrate against EDTA solution.

Magnesium in mg = Titre value of EDTA x 0.243

$$\text{Mg} = \frac{0.02 \text{ x Vx } 1000}{\text{W}}$$

Where:
V = ml of 0.02 M EDTA
0.02 = concentration of EDTA
W= weight in gramms of sample extracted

2.5 Data Analysis

The effects of drying techniques on the indigenous leafy vegetable samples were subjected to analysis of variance (ANOVA) using Genstat statistical software version 12th. Significant differences and were evaluated at 5 % (p = 0.05) level of significance. Where there was significance, means were separated using the Fishers protected least significant difference (LSD) procedure.

3. RESULTS

3.1 Mineral Concentration in Vegetables

3.1.1 Concentration of phosphorus (P) in vegetables

Fig. 1. shows the results of concentration of phosphorus in the leafy vegetables. Among the vegetables, *Amaranthus cruentus* significantly (p <0.05) had the highest concentration of phosphorus (0.79 %) and the *Celosia argentea* had the least (0.40 %).

3.1.2 Concentration of potassium (K) in vegetables

Potassium concentration in the various leafy vegetables were also determined and the results are shown in Fig. 2. *Amaranthus cruentus* significantly (p <0.05) had the higher concentration of potassium (2.22 %) than *Celosia argentea* and *Laportea aestuans* which had similar amounts of potassium.

3.1.3 Concentration of calcium (Ca) in vegetables

The results of concentration of calcium in the various leafy vegetables are presented in Fig. 3. There were significant (p < 0.05) variations in calcium concentrations among the vegetables. The concentrations of calcium in the vegetables were in a decreasing order of *Laportea aestuans* > *Celosia argentea* > *Amaranthus cruentus* with 3.01> 2.28 >2.04 % respectively,

