World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Effects of different drying methods on the micronutrients of four leafy vegetables traditionally consumed by some Clans in Izzi and Unwana, Ebonyi State, Nigeria

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World Journal of Advanced Research and Reviews, 2023, 20(02), 609–618

Publication history: Received on 23 September 2023; revised on 05 November 2023; accepted on 07 November 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.20.2.2238

Abstract

This study was carried out to evaluate the effects of different drying methods (Freeze drying, shade drying and oven drying at varied temperatures of 40°C, 50°C and 60°C) on the micronutrients (mineral and vitamin) contents of *L. cupanioides, F. ottonifolia, P. osun* and *C. pentandra*. The minerals contained in both dried and fresh leafy vegetable samples were analyzed by the dry ash extraction method, while vitamins (A, B_1, B_2, B_6 and E) contents of the leafy vegetable samples were determined spectrophotometrically. Vitamin C was determined titrimetrically after homogenizing each sample in 50ml 5.6M EDTA solution. The results from the study revealed that the various drying methods affected the leafy vegetable samples within and between them in the same pattern but to different degrees resulting to moisture lose with increase in minerals and increase in vitamin concentrations when compared with the fresh leafy vegetable samples. Freeze drying and shade drying had the best micronutrients retention effects across all the leafy vegetable samples while oven drying at varied temperatures of 40°C, 50°C and 60°C had gradual decrease in minerals and vitamins retention effects as the temperature increases. The difference in mineral and vitamin concentrations retention with respect to drying methods decreased in this order: Freeze drying > shade drying > oven drying at 40°C > oven drying at 50°C > oven drying at 60°C. The results of the various micronutrients for both fresh and dried leafy vegetable samples in this study ranged as thus: Calcium (72.59–398.10mg/100g), magnesium (41.16–461.07mg/100g), phosphorus (79.28–306.11mg/100g), iron (2.11–32.11mg/100g), zinc (0.19–18.88mg/100g), sodium (29.10–326.51mg/100g), potassium (0.8-196.31mg/100g), vitamin B_1 (0.31– 4.22mg/100g), vitamin B_2 (0.31 – 1.49mg/100g),vitaminB_6 (0.36–3.91mg/100g), vitamin A (110.01–548.22ug/g), vitamin C (159.84–818.46mg/100g) and vitamin E (0.16– 9.91mg/100g). In conclusion, the freeze drying and shade drying are the best drying methods for producing dried traditional leafy vegetables with higher micronutrients retention than oven drying at varied temperatures (40°C, 50°C and 60°C).

Keywords: Traditional leafy vegetables; Drying; Freeze drying; Retention and micronutrients

1. Introduction

Traditional Leafy Vegetables (TLVs) are vegetables indigenous to people of a given tribe, clan, community or region and are consumed by the people inhabiting the geographical area as a result of their traditional or religious belief (Chukwuemeka, 2016). Most people within a given location consume these TLVs as their ancestral heritage (Chukwuemeka, 2016). TLVs can also be defined as vegetables of a given locality which originated from an area but may or may not be confined to that particular region (Oboh, 2005). They account for about 10% of the world's higher plants often regarded as weeds (Raghuvanshi, 2001). Some TLVs grow in the wild and are readily available in the field as they do not require any formal cultivation but have useful adaptive characteristic features which help them tolerate adverse climatic conditions (Raghuvanshi, 2001). They are important sources of minerals, vitamins, fibre, protein and other nutraceutical properties (Yang and Keding, 2009).

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TLVs are perishable commodities as with other biological species/ plants because they have very high moisture content. Dehydration results in substantial reduction in weight and bulk with consequent savings in storage and distribution cost (Oboh, 2005). Echetama *et al,.* (1997) reported that vegetables dehydrated under solar exposure with appropriate pre-drying treatments compared favourably with freeze dried, cabinet and oven dried vegetables. Different drying temperatures also cause significant changes in the nutritional and storage properties of leafy vegetables (Harvest, 2011; Amaechi *et al.,* 2020). Using a specific drying method and slight difference in drying temperatures of leafy vegetables of similar properties can have substantial influence on their nutritional qualities (Oboh, 2005; Fasuyi, 2006; Clement, 2012). The different methods of drying and preserving leafy vegetables can therefore have effect on the nutritional and over all acceptability by different individuals (Harvest, 2011). Traditional leafy vegetables (TLVs) are considered as one food source that can be classified as protective foods since they supply vitamins and minerals and they play important metabolic roles. It is envisaged that the use of dried leafy vegetable foods will provide food security, alleviate hidden hunger hence reduce the prevalence of degenerative diseases (Amaechi *et al*., 2020). There are documented losses of nutrients (vitamins) from leafy vegetables during drying (Yadav and Seghal, 1997). Drying may alter the microstructure of leafy vegetables and influence the release of protein and other minerals during digestion (Dalmau *et al*., 2019; Amaechi *et al*., 2020). To consumers, the most desirable attributes of vegetables are their nutritional and sensory characteristics (Harvest, 2011). These determine an individual's preference for a given vegetable and as such drying using a specific method and a slight difference in drying temperatures of vegetables of similar properties can have substantial influence on its acceptability (Oboh, 2005; Fasuyi, 2006; Clement, 2012).The different methods of drying and preserving vegetables can therefore have effects on the nutritional and over all acceptability by the consumer.

