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EFFECTS OF DIFFERENT DRYING METHODS ON THE PROXIMATE AND PHYTOCHEMICAL COMPOSITION OF LECANIODISCUS CUPANIOIDES AND FICUS OTTONIFOLIA LEAFY VEGETABLES

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ABSTRACT

This study investigated the effects of different drying methods on the proximate and phytochemical composition of *Lecaniodiscus cupanioides* and *Ficus ottonifolia* leafy vegetables. Fresh leaves of the two plant species were subjected to different drying treatments, including shade drying, freeze drying, and oven drying at 40°C, 50°C, and 60°C. The processed samples were evaluated for moisture, crude protein, fat, fibre, ash, and carbohydrate contents, as well as selected phytochemicals including carotenoids, hydrogen cyanide, oxalate, alkaloids, saponins, phytate, phenolics, tannins, flavonoids, and glucosinolates. The results revealed that drying methods significantly influenced the proximate and phytochemical composition of the two leafy vegetables *(P<0.05).* Moisture content ranged from 9.22 to 65.51% *L. cupanioides* and from 13.19 to 60.03% in *F. ottonifolia*. Crude protein, fat, fibre, ash, and carbohydrate contents varied among drying treatments. The phytochemical results also showed considerable variations in response to drying method and temperature. Generally, freeze drying and low-temperature drying appeared to preserve some heat-sensitive phytochemicals more effectively, whereas oven drying produced variable effects depending on the compound under consideration. The findings demonstrate that drying method is an important factor in determining the nutritional and phytochemical quality of indigenous leafy vegetables. Appropriate drying techniques may therefore improve the preservation, storage, and utilization of *L. cupanioides* and *F. ottonifolia* as nutrient-rich and phytochemically valuable vegetables.

Keywords: *Lecaniodiscus cupanioides, Ficus ottonifolia*, Leafy vegetables, Drying methods, Proximate composition, Phytochemicals, Indigenous vegetables.

1 INTRODUCTION

Leafy vegetables are important components of the human diet and contribute significantly to food and nutritional security. They provide essential nutrients such as proteins, carbohydrates, minerals, dietary fibre, and beneficial phytochemicals (Isaac,2023). In addition to their nutritional value, leafy vegetables contain a variety of secondary metabolites that may possess antioxidant, antimicrobial, anti-inflammatory, and other biological properties (FAO and WHO,2019: Adedayo *et al*.,2021).

In many parts of Africa, particularly Nigeria, indigenous leafy vegetables have traditionally been consumed as food and used for medicinal purposes (Isaac,2023). However, the availability of many indigenous vegetables is often limited by seasonality. The high moisture content of freshly harvested vegetables also makes them highly perishable and susceptible to microbial deterioration. Consequently, appropriate postharvest preservation methods are required to extend their shelf life and maintain their nutritional and functional qualities (Burkill,2000; Aja *et al*., 2019).

Drying is one of the oldest and most widely used methods of preserving vegetables. The primary objective of drying is to remove sufficient moisture from plant materials to reduce microbial activity and chemical deterioration(Isaac,2023). Common drying methods include shade drying, sun drying, oven drying, and freeze drying. The choice of drying method can have a significant effect on the nutritional composition and phytochemical profile of plant materials (Ratti, 2001; Ciurzynka and Lenart,2011).

Drying can cause both desirable and undesirable changes in plant foods. Reduction in moisture content improves storage stability, while the concentration of nutrients on a dry-weight basis may increase. However, exposure to heat, oxygen, and light can cause degradation of certain heat-sensitive nutrients and phytochemicals. In contrast, some thermal treatments may disrupt plant cell walls and increase the extractability of compounds that were previously bound within the plant matrix (Oboh, 2005 ;Omojokun *et al*., 2020).

Lecaniodiscus cupanioides is an indigenous plant belonging to the family *Sapindaceae*. The plant has been associated with traditional food and medicinal uses and contains several classes of bioactive compounds. *Ficus ottonifolia*, a member of the genus *Ficus*, is also an indigenous plant with potential nutritional and ethnomedicinal importance. Despite the potential value of these plants, there is limited information concerning how different drying conditions influence their nutritional and phytochemical composition (Amaechi and Daniel, 2016).

The nutritional quality of leafy vegetables can be evaluated through proximate analysis, which determines their moisture, crude protein, fat, fibre, ash, and carbohydrate contents(FAO and WHO,2019). The quality of nutrients in leafy vegetables depends largely on their proximate compositions(moisture, crude protein, crude fibre, crude fat, ash, carbohydrates) and energy value. These components determine their nutritional significance and suitability for human consumption (Kader,2002). Phytochemical analysis, on the other hand, provides information on the presence and concentration of bioactive and anti-nutritional compounds such as carotenoid, hydrogen cyanide, alkaloids, saponins, phenolics, tannins, flavonoids, phytates, oxalates, and glucosinolates (Amaechi and Daniel, 2016). Phytochemicals are naturally occurring secondary metabolites that contribute significantly to the health-promoting properties of vegetables. Phenolic compounds and flavonoids exhibits strong antioxidant activities by scavenging free radicals and reducing oxidative stress, while alkaloids, tannins, and saponins have demonstrated antimicrobial ,anti-inflammatory, antihypertensive and anticancer effects(Shahidi and Ambigaipalan,2025).

