Comparative Evaluation of Traditional Processing Methods on the Nutritional Quality of *Bryophyllum pinnatum* (Lam.) Leaves.

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ABSTRACT

Bryophyllum pinnatum is a medicinal plant valued for its bioactive constituents and nutritional properties. This study investigated the effects of water blanching, sun drying, shade drying, and pan-roasting on the mineral and vitamin profiles of *B. pinnatum* leaves, using fresh leaves as controls. Mineral concentrations were determined by atomic absorption spectrophotometry, Nitrogen by Kjeldahl digestion, Phosphorus by vanadomolybdate colorimetry, and vitamins by HPLC and spectrophotometric methods. Shade drying significantly ($p < 0.05$) preserved Magnesium (23.60 mg/100g), Potassium (7.29 mg/100g), Nitrogen (3.07%), Phosphorus (0.54%), Vitamins A (3.19 mg/100g), C (291.98 mg/100g), and B1 (25.99 mg/100g) compared to other treatments. Conversely, roasting enhanced B2 (0.54 mg/100g) and B3 (0.07 mg/100g) retention. Blanching caused the greatest nutrient losses through thermal degradation and leaching, while sun drying demonstrated moderate preservation. These findings demonstrate that processing methods

profoundly influence the nutritional quality of *B. pinnatum*, with shade drying offering the optimal balance for nutrient retention. This research provides evidence-based guidance for post-harvest processing of *B. pinnatum* in traditional medicine and functional food applications.

Keywords: *Bryophyllum pinnatum,* post-harvest processing, nutrient retention, shade drying, traditional medicine

INTRODUCTION

The global resurgence of interest in plant-based therapeutics and functional foods has intensified scientific investigation into indigenous medicinal species (Achilonu *et al*., 2023). Traditional knowledge systems have long recognized the therapeutic value of numerous plant species, many of which serve as dual-purpose resources providing both nutrition and medicinal benefits (Korus, 2021). However, the translation of these traditional applications into evidence-based practice requires rigorous scientific validation, particularly regarding the effects of post-harvest processing on bioactive compound stability and nutrient bioavailability.

Bryophyllum pinnatum (Lam.) Oken (syn. Kalanchoe pinnata), belonging to the Crassulaceae family, is a succulent plant indigenous to tropical regions of Africa, Asia, and South America (Gill, 1992; Devbhuti *et al*., 2012). Traditionally known as "miracle leaf" or "life plant," it has been employed in ethnomedicine for managing gastrointestinal disorders, inflammatory conditions, hypertension, and dermatological infections (Akinpelu, 2008; Ojewole, 2002; Ali, 2013). Recent phytochemical investigations have identified an array of bioactive compounds, including bufadienolides, flavonoids, and phenolic acids, contributing to its anti-inflammatory, antimicrobial, antioxidant, and antihypertensive properties (Dhumane *et al*., 2024; Gupta *et al*., 2016). Additionally, *B. pinnatum* leaves are rich in essential minerals (calcium, magnesium,

potassium, zinc, iron) and vitamins (ascorbic acid, thiamine, niacin), making it a valuable nutritional resource (Milad *et al*., 2014).

Despite its widespread traditional use and promising nutritional profile, few studies have examined how common processing techniques influence nutrient retention in *B. pinnatum*. Post-harvest processing—including drying, roasting, and blanching is essential for preservation, but can significantly alter the nutritional composition of plant materials through mechanisms including thermal degradation, oxidative reactions, and leaching of water-soluble compounds (Korus, 2021; Verma *et al*., 2017). Understanding these processing effects is critical for optimizing the nutritional and therapeutic potential of *B. pinnatum*.

This study therefore aimed to: (i) evaluate the effects of four traditional processing methods (water blanching, sun drying, shade drying, and pan-roasting) on the mineral and vitamin composition of B. pinnatum leaves; (ii) identify processing conditions that maximize nutrient retention; and (iii) provide evidence-based recommendations for post-harvest handling of this plant in traditional medicine and food applications

MATERIALS AND METHODS

Plant Collection and Authentication

Fresh leaves of *Bryophyllum pinnatum* were collected in the early morning (06:00-07:00 h) from the Botanical Garden of the Department of Plant Biology, University of Ilorin, Nigeria (coordinates: 8.479° N, 4.542° E). The plant was identified and authenticated at the herbarium unit of the Department of Plant Biology, University of Ilorin with the voucher specimen number UILH/001/909/2026. Leaves were sorted for uniformity of maturity, cleaned with distilled water to remove surface contaminants, and processed within 4 h of collection.