Leafy vegetables are good sources of minerals and vitamins (Ihekoronye and Ngoddy, 1985; Olujobi, 2015). Leafy vegetables are important component of diet in many homes (Olujobi, 2015). Apart from the variety which they add to the menu (Mephba*et al*., 2007; Subukola *et al*., 2007). They are valuable sources of micronutrients especially in rural areas where they contribute substantially to minerals (Iron, calcium, magnesium, zinc, selenium, etc) and vitamins (vitamin A,B,C,D, E) which are usually in short supply in daily family diets(Mohammed and Sharif, 2011; Olujobi,2015). It is worthwhile to note that consumption of numerous types of leafy vegetables as sources of food could be beneficial to nutritionally marginal population, especially in developing countries where poverty and harsh climatic conditions is causing havoc to the rural populace in terms of their health insurance (Olujobi, 2015). Leafy vegetables are highly beneficial for maintenance of health and prevention of diseases (Olujobi, 2015). They serve as valuable source of micronutrients in Nigeria where different types of traditional leafy vegetables are consumed by the various ethnic groups for different reasons (Dentol *et al*., 1983; Mensah *et al*., 2008; Olujobi, 2015). They constitutes significant micronutrients sources especially in times of drought and famine for low income rural dwellers to meet the necessary dietary requirements at least for their immediate family (Lockett and Grivetti 2006; Grivetti and Ogle, 2000; Olujobi, 2015).

Micronutrients are substances required by the body in order to facilitate proper bodily functioning (WHO, 2021). They are crucial for the production of enzymes, hormones, energy, etc, (WHO, 2021). They play vital roles in promoting healthy development, disease prevention, blood clotting, fluid balance, growth, bone health and general wellbeing (WHO, 2021). The two major micronutrients are vitamins and minerals (WHO, 2021). Vitamins are grouped into two categories; fat and water soluble. Vitamins are organic molecules that can be broken down by factors such as heat, oxygen, acid, base or salt (Abizer, 2023). This means they can degrade when cooked, dried or exposed to air, acid, base or salt hence making it slightly difficult to ensure that we consume enough of them in our diet (Abizer, 2023). Minerals on the other hand are classified into trace and macro elements (WHO, 2021). They are inorganic and are not degraded by heat, air, acid, base or salt during cooking, drying, or when exposed to air, salt, acid or base (WHO, 2021). With the exception of vitamin D, micronutrients are not produced in human body. This means that our bodies absorbed minerals and vitamins from our diets and drinking water (WHO, 2021; Lizzie, 2023). The importance of micronutrients for good health and general well being are too significant that they cannot be underestimated (WHO, 2021). The exploitation of traditional leafy vegetables as sources of micronutrient needs re-orientation on the sustainability of these leafy vegetables for scientific research and documentation of findings before they are irretrievably lost to the future generations (Olujobi, 2015).

Traditional leafy vegetables (TLVs) are seasonal and are rarely seen during their off seasons. They are in many cases subjected to poor post harvest processes in an attempt to preserve them for use in their scarce period (Clement, 2012). There is dearth of information regarding the micronutrients potentials of traditional leafy vegetables. In the wake of prevalence of 'hidden hunger' due to the deficiency of vitamin A as well as minerals namely iron, zinc, selenium, there is need to explore these traditional leafy vegetables so as to ascertain which is the best and easy accessible preservation method for micronutrients retention. It is very sad that global and governmental measures tend to reduce the menacing effects of malnutrition in rural communities by introducing food supplements which are usually expensive and inaccessible to rural households. It is therefore, necessary to explore the use of TLVs as a means of alleviating micronutrients deficiency. TLVs can play this role since they are micronutrient rich, available and cheap (Smith and Ezyaguire, 2007). Preservation is often by sun drying which unfortunately may lead to the loss of important micronutrients. It is imperative that TLVs be preserved so that they can be used during off season as a good source of micronutrients. It is in view of these that this research sought to investigate the effects of different drying methods under varying oven temperatures as well as other dehydration methods on the micronutrients content of four selected TLVs namely *L. cupanioides, F. ottonifolia, P. osun and C. pentandra* consumed by some clans in Izzi and Unwana, Ebonyi State. The temperature regimes employed were oven temperatures of 40°C, 50°C and 60°C and the other dehydration methods include air/shade drying and freeze drying. Fresh/raw samples of the respective vegetables were used as control. This work seeks to scientifically evaluate the effect of different drying methods on the micronutrient contents of four selected traditional leafy vegetables.