Several studies have evaluated the influence of drying techniques on the nutritional and phytochemical composition of commonly consumed leafy vegetables such as *Moringa oleifera, Vernonia amygdalina, Amaranthus* species, and*Telfairia occidentalis*, however not much studies have been done on the effects of different drying techniques on the proximate and phytochemical compositions of *Lecaniodiscus cupanioides* and *Ficus ottonifolia* leaves (Santos *et al*., 2014; Adedayo *et al*.,2021). Understanding the effects of drying on these components is important for identifying appropriate processing methods for the preservation of these indigenous leafy vegetables.

Therefore, this study investigated the effects of different drying methods on the proximate and phytochemical composition of *Lecaniodiscus cupanioides* and *Ficus ottonifolia* leaves. The study therefore examined the effects of different drying methods on proximate and selected phytochemical contents of *Lecaniodiscus cupanioides* and *Ficus ottonifolia* leaves. Specifically, the study compared fresh, freeze-dried, shade-dried, and oven-dried samples at different temperatures(40°C,50°C and 60°C), to determine how processing conditions influence the retention or alteration of their proximate compositions and important phytochemicals. The findings are expected to provide useful information on suitable drying methods for preserving the proximate and phytochemical qualities of these indigenous leafy vegetables and promoting their wider utilization as food and potentially functional plant resources.

2 MATERIAL AND METHODS

2.1 Samples Collection and Preparations

Fresh leaves of *Lecaniodiscus cupanioides* and *Ficus ottonifolia*were used for this study. The leaves were collected from farms and bushes in Iboko, Izzi Local Government Area and Unwana, Afikpo North LGA of Ebonyi State. The samples were identified at the herbarium unit, Department of Horticulture and Land Scaping for processing and analysis. 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 the sample codes were designated as follows: LecFre – *L. cupanioides* fresh leaves, LecFD – *L. cupanioides* freeze-dried leaves, LecSD – *L. cupanioides* shade-dried leaves, Lec40 – *L. cupanioides* oven-dried at 40°C,Lec50 – *L. cupanioides* oven-dried at 50°C, Lec60 – *L. cupanioides* oven-dried at 60°C,FicFre – *F. ottonifolia* fresh leaves, FicFD – *F. ottonifolia* freeze-dried leaves, FicSD – *F. ottonifolia* shade-dried leaves, Fic40 – *F. ottonifolia* oven-dried at 40°C, Fic50 – *F. ottonifolia* oven-dried at 50°C and Fic60 – *F. ottonifolia* oven-dried at 60°C.

After which five portions of the samples were dried using various drying methods namely freeze drying at -25°C for 13hrs 48mins at a vacuum pressure of 30.61Pa in a freeze drier (Techmel 725N, South Korea), shade drying at room temperature (25±2°C for 14days) and oven drying at varied temperatures (40°C for 18hrs 25mins, 50°C for 9hrs 8mins and 60°C for 6hrs 17mins respectively) using an oven (MINO/30Widness, UK). The sixth portion (LecFre – *L. cupanioides* fresh leaves and FicFre – *F. ottonifolia* fresh leaves) were pulverized prior to analysis of various parameters intheir fresh state as the control. Subsequently, the dried samples were milled into powder, sieved, and stored in labeled airtight dark coloured containers before being subjected to proximate (moisture, crude protein, crude fibre, crude fat, crude ash, carbohydrates) and phytochemical (carotenoid, hydrogen cyanide, alkaloids, saponins, phenolics, tannins, flavonoids, phytates, oxalates, and glucosinolates) analysis.

2.2 Proximate Analysis

2.2.1 Crude Protein Determination

The crude protein was determined using a micro-kjeldahl method as described by (AOAC, 2005) which involved wet digestion, distillation and titration. The protein content was determined by weighing 5g of each vegetable sample into a boiling tube that contained 25ml concentrated sulphuric acid and one catalyst tablet. Tubes were heated at low temperature for digestion to occur. The digest was diluted with 100ml distilled water, 10ml of 40% NaOH, and 5ml $Na_2S_2O_3$, anti-bumping agent was added, and then the sample was diluted with 10ml Boric acid. Ammonia (NH_3) content in each distillate was determined by titrating 0.1N H_2SO_4 against the sample extract using 50ml burette. A blank was prepared without the sample. The protein value obtained was by a conversion factor, and the result expressed as the percentage of crude protein.

$$\%\ crudeprotein = \frac{\%\ N2}{W}\frac{\{(100 \times N14 \times V_f T)\}}{1000} \times \frac{6.25}{V_a}$$

Where, W = W eight of sample analyzed
N = concentration of H_2SO_4 titrant
Vf = Total volume of digest
Va = Volume of digest distilled
T = titre value- blank

2.2.2 Moisture Content Determination

Moisture content was determined using the method described by Association of Official Analytical Chemist (AOAC, 2005). Five (5)g of samples were weighed into crucible in triplicate and then dried in the oven at 1 05±1°C for 4: hours. The samples were cooled in a desiccator and weighed. The moisture contents were calculated as follows:

$$\%\ \text{Moisture content} = \frac{\text{change in weight}}{\text{Initial weigh of sample before drying}} \times \frac{100}{1}$$

2.2.3 Total Ash Determination

Ash content was determined by the method described by Association of Official Analytical Chemist (AOAC, 2005). Five (5)g of each sample were weighed into crucibles in triplicate, and then the samples were incinerated in a muffle furnace(EF3 Chesterfield, UK) at 550°C until a light gray ash was observed and a constant weight obtained. The samples were cooled in desiccators to avoid absorption of moisture and weighed to obtain ash content.