Processing Methods

Fresh leaves were divided into five batches (500g each) and subjected to the following treatments:

a. Water Blanching (T1): Leaves were immersed in boiling distilled water (100°C) for 3 minutes, immediately transferred to ice-water (4°C) for 2 minutes to halt thermal degradation, drained, and freeze-dried (-50°C, 48h) before grinding.

b. Shade Drying (T2): Leaves were spread on mesh trays (2 cm thickness) and dried in a well-ventilated room (25±2°C, relative humidity 60±5%) protected from direct sunlight for 22 days until constant weight.

c. Sun Drying (T3): Leaves were spread on mesh trays (2 cm thickness) and exposed to direct sunlight (average daytime temperature 32±3°C, relative humidity 55±8%) for 22 days, with periodic turning, until constant weight.

d. Pan Roasting (T4): Leaves were roasted in a stainless-steel pan over a gas flame (surface temperature 150±5°C) with continuous stirring for 10 minutes until they became crispy and slightly browned.

e. Fresh Leaves Control (T5): Untreated fresh leaves were freeze-dried (-50°C, 48h) immediately after collection.

All dried samples were ground to a fine powder (<0.5 mm particle size) using a laboratory blender, passed through a 60-mesh sieve, and stored in airtight amber glass containers at -20°C until analysis.

Mineral Digestion Procedure

Approximately 2 g of each powdered sample was weighed into 100 mL Kjeldahl digestion tubes. A digestion mixture containing 50 mL of normal HCl and 10 mL of concentrated HNO_3 was added to each tube. An acid blank was prepared simultaneously to monitor possible contamination. The mixtures were heated using a Kjeldahl digestion unit until clear solutions were obtained. After cooling, the digested samples were filtered using Whatman filter paper (125 mm), and the filtrates were diluted to 100 mL with deionized water.

Standard solutions of Mg, Cu, Fe, Zn, K, Na, and P were prepared according to the manufacturer's instructions for calibration of the Atomic Absorption Spectrophotometer (Bulk Scientific Model 231). Each mineral was analyzed at its specific wavelength, and calibration curves were generated from the standard solutions. Mineral concentrations in the samples were subsequently calculated from the corresponding calibration curves.

Determination of Nitrogen

Nitrogen content was determined using the Kjeldahl method according to AOAC (2010). One gram of each sample was digested with 20 mL of concentrated sulfuric acid (H_2SO_4) in the presence of a Kjeldahl catalyst mixture containing potassium sulfate (K_2SO_4) and copper sulfate ($CuSO_4$). The digestion process continued until a clear greenish solution was obtained. After cooling, the digest was diluted with distilled water.

The mixture was then distilled following the addition of 40% sodium hydroxide to liberate ammonia. The released ammonia was collected in a receiving flask containing boric acid solution

with a mixed indicator. The distillate was titrated with 0.1 N HCl until a colour change from blue to pink was observed. Nitrogen content was calculated using the standard Kjeldahl formula:

$$\%\text{Nitrogen (N)} = \frac{vol.\ of\ HCL\ used \times Normality\ of\ HCL \times 14.007}{Mass\ of\ sample \times 100}$$

Determination of Phosphorus

Phosphorus concentration was determined using the vanadomolybdate method as described by AOAC (2010). Approximately 0.5 g of the digested sample was transferred into a 50 mL volumetric flask. Distilled water and vanadomolybdate reagent were added, and the solution was diluted to volume. After standing for 30 minutes for colour development, absorbance was measured at 420 nm using a spectrophotometer. Phosphorus concentrations were determined from a calibration curve prepared using standard phosphorus solutions.

Vitamin Analysis

Vitamin A content was determined using the colorimetric method described by AOAC (2010). Approximately 2 g of the sample was saponified with alcoholic KOH in the presence of pyrogallol in a water bath. The mixture was extracted with hexane, dried over anhydrous sodium sulfate, and evaporated. The residue was dissolved in chloroform and reacted with antimony trichloride solution. Absorbance was measured at 620 nm using a spectrophotometer and Vitamin A was calculated using the provided formula.

$$\text{Vitamin A (mg)} = \text{A620nm x SL } \frac{V}{Wt}$$

Where:

A620nm = absorbance at 620nm wavelength

SL = slope of standard curve ($\frac{Vitamin\ A}{A620nm\ reading}$)

V = final volume in colorimetric tube

Wt = weight of sample

Vitamin B_1 (thiamine) was determined according to the AOAC (2010) procedure. Samples were extracted with 0.2 N HCl, heated, and enzymatically treated with phosphate enzyme solution. The extracts were purified and oxidized, and fluorescence intensity was measured using a fluorescence reader. Thiamine concentration was calculated from the fluorescence readings relative to the standard.