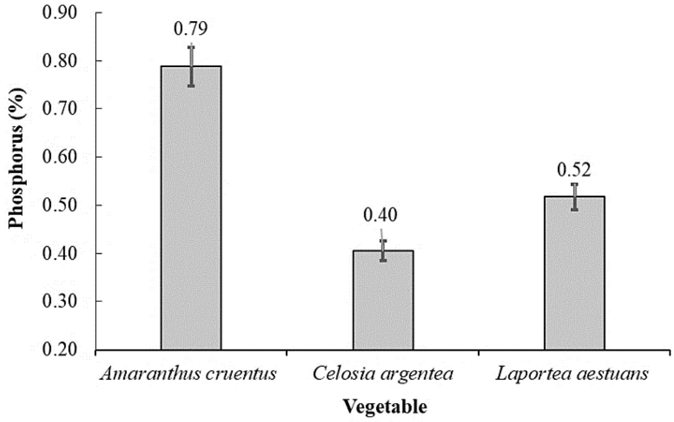

Fig. 1. Total phosphorus content in vegetables

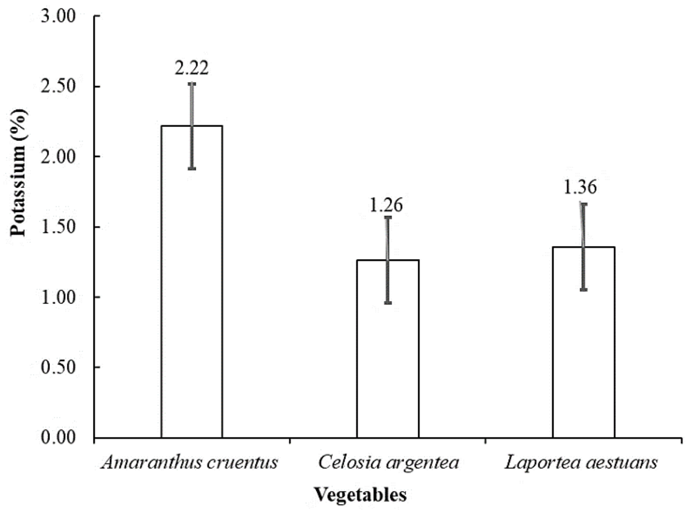

Fig. 2. Total potassium content in vegetables

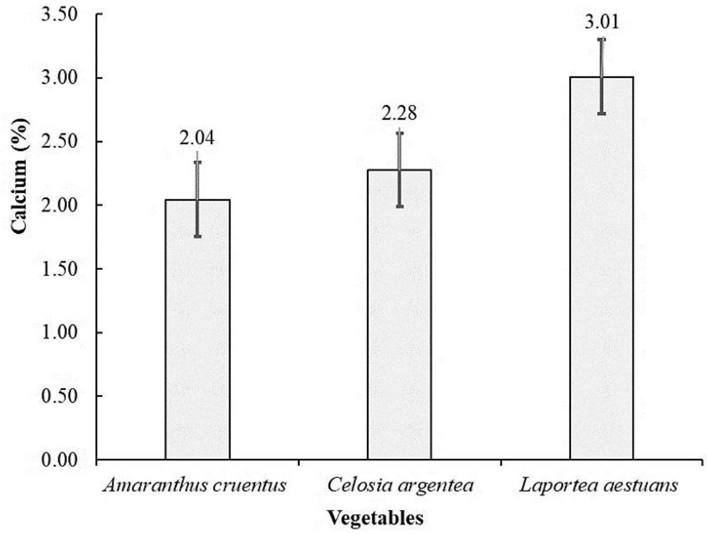

Fig. 3. Total calcium content in vegetables

3.1.4 Concentration of magnesium (Mg) in vegetables

Fig. 4. shows the results of concentration of magnesium in the leafy vegetables. The concentration of magnesium in *Amaranthus cruentus* was significantly ($p < 0.05$) highest, followed by the concentration in *Laportea aestuans* and *Celosia argentea* had the least.

3.1.5 Concentration of iron (Fe) in vegetables

Concentration of iron was significantly ($p < 0.05$) highest in *Celosia argentea* (613.1 mg/kg) among the vegetables (Fig. 5). This was followed by the concentration in *Amaranthus cruentus* (417.2 mg/kg) while *Laportea aestuans* had the least (239.4 mg/kg).

3.1.6 Concentration of zinc (Zn) in vegetables

The results of concentration of Zinc in the leafy vegetables are shown in Fig. 6. Among the vegetables, *Celosia argentea* significantly ($p < 0.05$) had the highest concentration of Zinc (49.43 mg/kg) and *Laportea aestuans* had the least (35.2 mg/kg). There was no significant difference in concentration of Zinc between *Amaranthus cruentus* and *Celosia argentea*.