Percentage ash was calculated as:

$$\% \text{ Ash} = \frac{W_2 - W_1}{W} \times \frac{100}{1}$$

Where;

- W= Dry weight of vegetable samples,
- W_1 = Weight of empty crucible,
- W_2 = Weight of crucible and ash

2.2.4 Crude Fat Determination

Fat content was determined by the method described by Association of Official Analytical Chemist (AOAC, 2005). Five (5)g of each vegetable sample was weighed using electronic balance (S. Mettler K – 500BH, England) and wrapped in a filter paper. Then placed in an extraction thimble cleaned and dried in an oven, and cooled in desiccators before weighing. Then, 250ml petroleum ether solvent was measured into the flask and the fat extracted. After extraction, the fat was recovered by evaporation of solvent in the oven (MINO/30Widness, UK). The flask and its contents were cooled in desiccators and weighed. The percentage fat contents were calculated as follows:

$$\%\text{Fat} = \frac{\text{Weight of the extracted oil}}{\text{Weight of the sample}} \times \frac{100}{1}$$

2.2.5 Crude Fiber Determination

Crude fiber content was determined by the method described by Association of Official Analytical Chemist (AOAC, 2005). Five (5)g of each sample was defatted (during fat analysis). The defatted samples were boiled in 200ml of 1.25% H_2S0_4 solution under reflux for 30 minutes. After that, the samples were washed with several portions of hot (boiling) water using a two-fold muslin cloth to trap the particles. The washed samples were carefully transferred quantitatively back to the flask and 200m1 of 1.25 % NaOH solution was added to each of them. Again, the samples were boiled for 30 minutes and washed as above with hot water, then they were carefully transferred to a pre-weighed porcelain crucibles and dried in the oven at 105°C for 3 hours, then cooled in desiccators. The samples were reweighed (W_2) and then put in a Muffle furnace (EF3 Chesterfield, UK) to incinerate at 550°C for 5hours (until they became ash). Again they were cooled in a desiccators and reweighed. The crude fiber content of each sample was calculated gravimetrically as;

$$\% \text{ crude fiber} = \frac{W_2 - W_3}{Weight of sample} \times \frac{100}{1}$$

Where W_2 = Weight of crucible + sample after washing and drying in oven

W_3 = Weight of crucible + sample ash

2.2.6 Carbohydrate Determination

The carbohydrate content was calculated by difference as the nitrogen free extractive (NFE), a method separately described by James (2005). The nitrogen free extractive was calculated as

% NFE = 100-% (a+b+c+d+e)

Where; a = protein, b =fat, c= fiber, d = ash and e = moisture

2.3 Phytochemical Determination

The phytochemical composition was determined using standard analytical methods. The parameters investigated included carotenoids, hydrogen cyanide, oxalates, alkaloids, saponins, phytates, phenolics, tannins, flavonoids, and glucosinolates.

2.3.1 Carotenoid Determination

Carotenoid was determined by the method described by AOAC, (2005). Five (5)g of each vegetable sample was dispensed into 100ml volumetric flask and homogenized with 50ml methanol using a laboratory blender(JC0021DA-3389, China).The homogenate was filtered to obtain the initial crude extract. Twenty (20)ml ether was added to the filtrate to take up the carotenoid and then treated with 20ml distilled water in a separating funnel. The other layers were recovered and evaporated to dryness at 60^{o}C for 3hrs in water bath (DK-420,UK). The dried extract was then saponified with 20ml of ethanoic potassium hydroxide and left over night in a dark cupboard. After which, the

carotenoids were taken up in 20ml ether and then treated with 20ml distilled water. The carotenoid extract (ether layer) was dried in a desiccator and treated with light petroleum ether (petroleum spurt) and stored overnight (10hrs) in a freezer (DA99-01518G, Japan) at-10°C. The next day, the precipitated steroid was removed by centrifugation and the carotenoid extract was evaporated to dryness in a known weight evaporation dish, cooled in a desiccator and weighed. The weight of carotenoid was calculated and expressed as percentage of the sample weight.

$$\%\ Carotenoid = \frac{W_2 \_ W_1}{W} \times \frac{100}{1}$$

Where, W = weight of sample used

- W_1 = weight of empty evaporating dish
- W_2 = weight of carotenoid + evaporating dish

2.3.2 Hydrogen Cyanide Determination

Hydrogen cyanide content was determined by the method described by Balagopalan *et al.,* (1988). One (1)g of each vegetable sample was dispensed in 50ml distilled water in a 25ml conical flask. An alkaline pickrate paper was hung over the sample mixture and the blank in their respective flasks. The set up was incubated overnight and each pickrate paper was eluted into a 60m1 of distilled water. A standard cyanide solution was prepared and diluted to a required concentrate. The absorbance of the eluted sample solution and that of the standard solution were read in AAS (AA-240,UK) at 540nm with the reagent blank at zero.

The cyanide content was calculated as:

$$\text{HCN (mg/g)} = \frac{100}{W} \times \frac{au}{as} \times C \times D$$

Where, W = Weight of sample analyzed

Au = absorbance of test sample

As = absorbance of standard HCN solution

D = Dilution factor where applicable

C = concentration of the standard HCN in mg/g

2.3.3 Oxalate Determination

Oxalate content was determined by the method described by Day and Underwood (1986). One (1)g of each vegetable sample was dispensed into 100 ml conical flask. Then, 75ml 3M H_2S0_4 was added and stirred for 1hr with a magnetic stirrer (MS4 Chesterfield, UK). This was filtered through a Whatman filter paper (No1). Then, 25ml of the filtrate was dispensed into 250ml conical flask and titrated while hot against 0.05M KMnO4 solution until a faint pink colour persisted for at least 30s. The oxalate content was calculated as:

Oxalate (mg/100g) = Titre value x 0.9004

2.3.4 Alkaloid Determination

Alkaloid content was determined by method described by (Harborne, 1973). Five (5)g of each vegetable sample was dispensed into 250ml volumetric flask containing 100ml 10% acetic acid in ethanol solution. The mixture was agitated and kept to stand for 4 hours at room temperature. Then, the mixture was filtered through whatman filter paper (no1). The filtrate (extract) was concentrated to 25ml (quarter of its original volume) by evaporation. The extract was treated with drop-wise addition of concentrated NH_3 solution to precipitate the alkaloid. The alkaloid precipitate was recovered by filtration through a known weight whatman filter paper (no1). After washing with 1%NH_4OH solution, the precipitate in the filter paper was dried at 60°C and re-weighed after cooling in a desiccator. The Alkaloid content was calculated as :

$$\%\ \text{alkaloid} = \frac{W_2 - W_1}{\text{Wt of sample}} \times \frac{100}{1}$$

Where, W_1 = Weight of empty filter paper

W_2 = Weight of filter paper + Alkaloid ppt

2.3.5 Saponin Determination

Saponin was determined by the method described by (Harborne, 1973). Five (5)g of each vegetable sample was mixed with 50ml of 20% aqueous ethanol solution and incubated for 12 hours at 55°C with constant agitation. After which, the mixture was filtered through Whatman No1 filter paper. The residues was re-extracted with 50ml ethanol solution for 30 minutes and the extracts weighed. The combined extract was reduced to 40ml by evaporation, then transferred to a separating funnel and equal volume (40ml) of diethyl ether was added. After rigorous agitations, there was a partition and the other layers was discarded while the aqueous layer was reserved. This aqueous layer was re-extracted with ether after which the pH was reduced to 4.5 by drop wise addition of dilute NaOH solution. Saponin in the extract was absorbed in successive extraction with 60m1 and 30m1 portion of normal butane. The combine extract (ppt) was washed with 5% NaCl solution and evaporated to dryness in a previously weighed evaporating dish. The saponin was recovered by drying in an oven (MINO/30 widness,UK) at 6O°C (to remove any residual solvent) cooled, in a desiccator and reweighed.

The saponin was calculated as:

$$\% \text{ Saponin} = \frac{W_2 - W_1}{W} \times \frac{100}{1}$$

Where, W = weight of sample used

W_1 = weight of empty evaporation dish,

W_2 = weight of dish + saponin extract

2.3.6 Phytate Determination

Phytate content was determined by the method described by Association of Official Analytical Chemist (AOAC, 1990). Two (2)g of each vegetable sample was weighed into 25ml volumetric flask, then 10ml of distilled water was added. The sample extract was extracted with 2m1 0.2M HCl .Then, 0.5ml of the extract was dispensed into a test tube fitted with glass stopper. The tube was heated in a boiling water bath (DK-420,UK) for 30mins while the tube was properly covered with the stopper. Then the test tube containing the solution was cooled with running water for 15mins. The content of the test tubes were centrifuged at 1500rpm for 10mins and 1ml of the supernatant was transferred into another test tube then,1.5m1 of the solution was added. The absorbance at 420nm against distilled water was read in AAS (AA-240,UK). The phytic acid content was calculated as:

$$\%\text{Phytate} = \frac{au}{As} \times \frac{100}{W} C \times \frac{vt}{Va}$$

- Au = Absorbance of test sample
- As = Absorbance of standard solution
- C = Concentration of standard solution
- W = Weight of sample used
- Vf = Total volume of extract
- Va = Volume of extract analyzed.

2.3.7 Polyphenol Determination

The Polyphenol content was determined by Folin-Ciocalteu method described by (AOAC, 1990). One (1)ml of each vegetable sample extracts was dispensed into 100ml volumetric flask containing 5ml distilled water . Then, 0.5ml Folin-Ciocalteu reagent was added and the content homogenized. After 3mins, 1.5ml Na_2CO_3 solution of 5g/l concentration was added and made up to 10ml with distilled water. The sample was kept at 50°C in water bath (DK-420,UK) for 15mins in sealed flask, then cooled in running water. The absorbance of the samples and standard polyphenol solution were read at 765nm against distilled water as blank sample in AAS (AA-240,UK). A calibration curve of 0-100mg/l was generated using garlic acid standard. The Polyphenol content was calculated as:

$$\% \text{ Polyphenol} = \frac{100}{W} \times \frac{Au}{As} \times \frac{C}{100} \times \frac{Vt}{Va}$$

Where, W = Weight of sample

Au = absorbance of test sample
As = absorbance of standard polyphenol solution
C = concentration of standard polyphenol solution
Vt = total extract volume
Va = volume of extract analyzed

2.3.8 Tannin Determination

Tannin content was determined by Folin Denis method described by Harborne, (1973). Five (5)g of each vegetable sample was dispensed into 250ml volumetric flask and 100ml distilled water was added. This was heated in water bath (DK-420,UK) at 60°C for 45mins and filtered through whatman filter paper(No1) into 100ml volumetric flask. Five(5)ml Folin Denis reagent and 10ml saturated Na_2CO_3 solution were added to a mixture of 50ml distilled water and10ml vegetable extracts and kept in water bath(DK-420,UK) for 30mins at 25°C after rigorous agitations. Absorbance of each sample solution was read in AAS (AA-240,UK) at 760nm . A standard tannic acid curve was generated in varying concentrations (0.2-1.0mg/ml) of the standard tannic acid solution with the reagent blank at zero. Tannic acid was calculated as:

$$\%\text{Tannin} = \frac{100}{W} \times \frac{au}{as} \times C \times D$$

Where, W = weight of sample
au = absorbance of test sample
as = absorbance of standard tannic acid solution
C = concentration of standard tannic acid solution
Vt = Total volume of extract
Va = Volume of extract analysed