2. Materials and methods

2.1. Collection and preparation of samples

Four fresh traditional leafy vegetables (TLVs) samples namely *Lecanioidiscus cupanioides* ("Ukpocha"), *Ficus ottonifolia* ("Oboko-ogologo"), *Ceiba pentandra* ("Akputor") and *Pterocarpus osun* ("Aramazu") were sourced from farms and bushes in Iboko, Izzi Local Government Area and UnwanaAfikpo North L.G.A of Ebonyi State, Nigeria. The samples were identified at the herbarium unit, Department of Horticulture and Landscaping, AkanuIbiam Federal Polytechnic, Unwana, Afikpo, Ebonyi State. The various leafy samples were picked, sorted, cleaned, washed well in water to remove dirt and allowed to drain off water. They were divided into six (6) equal portions of 2000g each and labeled A, B, C, D, E and F; After which five portions of the samples were dried using various drying methods namely freeze drying at -105°C for 10h 48mins at a vacuum pressure of 60Hz in a bench top freeze drier (Labconco N720401010, USA), shade drying at room temperature (25±2°C) and oven drying at varied temperatures (40°C, 50°C and 60°C respectively) using an oven (MINO/30Widness, UK). The sixth portion was used for analysis in its fresh state as the control. Subsequently, the dried samples were milled into powder, sieved, labeled and stored in an airtight dark coloured container before being subjected to various Minerals and vitamins analysis namely. Fresh samples were pulverized prior to analysis of various parameters.

2.2. Mineral analysis

The minerals content in both dried and fresh leafy vegetable samples were analyzed by the dry ash extraction method described by AOAC, (2005). Five (5)g of each sample was ashed in a muffle furnace (EF3 chesterfield, UK) at 550°C for 6h after which they were cooled in a desiccator and 50ml HCL was added to each sample and transferred to 250ml volumetric flask and made up to 100ml mark using deionized water. Minerals namely calcium, magnesium, phosphorus, iron, zinc, sodium and potassium in each extract was analyzed using atomic absorption spectrophotometer (AA-240, UK). The mineral content was calculated as:

$$\text{Mineral (mg/l00g)} = \frac{\text{Absorbance of test sample} \times \text{Conc, of Std}}{\text{Absorbance of Std}}$$

2.3. Vitamin analysis

Vitamin A, B_1, B_2, B_6 and E contents of the leafy vegetable samples were determined spectrophotometrically (Jenway 6715UV/Vis, UK) using 1cm path length cuvette, according to the methods described by Okwu and Emenike (2006) with some modifications. Five (5)g of each sample was homogenized and extracted using a mixture of absolute ethanol and 5% sodium hydroxide(10:1) and boiled for 30mins under reflux before adding petroleum ether. The extract mix was evaporated to dryness on a rotary evaporator. Small quantity of the residues was re-dissolved in appropriate carrier solvents for each vitamin. Vitamin standards were prepared in the carrier solvents at different concentrations. Their absorbance was read and used to create the calibration curves used to calculate the concentration of the vitamin on a dry weight basis. The absorbance of the vitamins was monitored as follows: thiamin (vitaminB_1) at 360nm, riboflavin (vitamin B_2) at 510nm, pyridoxine (vitamin B_6) at 480nm, vitamin A at 450nm and vitamin E at 295nm. Vitamin C was determined titrimetrically after homogenizing each sample in 50ml 5.6M EDTA solution. The homogenized samples were filtered through Whatman no.2 filter paper. Ten (10) ml of 30% potassium iodide was added to 20ml of filtrate and mixed thoroughly. The mixture was titrated against 0.1M $CuSO_4$ to a dark end point using 1% starch solution as the indicator (Okwu and Emenike, 2006).

$$\text{Vitamin (mg/l00g)} = \frac{\text{Absorbance of test sample} \times \text{Conc, of Std}}{\text{Absorbance of Std}}$$