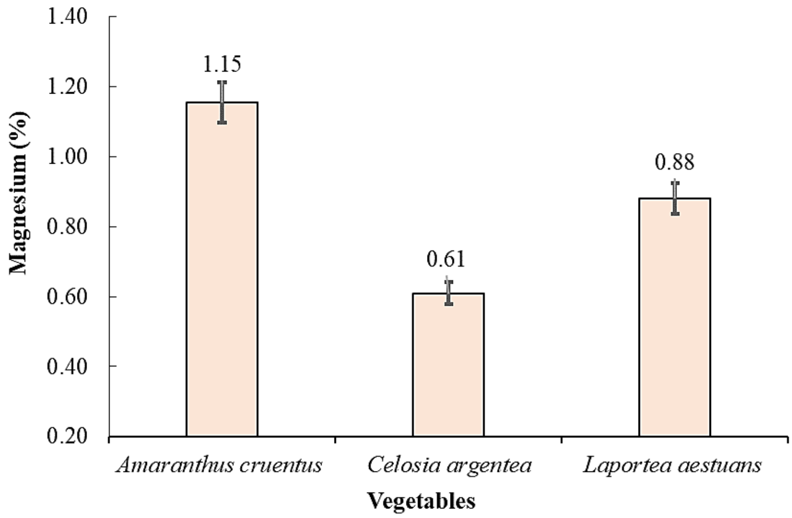

Fig. 4. Total magnesium content in vegetables

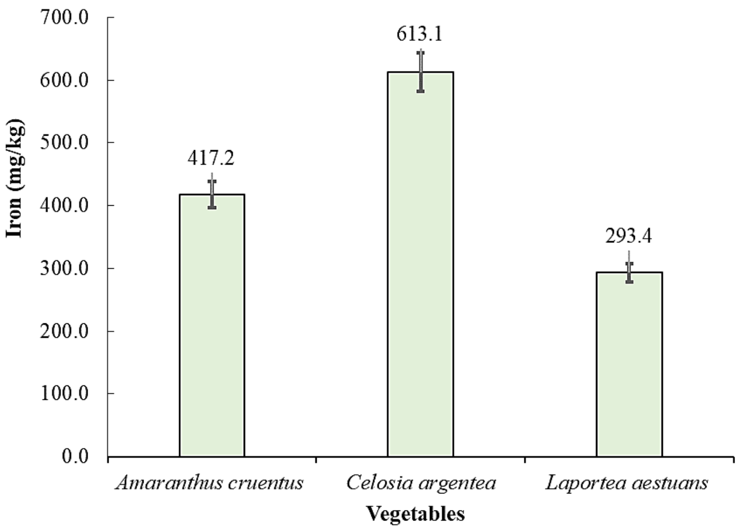

Fig. 5. Concentration of iron in vegetables

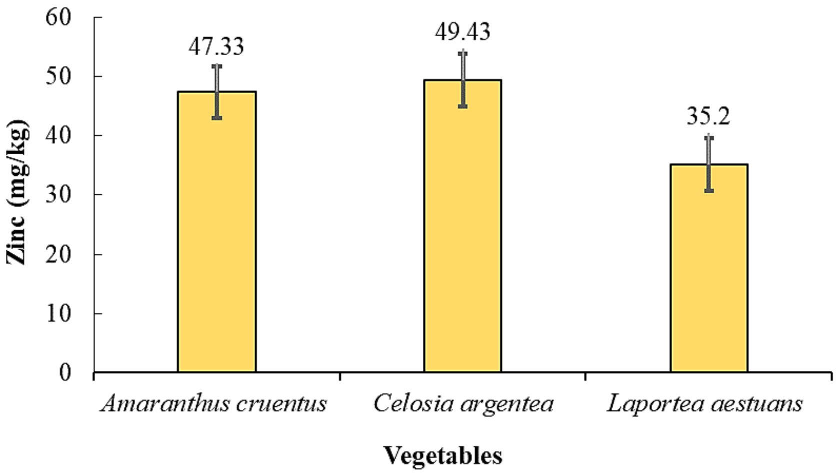

Fig. 6. Concentration of zinc in vegetables

3.2 Effect of Drying Methods on the Concentrations of Minerals in Vegetables

The effects of the different drying methods on the concentrations of some selected minerals were measured and the results are shown in Table 1. There were significant ($p < 0.05$) differences in the mineral's concentrations among the drying methods. Phosphorus concentration was similar in vegetables that were Solar and Freeze-dried which were higher than those that were Oven-dried. Vegetables that were Freeze-dried significantly ($p < 0.05$) had higher concentration of potassium (2.25 %) than those that were Solar-dried (1.55 %) but similar to those that were Oven-dried (1.93 %). The concentration of calcium in the vegetables was highest following Freeze drying (2.75 %) and least in Oven drying (2.11 %). The effect of the drying method on the concentration of magnesium in the vegetables resulted in concentrations in an increasing order of 0.91 < 1.13 < 1.54 % in Solar-dried, Oven-dried and Freeze-dried vegetables respectively.

Concentration of iron was significantly ($p < 0.05$) highest in vegetables that were Freeze -dried (541 mg/kg). This was followed by concentration in Oven-dried vegetables (414.80 mg/kg) and vegetables that were Solar-dried had the least (318.1 mg/kg). Zinc concentration was significantly ($p < 0.05$) higher in Freeze-dried vegetables than those that were Solar -dried which was also higher than those that were Oven-dried (Table 1).