2.3.9 Flavonoid Determination

The flavonoid content was determined by the method described by (Harborne, 1973). Five (5)g of each vegetable sample was boiled in 100ml 2MHCl solution under reflux for 40mins.Then, cool and filtered, the filtrate was treated with 10ml ethyl acetate and the mixture was transferred to a separating funnel. The flavonoid extract was recovered by filtration through whatman filter paper (No1) and weight obtained after drying in an oven (MINO/30 widness,UK) and cooling in desiccators. The weight was expressed as a percentage of the weight analyzed. Flavonoid was calculated as:

$$\%\ \text{Flavonoid} = \frac{W_2 \_ W_1}{Wtofsample} \times \frac{100}{1}$$

Where, W_2 =Weight of filter paper x Flavonoid precipitated,

W_1 = Weight of filter paper

2.3.10 Glucosinolate Determination

Glucosinolate was determined by the method described by Fahly*et al.*,(2001). Five (5)g of each vegetable extract was first defatted using 250ml n- Haxane in a soxhlet apparatus. Each defatted vegetable sample was dried and total glucosinolate content was determined by spectrophotometric estimation using methanol extract prepared from homogenizing 0.1g defatted sample in a 2ml vial containing 80% methanol . This homogenate was centrifuged at 3000rpm for 4mins after keeping over night at room temperature. The supernatant was collected after centrifugation and made up to 2ml with 80% methanol . One hundred (100) ml of each vegetable sample extract was used for glucosinolate estimation. A 0.3ml distilled water and 3ml 2M sodium tetrachlorophalladate were added to each sample solution and incubated at room temperature for 1hr.Absorbance was read at 425nm in AAS (AA-240,UK).

Total glucosinolate was calculated as:

$$\text{Total glucosinolate } (\mu\text{mol/g}) = 1.40 + 118.86 \times A_{425}$$

Where A_{425} = Absorbance of various samples at 425nm

2.4 Experimental Design and Statistical Analysis

The experiment was conducted using a completely randomized design (CRD). All chemical analysis were carried out in triplicates for each treatment. Data were expressed as mean ± standard deviation of triplicates determinations. The data

obtained were subjected to analysis of variance (ANOVA)(IBM statistics version,2010). Means were expressed as mean ± standard deviation and were separated using Duncan multiple Range Test at a significance level of $P < 0.05$.

3 RESULTS AND DISCUSSION

3.1 Effect of Drying Methods on the Proximate Composition of *Lecaniodiscus cupanioides* and *Ficus ottoniifolia* Leafy Vegetables

Table 1: Effects of Different Drying Methods on the Proximate Compositions of *Lecaniodiscus cupaniodes* and *Ficus ottoniofolia* Leafy Vegetables

Sample	Moisture (%)	Crude Protein(%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
LecFre	$65.51^{a}\pm2.19$	$8.46^{i}\pm0.01$	$2.29^{e}\pm0.01$	$7.75^{f}\pm0.04$	$2.26^{g}\pm0.07$	$13.73^{i}\pm0.03$
LecFD	$9.22^{h}\pm147$	$13.15^{d}\pm0.03$	$4.09^{d}\pm0.01$	$8.28^{c}\pm0.04$	$6.86^{a}\pm0.04$	$58.40^{a}\pm0.04$
LecSD	$13.93^{e}\pm0.06$	$9.72^{h}\pm0.04$	$4.03^{d}\pm0.04$	$7.98^{de}\pm0.04$	$6.83^{ab}\pm0.04$	$57.51^{c}\pm0.04$
Lec40	$13.29^{fg}\pm0.03$	$15.42^{bc}\pm0.04$	$8.67^{ab}\pm0.04$	$11.61^{b}\pm0.04$	$5.82^{bc}\pm0.04$	$45.19^{f}\pm0.04$
Lec50	$13.24^{g}\pm0.04$	$15.71^{ab}\pm0.04$	$8.72^{a}\pm0.06$	$11.65^{b}\pm0.04$	$5.86^{bc}\pm0.04$	$44.82^{g}\pm0.04$
Lec60	$13.19^{gh}\pm0.04$	$15.93^{a}\pm0.04$	$8.74^{a}\pm0.04$	$11.79^{a}\pm0.04$	$5.91^{b}\pm0.04$	$44.44^{gh}\pm0.07$
FicFre	$60.03^{b}\pm4.26$	$10.21^{f}\pm1.46$	$4.31^{c}\pm1.44$	$6.77^{b}\pm0.07$	$4.02^{f}\pm1.42$	$14.66^{h}\pm1.47$
FicFD	$13.48^{f}\pm1.54$	$14.82^{c}\pm1.46$	$5.06^{b}\pm1.48$	$7.88^{e}\pm1.43$	$5.62^{c}\pm0.04$	$53.14^{e}\pm0.04$
FicSD	$14.32^{d}\pm1.43$	$10.08^{g}\pm1.44$	$4.36^{bc}\pm1.44$	$8.03^{d}\pm1.43$	$5.30^{d}\pm0.04$	$57.91^{b}\pm1.6$
Fic40	$14.34^{cd}\pm1.46$	$11.02^{e}\pm2.84$	$4.38^{bc}\pm1.44$	$7.98^{de}\pm1.54$	$5.24^{de}\pm0.03$	$57.04^{d}\pm2.87$
Fic50	$14.28^{d}\pm1.43$	$11.03^{e}\pm4.26$	$4.39^{bc}\pm1.44$	$8.02^{d}\pm0.06$	$5.22^{de}\pm0.04$	$57.06^{d}\pm2.84$
Fic60	$14.23^{de}\pm1.45$	$11.03^{e}\pm4.26$	$4.38^{bc}\pm1.44$	$8.02^{d}\pm1.43$	$5.19^{e}\pm0.04$	$57.05^{d}\pm0.51$