3. Results and discussion

3.1. Effect of different drying methods on mineral content of*L.cupanioides, F. ottonifolia, P. osun and C. pentandra*

Results in table1 revealed the effect of different drying methods on mineral content of *L. cupanioides ,F. ottonifolia, P. osun* and *C.pentandra*leafy vegetable samples compared with mineral content of fresh leafy vegetable samples. Drying resulted to moisture lose with increase in mineral nutrient concentration. Drying temperature had varied effects on mineral concentrations such that low temperature employed in freeze drying and shade drying retained higher mineral concentration than oven drying temperatures of 40^{o}C, 50^{o}C and 60^{o}C. Increased oven temperature resulted to gradual decrease in mineral concentrations which could be attributed to higher oxidation rate of minerals with increase in oven temperature (Amaechi *et al.,* 2020). Difference in mineral concentration with respect to drying method decreased in this order: Freeze drying > shade drying > oven drying at 40^{o}C > oven drying at 50^{o}C > oven drying at 60^{o}C. The abundance of minerals in fresh and dried vegetable samples analyzed was in this order: Magnesium > Calcium >Sodium > Phosphorous > Potassium > Iron >Zinc. This was not in agreement with Moyo *et al*., (2011) and Amaechi *et al.,* (2020), who reported abundance of mineral elements in fresh and dried *M. oleifera* in the following order: Calcium > Potassium > Sodium > Magnesium > Phosphorous > Zinc > Iron. Calcium, Magnesium, Phosphorous, Sodium, Iron and Zinc contents of fresh and dried leafy vegetable samples in this study were higher than Calcium, Magnesium, Phosphorous, Sodium, Iron and Zinc contents of fresh and dehydrated *M. oleifera* leaves which had values of 86.29 – 284.75mg/100g, 11.26 – 69.03mg/100g, 8.30 – 43.32mg/100g, 69.15 – 187.26mg/100g, 0.80 – 2.28mg/100g and 0.87 – 3.94mg/100g respectively (Amaechi *et al*., 2020). Table 1 revealed that mineral concentrations in the various samples are in these order; Calcium: *F.ottonifolia>C.pentandra>L.cupanioides>P.osun,*Magnessium:*F.ottonifolia>C.pentandra>P.osun>L.cupanioides,* Phosphorous: *F.ottonifolia>L.cupanioides>P.osun>C.pentandra,* Iron: *P. osun>F.ottonifolia> L. cupanioides> C. pentandra,* Zinc: *F.ottonifolia>L.cupanioides>P.osun> C. pentandra,* Sodium: *L.cupanioides> C. pentandra>P.osun>F.ottonifolia,* Potassium: *F.ottonifolia> L. cupanioides>P.osun>C.pentandra*. Considering the concentration of mineral nutrients analyzed, it was observed that *F. ottonifolia* had the highest concentration of the following mineral elements namely; Calcium, Magnesium, Phosphorous, Zinc and Potassium in both fresh and dried leafy vegetable samples. Therefore its consumption should be encouraged. It is worthy of note that *P. osun* had the highest iron concentration. This suggests that adequate consumption of this vegetable is highly encouraged as it can provide an avenue of combating anaemia among human populations who consume it. The dried leafy vegetable samples investigated in this study are cheap source of dietary mineral elements that will meet daily mineral elements requirement for healthy individuals e.g calcium (220 – 420mg/day), magnesium (2 – 2.3mg/day), sodium (1 – 250mg/day), phosphorous (4 – 4.7mg/day), potassium (18 – 27mg/day), iron (0.07 – 0.2mg/day), zinc (2.3mg/day),WHO, (2004). Calcium is very important for bone and teeth formation (Vunchi *et al.,* 2011). Magnesium is important for correction of diseases associated with circulatory system (Vunchi*etal.,*2011).Sodium and potassium play vital role in maintenance of acid – base balance in the body, balance in the ratio of sodium and potassium is important in managing hypertensive patients (Adeyeye,2002). Phosphorous is good for utilization of carbohydrate, fat, and protein for proper growth, maintenance and repair of cells and tissues as well as for healthy teeth and bone formation (WHO, 2004). Iron is good for blood formation and normal functioning of central nervous system (Adeyeye and Otoketi, 1999). Zinc is good for boosting healthy immune system, supports healthy skin and proper wound healing as well as growth and development (WHO, 2004). This entails that consumption of these leafy vegetable samples will provide adequate mineral nutrients that can proffer different health benefits associated with them.

Table 3 Effect of Different Drying Methods on Mineral Contents of *L.cupanioides, F. ottonifolia, P. osun and C. pentandra*