3.3 Combined Effect of Drying Method and Type of Vegetable on Mineral Compositions

The results of interaction effect of drying method and vegetables on mineral compositions are presented in Table 2. Concentration of total phosphorus was significantly ($p < 0.05$) highest in *Amaranthus cruentus* Freeze-dried (1.02 %) among the interactions. Total potassium was not affected ($p > 0.05$) by the various combinations of drying methods and type of vegetable. Calcium content was significantly ($p < 0.05$) highest in Freeze drying followed by Solar drying and least in Oven drying across all vegetables with the exception of *Celosia argentea* where Oven drying had higher calcium than Solar drying. Similar to the observations in calcium, concentration of magnesium was significantly higher in Freeze drying than the others in all the vegetables.

Iron concentration was similar between Oven and Freeze dryings in *Amaranthus cruentus* (487.2 and 519.1 mg/kg) which were higher ($p < 0.05$) than Solar drying (374.1 mg/kg). In *Celosia argentea*, iron was highest in Freeze drying, followed by Oven and Solar drying. Freeze drying had higher iron concentration in *Laportea aestuans* than Oven and solar dryings which had similar concentrations. Freeze drying had higher concentration of zinc in *Amaranthus cruentus* and *Celosia argentea* compared to the other drying methods. However, in *Laportea aestuans*, zinc concentration was higher in Freeze drying (45.33 mg/kg) followed by Oven and Solar drying, 42.6 and 38.31 mg/kg, respectively (Table 2).

Table 1. Effect of drying method on mineral composition in vegetables

Drying method	Total phosphorus	Total potassium	Total calcium	Total magnesium	Iron	Zinc
		(%)			(mg/kg)	
Solar drying	0.68b	1.55a	2.38b	0.91a	318.10b	44.63b
Oven drying	0.60a	1.93ab	2.11a	1.13b	414.80a	39.26a
Freeze drying	0.69b	2.25b	2.75c	1.54c	541.00c	46.13c
p value	<0.001	0.011	<0.001	<0.001	<0.001	<0.001
CV (%)	2.8	21	3.7	5.7	3.5	1.9

**Means with same letters in a column are not significant different at 0.05 probability (p > 0.05)*

Table 2. Combined effect of type of vegetable and drying method on mineral compositions

Vegetable	Drying method	Total phosphorus	Total potassium	Total calcium	Total magnesium	Iron	Zinc
		(%)				(mg/kg)	
A. cruentus	Solar	0.74e	1.48a	2.09b	1.17a	374.1b	42.97d
	Oven	0.83d	1.86a	2.22a	1.28b	487.2c	41.5cd
	Freeze	1.02f	2.27a	2.51c	1.35c	519.9c	47.7e
C. argentea	Solar	0.51b	1.51a	2.17c	1.10b	614.4d	32.6f
	Oven	0.61c	1.90a	3.18e	1.11b	726.7b	52.67bc
	Freeze	0.94a	2.24a	3.47d	1.56d	794.7e	55.37g
L. aestuans	Solar	0.40c	1.63a	3.03e	0.94a	302.7b	38.33b
	Oven	0.53a	2.03a	3.79b	1.17bc	328.6c	42.61a
	Freeze	0.67c	2.22a	3.68f	1.73d	395.5a	45.33a
p value		<0.001	0.99	<0.001	<0.001	<0.001	<0.001
CV (%)		2.8	21	4.1	5.7	3.5	1.9

**Means with same letters in a column are not significant different at 0.05 probability (p > 0.05)*

4. DISCUSSION

Phosphorus functions as constituent of bones, teeth, ATP and nucleic acids. It helps in buffering system and is involved in the synthesis of phospholipids and phosphoproteins [18]. According to Soetan et al*.* [19] important sources of phosphorus include phosphate food additives, green leafy vegetables and fruits. In this study, phosphorus concentration varied among the vegetables with *A. cruentus* having higher (0.79 %) than *Celosia argentea* (0.40 %) and *Laportea aestuans* (0.52 %). This indicates that *A. cruentus* could be a good source of phosphorus compared to the other vegetables, and about 0.7 grams of phosphorus is needed in the body to promote growth in adult daily [20], *A. cruentus* would be able to provide almost 100 % of the requirement. Since phosphorus is required for mineralization of bone and other processes of metabolism, intake of *A. cruentus* will aid in healthy bone formation in human body. Contrary to the results of this study, Makobo et al. [21] recorded highest phosphorus content in *C. argentea* and recommended the species as a good source of phosphorus for consumption.