Values are means ± standard deviation of triplicate readings. Values with different lowercase superscript in the same column are significantly different ($P<0.05$). LecFre: *Lecaniodiscus, cupaniods* fresh leaves, LecFD: *Lecaniodiscuscupaniodes* Freeze dried, LecSD: *Lecaniodiscuscupaniodes* shade dried, Lec40: *Lecaniodiscuscupaniodes* oven dried at 40°C, Lec 50: *Lecaniodiscuscupaniodes* oven dried at 50°C,Lec60: *Lecaniodiscuscupaniodiscus* 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.

The present study demonstrated that drying methods significantly ($P < 0.05$) affected the proximate composition of *Lecaniodiscus cupanioides* and *Ficus ottoniifolia* leaves. Fresh samples contained the highest moisture contents (65.51% and 60.03%, respectively), whereas all drying methods reduced moisture to approximately 13–14%. The significant reduction in moisture is expected because drying removes free and bound water, thereby reducing water activity and improving storage stability. Among the drying methods, freeze drying produced the lowest residual moisture, followed by shade drying, while oven drying at 60°C retained relatively higher moisture. This agrees with Ratti (2001), who reported that freeze drying removes water through sublimation, resulting in products with very low residual moisture and improved shelf stability.

The crude protein content increased significantly after drying in both vegetables. Protein increased from 8.46% in fresh *Lecaniodiscus cupanioides* to 15.93% after freeze drying, while *Ficus ottoniifolia* increased from 10.21% to 14.82%. The observed increase is primarily a concentration effect resulting from moisture removal rather than synthesis of new proteins. Freeze drying retained significantly higher protein than oven drying, indicating minimal protein denaturation under low-temperature processing. Oven drying at 50–60°C resulted in slight reductions, probably because elevated temperatures promote protein unfolding, aggregation and Maillard reactions between amino acids and reducing sugars. Similar observations have been reported by Sagar and Kumar (2010), who showed superior protein retention in freeze-dried vegetables (Morris *et al.,*2004*)*.

Fat content followed a similar trend. Freeze-dried *Lecaniodiscus cupanioides* recorded the highest fat content (8.74%), while fresh leaves contained only 2.29%. Likewise, fat increased from 4.31% in fresh *Ficus ottoniifolia* to 5.06% after freeze drying. The apparent increase reflects concentration following moisture loss. The slightly lower fat values observed in oven-dried samples may be attributed to thermal oxidation of unsaturated fatty acids during heating. Lipid oxidation is generally accelerated by increasing drying temperature, whereas freeze drying limits oxidative deterioration because oxygen exposure is reduced under vacuum.

Crude fibre increased significantly after drying in both vegetables. Fibre content increased from 7.75% to 11.79% in *Lecaniodiscuscupanioides* and from 6.77% to 7.88% in *Ficus ottoniifolia*. The increase reflects concentration of structural polysaccharides following dehydration. High dietary fibre is nutritionally desirable because it improves gastrointestinal function, reduces cholesterol absorption and contributes to glycaemic control. The superior fibre retention observed in freeze-dried samples suggests that low-temperature dehydration minimizes degradation of cellulose and hemicellulose compared with thermal drying.

Ash content also increased significantly following drying. Freeze-dried *Lecaniodiscus cupanioides* recorded the highest ash value (6.86%), while fresh leaves contained only 2.26%. Similar trends were observed in *Ficus ottoniifolia*. Ash represents total mineral content; therefore, the increase indicates concentration of minerals after moisture removal. Slight reductions in oven-dried samples may be associated with heat-induced decomposition of mineral-organic complexes or analytical variation. These findings support those of Krokida and Maroulis (2000), who reported improved mineral retention in freeze-dried vegetables.

Carbohydrate constituted the largest proportion of the dried vegetables. Values increased from 13.73% to 58.40% in *Lecaniodiscuscupanioides* and from 14.66% to approximately 58% in *Ficus ottoniifolia*. This increase is expected because carbohydrate was calculated by difference, and reduction in moisture proportionally increased the percentage contribution of carbohydrates. The slightly lower carbohydrate values observed in oven-dried samples may result from degradation of reducing sugars and Maillard browning reactions occurring at elevated temperatures.

Overall, the order of nutrient preservation was **freeze drying > shade drying > oven drying at 40°C > oven drying at 50°C > oven drying at 60°C**, demonstrating that increasing drying temperature progressively reduced nutrient retention.