Sample	Calcium mg/100g	Magnesium mg/100g	Phosphorus mg/100g	Iron mg/100g	Zinc mg/100g	Sodium mg/100g	Potassium mg/100g
LecFre	72.59^{m}±1.49	41.16^{n}±2.86	94.03^{l}±2.84	2.11^{ghi}±1.40	1.86^{ij}±0.23	111.30^{l}±0.03	6.92^{k}±1.43
LecFD	298.16^{d}±4.27	176.01^{f}±4.24	306.11^{a}±3.12	18.96^{c}±1.46	18.88^{a}±1.44	261.12^{d}±4.27	30.66^{g}±2.85
LecSD	281.31^{ef}±2.86	164.39^{g}±2.86	292.36^{b}±2.43	11.61^{d}±1.44	17.25^{a}±1.44	246.36^{g}±4.27	26.92^{g}±2.86
Lec40	270.80^{h}±2.86	158.66^{gh}±3.21	287.21^{bc}±0.00	7.40^{ef}±1.41	14.99^{b}±1.46	196.04^{h}±2.86	22.02^{h}±4.23
Lec50	264.46^{hi}±2.88	152.09^{hi}±2.83	278.37^{d}±2.86	3.01^{g}±0.03	13.02^{bc}±1.43	181.49^{i}±2.87	18.96^{gh}±1.65
Lec60	261.03^{i}±4.26	149.32^{hi}±2.86	269.82^{e}±8.57	2.91^{gh}±1.13	11.18^{c}±1.43	169.09^{j}±1.46	16.71^{i}±1.44
FicFre	287.61^{f}±2.87	323.71^{e}±2.86	181.53^{i}±1.44	10.86^{de}±0.03	5.23^{ef}±1.43	29.10^{p}±4.24	105.12^{f}±2.86
FicFD	398.10^{a}±1.69	461.07^{a}±2.86	282.16^{cd}±4.47	23.40^{b}±1.44	8.09^{d}±1.43	41.68^{n}±2.87	196.31^{a}±2.86
FicSD	377.16^{b}±15.58	434.68^{b}±2.87	268.08^{e}±4.28	18.62^{c}±1.46	8.03^{d}±1.43	37.39^{no}±2.87	158.26^{b}±2.86
Fic40	348.08^{c}±31.15	411.92^{c}±0.03	241.71^{f}±2.87	18.39^{c}±1.47	7.46^{de}±1.44	33.31^{op}±1.44	148.76^{c}±4.34
Fic50	321.09^{c}±4.27	406.71^{c}±2.86	238.42^{f}±2.86	15.06^{cd}±1.47	7.32^{de}±1.44	31.27^{p}±2.86	142.28^{d}±4.27
Fic60	311.02^{d}±0.01	389.82^{d}±9.87	236.99^{f}±2.87	14.91^{cd}±1.44	7.19^{de}±1.43	29.61^{p}±2.84	137.11^{e}±2.84
PteFre	32.16^{n}±2.87	79.68^{m}±4.28	92.56^{l}±2.86	12.28^{d}±1.41	1.26^{ij}±0.03	103.90^{m}±1.41	3.64^{n}±1.44
PteFD	126.01^{k}±2.83	108.20^{j}±2.83	167.70^{j}±2.86	32.11^{a}±2.86	4.69^{f}±1.43	196.10^{h}±1.41	8.98^{ij}±1.46
PteSD	122.08^{k}±1.44	102.60^{jk}±1.55	161.10^{j}±4.24	29.98^{ab}±0.06	4.45^{f}±0.03	164.50^{j}±1.55	5.28^{l}+1.44
Pte40	98.04^{l}±2.84	98.24^{kl}±2.87	146.15^{k}±4.28	22.86^{b}±2.86	4.38^{f}±0.03	148.20^{k}±2.83	5.02^{l}±1.43
Pte50	93.06^{l}±2.86	93.16^{l}±4.27	142.11^{k}±2.84	17.72^{c}±0.06	4.35^{f}±0.06	146.12^{k}±2.84	4.94^{m}±1.44
Pte60	91.04^{l}±2.86	92.08^{l}±2.86	140.80k±2.83	14.57^{cd}±2.86	4.28^{f}±0.04	145.60^{k}±3.11	4.91^{m}±1.46
CeiFre	189.17^{j}±5.69	106.91^{jk}±1.48	79.28^{m}±5.69	4.68^{fg}±1.44	0.19^{j}±0.03	109.16^{lm}±4.27	0.8^{o}±0.06
CeiFD	316.50^{cd}±2.83	183.11^{f}±4.24	236.28^{f}±2.86	9.28^{e}±0.07	3.12^{f}±0.00	326.51^{a}±0.01	5.96^{l}±1.41
CeiSD	310.20^{d}±1.56	176.90^{f}±8.48	215.12^{g}±4.26	8.69^{e}±0.04	3.09^{fi}±0.01	316.11^{b}±1.43	5.13^{l}±1.44
Cei40	288.71^{f}±2.87	158.60^{gh}±7.07	192.81^{h}±2.84	5.94^{f}±0.04	2.00^{ij}±0.00	296.11^{c}±0.27	5.03^{l}±1.43

Cei50	282.11^{fg}±2.83	151.20^{hi}±2.83	189.61^{hi}±7.08	5.78^{f}±0.03	1.81^{ij}±0.00	281.16^{d}±0.06	4.98^{ij}±1.54
Cei60	278.71^{g}±2.84	148.11^{i}±4.24	185.70^{hi}±4.52	5.41^{f}±0.04	1.80^{ij}±0.00	275.11^{e}±1.43	4.95^{ij}±0.66
LSD	5.99	7.19	6.77	2.44	1.74	4.46	4.02

Values are means ± standard deviation of triplicate readings. Values with different lowercase superscript in the same column are significantly different (P<0.05). LecFre: *Lecanioidiscus, cupanioides* fresh leaves, LecFD: *Lecanioidiscus cupanioides* Freeze dried, LecSD: *Lecanioidiscus cupanioides* shade dried, Lec40: *Lecanioidiscus cupanioides* oven dried at 40^{o}C, Lec 50: *Lecanioidiscus cupanioides* oven dried at 50^{o}C,Lec60: *Lecanioidiscus cupanioides* oven dried at 60^{o}C, Ficfre= *Ficus ottonifolia* fresh leaves, FicFD = *Ficus ottonifolia* leaves freeze dried, FicSD = *Ficus ottonifolia* leaves shade dried, Fic 40 = *Ficus ottonifolia* leaves oven dried at 40^{o}C, *Ficus ottonifolia* leaves oven dried at 50^{o}C, Fic60 = *Ficus ottonifolia* leaves oven dried at 60^{o}C, PteFre = *Pterocarpus osun* Fresh Leaves, PteFD = *Pterocarpus osun* leaves freeze dried, PteSD = *Pterocarpus osun* leaves shade dried, Pte40 = *Pterocurpus osun* leaves oven dried at 40^{o}C, Pte50 = *Pterocarpus osun* leaves oven dried at 50^{o}C, Pte60 = *Pterocarpus osun* leaves oven dried at 60^{o}C,CeiFre = *Ceiba pontandra* fresh leaves, CeiFD = *Ceiba pentandra* leaves freeze dried, Cei40 = *Ceiba pentandra* leaves oven dried at 40^{o}C, Cei50 = *Ceiba pentandra* leaves oven dried at 50^{o}C Cei60 = *Ceiba pentandra* leaves oven dried at 60^{o}C. CeiSD = *Ceiba pentandra* leaves shade dried.