Phosphorus concentration were higher in all the dried vegetables by all drying methods compared to fresh vegetables (Fig. 1 and Table 2). This suggest that, drying improved the phosphorus content in vegetables in this study. Reports from other studies proved otherwise where phosphorus contents were higher in fresh vegetables than solar and oven- dried vegetables and attributed it to the higher temperature during the drying process [22,23].

Plant products contain much potassium and sources include vegetables, fruits and nuts [19]. Comparatively potassium concentration was higher in *A. cruentus* (2.22 %) than *C. argentea* (1.26 %) and *L. aestuans* (1.36 %) in this study (Fig. 2) which could be attributed to the fact that they are different species with different genetic make-up and hence, the variations observed. Concentration of potassium recorded in the vegetables in the study were higher compared to values reported by Mensah et al. [24] as 0.38 and 0.48 % in *Corchorus olitorius* and *A. cruentus* respectively. Other studies on the other hand have reported higher concentrations of potassium in vegetables than observed in this study. For instance, Mhlontlo et al. [25] observed potassium content for *Amaranthus* species between 3.3 and

4.7%. Thinking about the everyday prerequisite of 4.7 grams for a grown-up and 3.0 g/100 g for an offspring of 1-3 years of age, *A. cruentus* will be the best vegetable with high potassium content as 100 grams of the species intake every day can give around 50 % of the day by day prerequisite for a grown-up and all the day by day required admission for young children of 1-3 years old recommended by NAS, [20].

The effects of drying methods on potassium concentrations in the vegetables in this study revealed that, concentration of potassium in all the vegetables were generally increased over the fresh vegetables in the Freeze drying but decreased in Solar and Oven drying (Fig. 2 and Table 2). This indicates that, Freeze drying was effective in retaining and improving potassium content in the vegetables. The decrease in the values of the oven-dried and solar- dried samples indicated that oven and solar drying method may cause destruction of these important elements. This observation agrees with the work of Morris et al. [26]. Other researchers have reported higher potassium content in Solar and Oven-dried samples than fresh vegetables [27,28].

Calcium is an important constituent of bones and teeth and is involved in regulation of nerve and muscle function. It also plays an important role in enzyme activation. Sources include leafy vegetables, nuts and bones [19,29]. The concentration of calcium in the study was higher in *L. aestuans* (3.10%) compared to *C. argentea* (2.28 %) and *A cruentus* (2.04%) (Fig. 3). Taking into consideration the everyday necessity of 1.3 grams for a grown-up, all the vegetables in this study will be a great provider of calcium as about 100 grams of the plants eaten everyday will be sufficient to give over 100% of the 1.3 grams day by day prerequisite for grown-ups [20].

Other scientific studies have reported quantities of calcium in leafy vegetables. Examples, Mensah et al [24] reported lower values compared to the values of this study of 0.21, 0.23 and 0.12% calcium in *A. cruentus, Basella ruba* and *Cochorus olitorius* respectively. Higher values of calcium (12.0 – 45.0 %) than those in this study have also been reported by Remans et al. [30] in different varieties of *Amaranthus*.

Comparatively, all the drying methods generally increased calcium contents in all the vegetables over the fresh vegetables (Fig. 3 and Table 2). This suggests that drying improves the concentration of calcium in vegetables. This observation confirms the findings of Negi and Roys, [22] who observed an increment in the amount of calcium in solar and oven-dried vegetables than the raw sample. Calcium is a fundamental mineral for the body's legitimate development and upkeep. It assists with building and keeping up with healthy life.