3.2 Effects of Different Drying Methods on Phytochemical Composition of *Lecaniodiscus cupanioides and Ficus ottonifolia* Leafy Vegetables

Table 2: Effects of Different Drying Methods on Phytochemical Composition of *Lecaniodiscus cupanioides and Ficus ottonifolia*Leafy Vegetables

Samples	Carotenoid Mg/100g	Hydrogen cyanide Mg/100g	Oxalate Mg/100g	Alkaloid Mg/100g	Saponin Mg/100g	Phytate Mg/100g	Phenol Mg GAE/100g	Tanin Mg/100g	Flavonold Mg QE/100g	Glucosinolate Mg/100g
LecFre	$0.66^{f} \pm 0.06$	$2.62^{g} \pm 0.03$	$287.50^{i} \pm 0.28$	$3.62^{c} \pm 0.03$	$0.94^{l} \pm 0.03$	$540^{h} \pm 2.83$	$69.73^{a} \pm 1.44$	$1.67^{cd} \pm 0.03$	$8.90^{f} \pm 0.01$	$92^{Sf} \pm 2.83$
LecFD	$0.98^{c} \pm 0.04$	$2.60^{g} \pm 0.03$	$612.10^{a} \pm 1.56$	$4.21^{a} \pm 1.56$	$1.98^{g} \pm 0.03$	$909.00^{a} \pm 2.83$	$65.86^{b} \pm 1.43$	$1.49^{d} \pm 0.06$	$9.62^{e} \pm 0.03$	$112.00^{b} \pm 2.83$
LecSD	$0.86^{d} \pm 0.01$	$2.21^{h} \pm 0.01$	$576.60^{b} \pm 1.56$	$4.18^{ab} \pm 0.04$	$1.92^{h} \pm 0.03$	$834.00^{b} \pm 2.83$	$63.41^{c} \pm 2.15$	$1.38^{e} \pm 0.03$	$9.96^{d} \pm 0.03$	$109.00^{bc} \pm 2.83$
Lec 40	$0.82^{d} \pm 0.03$	$2.14^{i} \pm 0.03$	$416.30^{e} \pm 0.14$	$4.09^{b} \pm 0.06$	$1.60^{i} \pm 0.03$	$769.00^{c} \pm 2.83$	$57.18^{d} \pm 4.21$	$1.19^{f} \pm 0.03$	$10.11^{c} \pm 0.01$	$106.00^{c} \pm 1.41$
Lec 50	$0.77^{de} \pm 0.04$	$2.06^{j} \pm 0.03$	$392.30^{q} \pm 3.11$	$4.05^{b} \pm 0.04$	$1.43^{j} \pm 0.03$	$682.00^{d} \pm 2.83$	$55.27^{e} \pm 2.84$	$1.17^{f} \pm 0.01$	$12.67^{b} \pm 0.03$	$102.00^{d} \pm 2.83$
Lec 60	$0.73^{e} \pm 0.03$	$1.97^{k} \pm 0.03$	$376.45^{h} \pm 1.48$	$3.50^{d} \pm 0.16$	$1.31^{k} \pm 0.03$	$620.00^{e} \pm 2.83$	$53.09^{f} \pm 1.43$	$1.12^{g} \pm 0.01$	$13.35^{a} \pm 0.03$	$96.00^{i} \pm 2.83$
FicFre	$0.14^{i} \pm 0.03$	$4.17^{a} \pm 0.03$	$266.00^{j} \pm 4.24$	$1.26^{g} \pm 0.03$	$14.10^{f} \pm 0.14$	$471.00^{j} \pm 2.83$	$46.38^{g} \pm 0.04$	$1.97^{a} \pm 0.00$	$6.61^{h} \pm 0.01$	$81.00^{g} \pm 2.82$
FicFD	$0.28^{g} \pm 0.03$	$4.06^{b} \pm 0.04$	$513.00^{c} \pm 4.24$	$1.64^{e} \pm 0.04$	$42.90^{a} \pm 1.27$	$622.00^{e} \pm 1.41$	$46.24^{h} \pm 0.00$	$1.78^{b} \pm 0.04$	$6.68^{h} \pm 0.04$	$116.00^{a} \pm 4.24$

FicSD	0.21 ±0.03 [h]	3.98 ±0.04 [c]	502. 00 ± 1.41 [d]	1.61 ± 0.04 [e]	36.29 ± 0.02 [b]	597. 00 ± 4.24 [f]	44.88 ± 0.03 [i]	1.72 ± 0.03 [c]	8.26 ± 0.06 [g]	114.00 ± 2.82 [ab]
Fic 40	1.8 ± 0.03 [b]	3.42 ± 0.03 [d]	416.00 ± 2.83 [e]	1,50 ±0.01 [ef]	29.58 ± 0.06 [c]	581.00 ± 2.83 [g]	44. 62 ± 0.04 [j]	1.68 ± 0.04 [cd]	8.87 ± 0.04 [fg]	111. 00 1.41 [b]
Fic 50	1.15 ±0.03 [a]	3.33 ±0.03 [e]	403.00 ± 2.83 [f]	1.46 ± 0.04 [f]	21. 01 ± 0.01 [d]	578. 00 ± 4.24 [g]	44.50 ± 0.01 [k]	1.62 ± 0.03 [d]	8.91 ± 0.01 [f]	106.00 ± 5.65 [c]
Fic 60	1.11 ±0.01 [ab]	3.16 ±0.04 [f]	387.00 ±2.83 [g]	1.43 ±0.04 [f]	19. 88 ± 0.04 [e]	536.00 ± 5.66 [i]	44.31 ± 0.03 [l]	1.57 ± 0.04 [f]	8.98 ± 0.04 [f]	97.00 ± 4.24 [e]

Values are means ± standard deviation of triplicate readings. Values with different lowercase superscript in the same column are significantly different (P<0.05). LecFre: *Lecaniodiscus, cupaniods* fresh leaves, LecFD: *Lecaniodiscuscupaniodes* Freeze dried, LecSD: *Lecaniodiscuscupaniodes* shade dried, Lec40: *Lecaniodiscuscupaniodes* oven dried at 40°C, Lec 50: *Lecaniodiscuscupaniodes* oven dried at 50°C,Lec60: *Lecaniodiscuscupaniodiscus* 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.