3.2. Effect of different drying methods on vitamin contents of *L.cupanioides, F. ottonifolia, P. osun and C. pentandra*

Table 2 showed results on the effect of different drying methods on the vitamin contents of *L. cupanioides, F. ottonifolia, P.osun* and *C. pentandra* leafy vegetable samples. Drying resulted to a significant decrease (p>0.05) in the vitamin (A, B_1, B_2, B_6, C and E) contents of the various leafy vegetable samples when compared with their fresh leafy samples. The results indicated that drying affected all the leafy vegetable samples in the same pattern but to different degrees. Freeze drying had the best vitamin retention effect across all the leafy vegetable samples, shade drying had the second best vitamin retention effect while oven drying at varied temperatures of 40^{o}C, 50^{o}C and 60^{o}C had gradual decrease in vitamin retention effects as the temperature increases. The order by which the various drying methods retained vitamins in the leafy vegetable samples were as follows: Freeze drying > shade drying > oven drying at 40^{o}C > oven drying at 50^{o}C > oven drying at 60^{o}C.VitaminB_1 content of both fresh and dried leafy vegetable samples obtained in this study ranged as follows: *C. cupanioides*(0.31mg/100g and 0.68mg/100g), *F.ottonifolia*(0.68mg/100g and 1.82mg/100g), *P.osun* (1.52mg/100g and 2.95mg/100g) and *C. pentandra*(0.91mg/100g and 4.22mg/100g). The vitamin B_1 content for both fresh and dried leafy vegetable samples in this study ranged between 0.31mg/100g and 4.22mg/100g which are higher than vitaminB_1 content of fresh *T, occidentalis* leaves(0.08mg/100g) as well as 0.25mg/100g for raw *P. mildbraedii* leaves (Okpalama*et al*., 2016: Amaechi *et al*., 2020). Vitamin B_1 content of both fresh and dried leafy vegetables in this study will be sufficient to provide nutritional needs of infants and children (0.02-0.06mg/day), male and female of various age groups (0.09-1.1mg/day), pregnant and lactating females (1.4mg/day) of healthy individuals (FNB/IM/NA, 1998). VitaminB_1 function as co-enzymes in carbohydrate and branched chain amino acid metabolism (FNB/IM/NA, 1998). Thiamine(Vitamin B_1) is also essential for glucose metabolism and plays a key role in nerves, muscles and heart functions in growing children, lactating and pregnant mothers(WHO,2004).

Vitamin B_2(Riboflavin) content of both fresh and dried leafy vegetable samples in this study ranged between 0.31mg/100g and 1.49mg/100g which is low when compared with (Olujuobi,2015), who reported 0.75- 1.61mg/100g as the vitamin B_2 contents of five indigenous tree leaves used as vegetable in Ekiti State. These may not meet the daily recommended requirements of 1.8-2.5mg/day for healthy individuals of all ages (EFSA, 2017). Therefore, there is need to boost vitaminB_2 intake from other food sources if any of these vegetables analyzed are used for cooking. VitaminB_2 is essential for cell development and conversion of nutrients into energy especially for growing children, lactating and pregnant women (EFSA, 2017).

Vitamin E (tocopherol) content of both fresh and dried leafy vegetable samples in this study ranged between 0.16mg/100g – 9.91mg/100g.The values obtained in this study did not agree with values (0.21mg/100g -0.44mg/100g) and (2.64mg/100g -5.13mg/100g) reported by Olujobi, (2015) and Amaechi*et al*.,(2020) for five indigenous tree leaves used as vegetables in Ekiti State and *M. oleifera* leaves. Vitamin E content of the various fresh and dried leafy vegetable samples studied would be sufficient to supply about 37.71 – 73.29% of RDA of 7mg/day for children and insufficient to supply 17.40-46.64% RDA of 11-15mg/day for male and female healthy adult individuals(FNB/IM/NA,2000). Therefore, adults will need other food source to boost their vitamin E intake. Vitamin E is essential for the production of enzymes and hormones needed for proper growth and development (Adeyeye, 2014).