% thaimine (mg) = $\frac{X}{Y} \times \frac{1}{5} \times \frac{25}{V} \times \frac{100}{W}$

Where:

W = weight of sample, X = reading of sample – reading of blank standard

Y = reading of thiamine standard – reading of blank standard

V = volume of solution used for test on the column

Vitamin C (ascorbic acid) content was determined by titration using 2,6-dichlorophenol indophenol dye following the AOAC (2010) method. The sample was homogenized in acetic acid solution, filtered, and titrated with the dye solution until the endpoint was reached. Ascorbic acid content was calculated using the standard formula:

Ascorbic acid (mg) = C x V x ($\frac{DF}{wt}$)

Where, C = $\frac{mg\ ascorbic\ acid}{1mL\ dye}$

V = volume of dye used for the titration of a diluted sample

DF = dilution factor

Wt = weight of sample

Vitamins B_2 and B_3 were analyzed using High-Performance Liquid Chromatography (HPLC). Samples were extracted using appropriate solvents, sonicated, centrifuged, and filtered before injection into the HPLC system equipped with a C18 column and UV-Visible detector. Quantification was achieved by comparing peak areas with calibration curves prepared from standard solutions.

STATISTICAL ANALYSIS

All experiments were conducted in triplicate, and the results were expressed as mean ± standard deviation. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS). One-way analysis of variance (ANOVA) was used to determine significant differences among treatments, and mean separation was performed using Duncan's Multiple Range Test (DMRT) at a significance level of $p < 0.05$.

Results and Discussion

Table 1: Mineral Composition of *Bryophyllum Pinnatum* leaves as affected by processing methods

Treatment	Mg	Zn	Na	Fe	Cu	N	P	K
				mg/100g				
T1	20.25^{d}	0.192^{a}	31.06^{c}	2.56^{b}	0.25^{c}	1.76^{d}	0.051^{b}	3.68^{d}
T2	23.60^{a}	0.059^{a}	33.50^{a}	2.71^{a}	0.27^{b}	3.07^{a}	0.540^{a}	7.29^{a}
T3	21.94^{b}	0.061^{a}	32.73^{b}	2.37^{d}	0.23^{d}	2.54^{b}	0.500^{a}	6.51^{b}
T4	21.71^{c}	0.040^{a}	30.20^{d}	2.52^{c}	0.28^{a}	0.80^{e}	0.207^{ab}	2.45^{e}
T5	17.66^{e}	0.070^{a}	28.50^{e}	2.16^{e}	0.21^{e}	2.29^{c}	0.077^{b}	5.18^{c}
Sig.	<0.0001	0.496	<0.0001	<0.0001	<0.0001	<0.0001	0.04	<0.0001

Mean values followed by the same letter (s) along the column are statistically similar at $p<0.05$: T1 = Water blanching, T2 =Shade drying, T3 =Sun drying, T4 =Roasting, T5 = Fresh leaves.

The mineral composition of *Bryophyllum pinnatum* leaves subjected to different processing methods is presented in Table 1. The results revealed that the mineral content varied depending on the processing technique applied. The concentrations of the analyzed minerals ranged from 0.04 to 33.50 mg/100 g across all treatments.

Magnesium content differed significantly among the treatments. Shade-dried leaves recorded the highest magnesium concentration (23.60 mg/100 g), whereas the lowest value was observed in the fresh leaf samples (17.66 mg/100 g). The relatively higher magnesium level in the shade-dried

samples may be associated with the reduction in moisture content during drying, which leads to an apparent concentration of minerals in the dried material.

Zinc concentrations did not differ significantly among the processing methods ($p > 0.05$), although slight numerical variations were observed. Water-blanched leaves showed the highest zinc content (0.192 mg/100 g), followed by fresh leaves (0.070 mg/100 g), while the lowest value was recorded in roasted samples (0.040 mg/100 g).