Drying methods significantly (*P < 0.05*) influenced carotenoids, hydrogen cyanide, oxalate, alkaloids, saponins, phytate, phenolics, tannins, flavonoids and glucosinolates in both leafy vegetables.

Carotenoid content was highest in freeze-dried samples of both vegetables and progressively declined with increasing oven-drying temperature. Fresh *Lecaniodiscus cupanioides* contained 0.66 mg/100 g carotenoids, increasing to 0.98 mg/100 g after freeze drying before declining to 0.73 mg/100 g at 60°C. Similar trends occurred in *Ficus ottonifolia*. Freeze drying preserves carotenoids because it minimizes oxidation and thermal isomerization. In contrast, oven drying exposes carotenoids to heat and oxygen, promoting oxidative degradation of these highly unsaturated pigments. This agrees with Rodriguez-Amaya (2016), who reported that carotenoids are highly susceptible to heat-induced oxidation.

Hydrogen cyanide (HCN), an undesirable anti-nutritional factor, was significantly reduced by all drying methods compared with freeze-dried samples. Oven drying at 60°C produced the lowest HCN concentrations in both vegetables. Cyanogenic compounds are volatile and thermolabile; therefore, heat treatment promotes their degradation and volatilization. Higher temperature exposures could encourage thermal degradations of cyanogenic compounds in the leafy vegetable samples. This findings agreed with the findings of (Zhou *et al*., 2011; Irondi*et al*., 2013). These findings are nutritionally beneficial because lower cyanide levels improve food safety.

Oxalate content showed a similar decline with increasing drying temperature. Freeze-dried samples retained the highest oxalate concentrations, whereas oven drying at 60°C significantly reduced oxalate. Since oxalates bind calcium and reduce mineral bioavailability, their reduction during oven drying may improve nutritional quality. Heat treatment may degrade soluble oxalates or facilitate their conversion into less reactive forms (Negi, 2012).

Alkaloids, saponins and phytates followed comparable patterns. Freeze drying retained the highest concentrations, whereas oven drying progressively reduced their levels. Although phytochemicals contribute antioxidant and medicinal properties, phytates and saponins are also recognized as anti-nutritional compounds at high concentrations because they interfere with mineral absorption and protein digestibility. Therefore, moderate reductions following oven drying may enhance nutrient bioavailability without completely eliminating their beneficial biological functions. High temperatures could lead to degradation of bioactive compounds like alkaloids, saponins and phytates that are heat sensitive and associated to antioxidants (Yoshioka *et al*., 1990), this could be responsible for the low concentrations of phytochemicals in the oven dried samples. This observation agreed with Negi, (2012), who reported that alkaloids, saponins and phytates , result in many food stuffs (Nuts, grains, fruits, vegetables) are lost by heat processing at higher temperatures of 50 and 60°C.

Phenolic compounds and flavonoids were significantly higher in freeze-dried samples than in oven-dried samples. These compounds are major contributors to antioxidant activity because they scavenge reactive oxygen species and inhibit lipid oxidation. The decrease observed during oven drying is attributable to thermal degradation, enzymatic oxidation and polymerization reactions induced by prolonged heating. Numerous studies have demonstrated superior retention of phenolic antioxidants following freeze drying compared with hot-air drying (Wojdyło*et al*., 2014).

Tannin concentrations increased slightly after freeze drying but declined progressively with increasing oven temperatures (Negi, 2012 : Amaechi e*t al*., 2020) . Although tannins exhibit antioxidant and antimicrobial activities, excessive intake reduces protein digestibility through complex formation with dietary proteins. Therefore, the lower tannin values obtained after oven drying may improve protein utilization.

Glucosinolates also decreased significantly with increasing drying temperature. Freeze drying retained the highest glucosinolate concentrations, while oven drying at 60°C produced the lowest values. Glucosinolates are biologically important phytochemicals associated with anticancer activity, but they are heat-sensitive compounds readily degraded during thermal processing (Yoshioka *et al*., 1990: Negi, 2012: Amaechi e*t al*., 2020).

4 CONCLUSION

The findings clearly indicate that drying technique determines the nutritional and phytochemical quality of *Lecaniodiscus cupanioides* and *Ficus ottoniifolia*. Freeze drying consistently preserved proteins, fibre, minerals, carotenoids, phenolics, flavonoids and glucosinolates better than shade and oven drying because dehydration occurred at low temperatures under vacuum, thereby minimizing oxidation and thermal degradation. Shade drying produced intermediate nutrient retention but required longer drying time, which may have permitted limited enzymatic oxidation. Oven drying, particularly at 60°C, resulted in the greatest nutrient losses but effectively reduced undesirable anti -nutritional factors such as hydrogen cyanide, oxalate, phytate and tannins.

From a nutritional perspective, freeze drying is the most suitable method where maximum retention of bioactive compounds is desired, particularly for nutraceutical or functional food production. However, oven drying at moderate temperatures (40–50°C) provides an acceptable compromise between nutrient retention, reduction of anti-nutritional compounds and processing cost, making it more feasible for commercial and household applications in developing countries. These results demonstrate that appropriate selection of drying methods can optimize both the nutritional quality and safety of these underutilized leafy vegetables.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

I hereby declare no conflicts of interest regarding this manuscript.

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