Magnesium helps in the regulation of protein synthesis, muscle and nerve functions, oxidative phosphorylation and glycolysis. It is also responsible for the formation of protein and nerve transmission in the body [31]. Leafy vegetables are good source of magnesium (Soetan et al. [19]. Concentration of magnesium in this study ranged from 0.61 % in *C. argentea* to 1.15 % in *A. cruentus*. The human body contains about 760 mg of magnesium at birth, about 5 g at age 4–5 months, and 25 g when adult. For the body's magnesium, 30–40 % is found in muscles and soft tissues, 1 % is found in extracellular fluid and the remainder is in the skeleton, where it accounts for up to 1 % of bone ash. The vegetables in the study consist of essential magnesium and can give more than the 0.4 grams needed for the body daily [20]. Because magnesium plays a beneficial role in the health of teeth and bone as well as the regulation of protein synthesis, intake of these vegetables will be more helpful to the body.

Magnesium contents in *A. cruentus, C. argentea* and *L. aestuans* improved after dehydrating them with Solar, Oven and Freeze drying compared to the fresh vegetables (Fig. 4 and Table 2), an indication that drying of these leafy vegetables is needed to improve mineral compositions. The results corroborate the findings of David and Whitefield [32] who reported an increase in magnesium content of vegetables after solar drying.

Iron functions as haemoglobin in the transport of oxygen and in cellular respiration, as essential component of enzymes involved in biological oxidation such as cytochromes C, C1, and A1 [33]. Sources include red meat, spleen, heart, liver, kidney, fish, egg yolk, nuts, legumes, molasses, iron cooking ware, dark green leafy vegetables [19]. Concentrations of iron in the vegetables observed in this study were higher, 613.1 mg/kg in *C. argentea*, 417.2 mg/kg in *A. cruentus* and 293.4 mg/kg in *L. aestuans* compared to values reported by Mensah et al. [24] in *A. cruentus, Cochorus olitorius* and *Basella rubra* with 120, 40 and 40 mg/kg respectively. The vegetables in this study are endowed with essential irons and can give more than 100% of the 11milligram needed in grown-up daily [20]. Because iron aids in haemoglobin formation, intake of *C. argentea, A. cruentus* and *L. aestuans* will improve the blood haemoglobin levels and reduce the risk of anaemia in consumers considerably.

Concentrations of iron in all the vegetables were improved by all the drying methods over the fresh vegetables (Fig. 5 and Table 2), an indication that drying of these leafy vegetables is needed to improve mineral compositions. However, this observation contradicts the reports by other studies [34,26,35] where drying methods decreased iron concentration relative to the fresh vegetables.

Zinc is another important micronutrient playing important roles in fetal development, normal growth and sexual maturation of human beings. According to Roohani et al. [36] deficiency in zinc could lead to low immunity. In this study, concentrations of zinc ranged from 35.2 mg/kg in *L. aestuans* to 49.43 mg/kg in *C. argentea*. The values recorded in this study were lower compared to values that have been reported by other studies such as Usunobun and Okolie [37] who reported 5430 mg/kg in *C. argentea*. However, these vegetables will be good sources of zinc and provide enough for consumption considering the daily requirement of 4 and 14 mg/day of zinc for children and adult respectively [38]. Concentrations of zinc in all the vegetables were also improved by all the drying methods over the fresh vegetables (Fig. 6 and Table 2), an indication that drying of these leafy vegetables is needed to improve mineral compositions.

5. CONCLUSION

The study revealed that *A. cruentus* significantly ($p < 0.05$) had the highest phosphorus (0.79%), potassium (2.22%) and magnesium (1.15%) and *C. argentea* recorded the least concentrations (0.40, 1.26 and 0.61%) respectively. The concentration of calcium was in ascending order of *A. cruentus* < *C. argentea* < *L. aestuans* with 2.04 < 2.28 < 3.03% respectively. Iron and zinc contents were higher in *C. argentea* than *A. cruentus* and *L. aestuans*. Moreover, calcium content in freeze dried vegetables with exception of *C. argentea* increased as compared to Solar and Oven drying. Also, the concentration of phosphorus was in ascending order of *C. argentea* < *L. aestuans* < *A. cruentus* with 0.44 < 0.60 < 1.04 % respectively for freeze drying. It can therefore be concluded that the three indigenous leafy vegetables are good sources of nutrients and these three drying techniques are for the preservation of their nutrients as well as preventing postharvest losses.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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