Vitamin C contents of both fresh and dried leafy vegetable samples in this study ranged between 159.84mg/100g and 818.46mg/100g. The vitamin C contents obtained in this study were higher when compared with the values of vitamin C(108.38mg/100g -261.64mg/100g and 13.35mg/100g - 19.34mg/100g) obtained from five indigenous tree leaves used as vegetable in Ekiti State and *M. oleifera* reported by Olujobi (2015) and Amaechi*et al.,*(2020). Vitamin C contents of both fresh and dried leafy vegetable samples studied are capable of providing the daily recommended 15- 200mg/day vitamin C requirements for all healthy individuals (WHO, 2004). Vitamin C is essential in boosting immune system, cellular functions, prevent iron deficiency anaemia as well as promoting general wellness (WHO, 2004).

The vitamin A content of the various fresh and dried leafy vegetable samples analyzed ranged between 110.01ug/g and 548.22ug/g. The vitamin A contents obtained in this study is less than the vitamin A contents(545.77ug/g – 1097.01ug/g) obtained from five indigenous tree leaves used as vegetables in Ekiti State reported by Olujobi (2015) but higher than vitamin A contents (3.08ug/g – 10.86ug/g) obtained from *M. oleifera* leaves as reported by Amaechi *et al*.,(2020). Therefore, the consumption of these leafy vegetables in fresh or dried forms will adequately provide the daily requirements of 300-400mcg/day for males and females healthy individuals (FNB/IM/NA, 2001). Vitamin A is essential for sperm and egg development. It is also important in vision and eye health as well as cell growth and immune functions (WHO, 2004).

The results of vitamin B_6 (pyridoxal) for fresh and dried leafy vegetable samples as revealed in table2 ranged between 0.36mg/100g and 3.91mg/100g. Consumption of either fresh or dried leafy vegetable samples in this study will sufficiently meet the recommended daily needs of 1.3 – 1.7mg/day of pyrodoxin for healthy individuals (WHO, 2004). Vitamin B_6 is essential for promoting brain health, correction of red blood cells and neurotransmitters as well as help in carbohydrate, protein and fat metabolism (WHO, 2004).

Table 3.2 Effect of Different Drying Methods on Vitamin Contents of *L.cupanioides, F. ottonifolia, P. osun and C. pentandra*

Samples	Thiamine B_1(Mg/100g)	Riboflavin B_2(Mg/100g)	Tocopherol Vit E(Mg/100g)	Ascorbate Vit C (Mg/100g)	Retinol Vit A (μg/g}	Pyridoxal B_6(Mg/100g)
LecFre	0.68^{ijk}±0.01	0.71^{d}±0.01	0.32^{o}±0.3	221.17^{j}±1.17	548.22^{a}± 5.79	0.59^{i}±0.03
LecFD	0.52^{jkl}±0.06	0.68^{de}±0.07	0.27^{o}±0.04	199.02^{k}±0.85	492.31^{b}± 4.57	0.53^{ij}±0.07
LecSD	0.46^{kl}±0.03	0.50^{ef}±0.03	0.24^{o}±0.06	186.46^{kl}±2.26	398.84^{c}± 7.32	0.48^{ijk}±0.23
Lec40	0.38^{l}±0.04	0.47^{efg}±0.06	0.20^{o}±0.03	180.01^{l}±2.89	352.38^{d} ± 3.15	0.42^{jk}±0.23
Lec50	0.36^{l}±0.04	0.45^{efg}±0.06	0.18^{o}±0.01	171.92^{lm}±1.69	350.09^{d}± 2.57	0.39^{jk}±0.06
Lec60	0.31^{l}±0.23	0.42^{fgh}±0.04	0.16^{o}±0.03	159.84^{m}±1.48	313.02^{e}± 2.63	0.36^{k}±0.04
FicFre	1.82^{f}±0.06	1.49^{a}±0.38	9.91^{a}±0.03	608.54^{e}±2.09	306.17^{ef}± 4.64	2.68^{d}±0.08
FicFD	1.49^{g}±0.03	1.45^{a}±0.03	9.89^{a}±0.06	578.61^{f}±3.94	297.04^{fg}± 15.37	2.43^{ef}±0.09
FicSD	1.15^{h}±0.03	0.65^{de}±0.09	8.40^{d}±0.03	473.27^{h}±31.35	292.10^{g}± 6.99	2.38^{fg}±0.01
Fic40	0.82^{i}±0.03	0.46^{efg}±0.04	7.94^{e}±0.09	471.01^{h}±2.94	261.36^{h} ±2.84	2.30^{fg}±0.01
Fic50	0.74^{ij}±0.04	0.37^{ghi}±0.04	5.66^{g}±0.17	469.88^{h}±0.32	256.11^{h} ±19.71	2.27^{g}±0.04
Fic60	0.68^{ijk}±0.04	0.31^{hi}±0.04	3.18^{i}±0.04	431.93^{i}±4.24	241.71^{i}± 3.31	2.33^{fg}±0.07
PteFre	2.95^{b}±0.03	1.10^{bc}±0.03	9.47^{b}±0.03	818.46^{a}±10.59	261.0^{h} ± 2.60	2.92^{c}±0.04
PteFD	2.58^{c}±0.06	0.92^{cd}±0.01	9.11^{c}±0.03	760.11^{b}±8.43	211.94^{j}± 3.12	2.53^{e}±0.03
PteSD	2.39^{d}±0.03	0.68^{de}±0.03	7.87^{e}±0.03	753.07^{b}±16.14	184.69^{kl}± 2.22	2.48^{f}±0.03
Pte40	2.15^{e}±0.03	0.52^{ef}±0.01	5.94^{f}±0.04	681.99^{c}±1.81	161.7^{m}± 2.62	2.29^{fg}±0.03
Pte50	1.87^{f}±0.03	0.47^{efg}±0.03	4.11^{h}±0.03	661.02^{d}±3.12	134.06^{no}± 10.14	1.90^{h}±0.07
Pte60	1.52^{f}±0.01	0.41^{fgh}±0.04	3.26^{i}±0.42	540.16^{h}±4.16	110.01^{p}±2.89	0.59^{i}±0.01
CeiFre	4.22^{a}±0.08	1.19^{b}±0.04	1.29^{j}±0.04	619.20^{e}±4.06	188.09^{k}± 1.74	3.91^{a}±0.04
CeiFD	3.98^{a}±0.42	0.97^{c}±0.03	1.13^{jk}±0.03	591.07^{f}±5.57	172.19^{lm}± 1.65	3.46^{b}±0.06
CeiSD	3.61^{b}±0.17	0.90^{cd}±0.01	0.93^{kl}±0.04	582.60^{f}±2.88	159.01^{m} ± 1.34	3.01^{c}±0.04
Cei40	2.49^{d}±0.29	0.71^{d}±0.03	0.74^{lm}±0.03	473.20^{h}±1.99	141.92^{m}± 0.27	2.68^{d}±0.09
Cei50	1.08^{h}±0.04	0.68^{de}±0.04	0.56^{mn}±0.03	435.09i±4.28	126.34^{o}±1.30	2.44^{ef}±0.13
Cei60	0.91^{hi}±0.02	0.65^{de}±0.01	0.39^{no}±0.07	418.60^{i}±1.98	110.05^{p} ± 1.47	1.98^{h}±0.15
LSD	0.20	0.15	0.18	6.21	11.05	0.11

Values are means ± standard deviation of triplicate readings. Values with different lowercase superscript in the same column are significantly different (P<0.05). LecFre: *Lecanioidiscus, cupanioides* fresh leaves, LecFD: *Lecanioidiscus cupanioides* Freeze dried, LecSD: *Lecanioidiscus cupanioides* shade dried, Lec40: *Lecanioidiscus cupanioides* oven dried at 40°C, Lec 50: *Lecanioidiscus cupanioides* oven dried at 50°C,Lec60: *Lecanioidiscus cupanioides* oven dried at 60°C, Ficfre= *Ficus ottonifolia* fresh leaves, FicFD = *Ficus ottonifolia* leaves freeze dried, FicSD = *Ficus ottonifolia* leaves shade dried, Fic 40 = *Ficus ottonifolia* leaves oven dried at 40°C, *Ficus ottonifolia* leaves oven dried at 50°C, Fic60 = *Ficus ottonifolia* leaves oven dried at 60°C, PteFre = *Pterocarpus osun* Fresh Leaves, PteFD = *Pterocarpus osun* leaves freeze dried, PteSD = *Pterocarpus osun* leaves shade dried, Pte40 = *Pterocurpus osun* leaves oven dried at 40°C, Pte50 = *Pterocarpus osun* leaves oven dried at 50°C, Pte60 = *Pterocarpus osun* leaves oven dried at 60°C,CeiFre = *Ceiba pontandra* fresh leaves, CeiFD = *Ceiba pentandra* leaves freeze dried, Cei40 = *Ceiba pentandra* leaves oven dried at 40°C, Cei50 = *Ceiba pentandra* leaves oven dried at 50°C Cei60 = *Ceiba pentandra* leaves oven dried at 60°C. CeiSD = *Ceiba pentandra* leaves shade dried.

4. Conclusions

The findings of this study revealed that the various drying methods affected all the leafy vegetable samples in the same pattern but to different degrees resulting to moisture lose with increase in mineral and decrease in vitamin concentrations. Freeze drying had the best mineral and vitamin retention effect across all the leafy vegetable samples seconded by shade drying while oven drying at varied temperatures of 40°C, 50°C and 60°C, had gradual decrease in mineral and vitamin retention effect as the temperature increases. The difference in mineral and vitamin concentrations retention with respect to drying methods decreased in this order: Freeze drying > shade drying > oven drying at 40°C > oven drying at 50°C > oven drying at 60 °C.

Compliance with ethical standards

Acknowledgments

Special gratitude to YAHWEH most merciful for His grace to sail through this research. I acknowledge and appreciate Tertiary Education Trust Fund (TETFund), for sponsoring this research through her Institution Based Research(IBR) initiative.

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