Sodium content was highest in the shade-dried samples (33.50 mg/100 g) and lowest in the fresh leaves (28.50 mg/100 g). A similar trend was observed for iron, with shade-dried leaves exhibiting the highest iron concentration (2.71 mg/100 g), while the lowest value was recorded in fresh leaves (2.16 mg/100 g).

Copper content was comparatively higher in roasted samples (0.28 mg/100 g), whereas the lowest concentration was observed in fresh leaves (0.21 mg/100 g). Nitrogen content also varied significantly among treatments, with the highest value recorded in shade-dried leaves (3.07 mg/100 g) and the lowest value observed in roasted samples (0.80 mg/100 g).

Phosphorus followed a similar pattern, with the highest concentration recorded in shade-dried samples (0.540 mg/100 g), while the lowest values were observed in both water-blanched and fresh samples. Potassium content was also highest in the shade-dried leaves (7.29 mg/100 g) and lowest in roasted samples (2.45 mg/100 g).

Overall, the results indicate that *Bryophyllum pinnatum* leaves contain appreciable amounts of both macro- and micro-minerals, including Magnesium, Sodium, Nitrogen, Phosphorus, Potassium, Zinc, Iron, and Copper. The relatively higher mineral concentrations observed in the

shade-dried samples may be attributed to the concentration effect resulting from moisture removal during drying. Unlike blanching, which may lead to mineral loss through leaching into the processing water, shade drying minimizes nutrient loss because the material is dehydrated without direct exposure to water or excessive heat.

These findings are consistent with the report of Khatoniar *et al*. (2019), who observed that shade drying is an effective dehydration technique for preserving nutritional quality in plant materials. The absence of direct sunlight and lower processing temperatures during shade drying may help maintain the nutritional composition of plant tissues compared with other drying methods.

The lower mineral levels observed in roasted and water-blanched samples may be attributed to the effects of heat treatment and potential nutrient loss during processing. In particular, blanching involves immersion in hot water, which can promote the leaching of water-soluble minerals into the processing medium. Consequently, minerals such as potassium and magnesium may be partially lost during blanching due to their solubility and mobility in aqueous environments. Similar observations have been reported by Verma *et al*. (2017), who noted that hydrothermal processing can lead to reductions in mineral content in leafy vegetables due to leaching.

This observation is consistent with the findings of Huang *et al*. (2016), who reported that blanching can cause losses of water-soluble nutrients in vegetables. Likewise, Akindahunsi and Oboh (1999) reported that processing techniques such as soaking, abrasion, and blanching may significantly reduce the mineral composition of leafy vegetables. In addition, Fratianni *et al*. (2024) highlighted that common household cooking methods, including boiling and steaming, can influence the mineral profile of vegetables through mechanisms such as leaching and structural changes within plant tissues.

Fresh leaves, which served as the control in this study, exhibited comparatively lower concentrations of some minerals such as magnesium and potassium when compared with certain processed samples. This observation may be explained by the reduction in moisture content during drying processes, which results in a concentration effect that increases the apparent mineral content on a dry-weight basis. Drying processes remove water from plant tissues while largely retaining inorganic minerals, thereby increasing the relative mineral concentration in the dried material.

The relatively higher iron content observed in processed samples compared with fresh leaves may also be attributed to the same concentration effect resulting from dehydration. Lisiewska *et al*. (2006) similarly reported that dehydration can increase the apparent mineral concentration in leafy vegetables due to water loss during drying. Comparable findings were reported by Singh *et al*. (2007), who observed that dehydrated bathua leaves contained substantially higher iron levels than fresh leaves. Joshi and Mehta (2010) also reported increased nutrient concentrations in dried drumstick leaves compared with their fresh counterparts.

The significantly higher Sodium content recorded in shade-dried *Bryophyllum pinnatum* leaves may also be explained by the absence of water contact during drying, which prevents mineral leaching. Shade drying removes moisture gradually while minimizing exposure to high temperatures and direct sunlight, thereby preserving the mineral composition of the plant material. Similar findings have been reported by Idowu *et al*. (2022), who noted that shade drying often results in better nutrient retention in leafy vegetables compared with high-temperature processing methods.

The variation in zinc content among the processed samples may be influenced by differences in processing conditions and the physical structure of the plant tissues. Although water-blanched

samples showed slightly higher zinc levels compared with other treatments, the differences among treatments were relatively small. Zinc in plant tissues is often associated with proteins and cellular components, which may reduce its susceptibility to leaching during short blanching periods. The lower zinc levels observed in roasted samples may be related to structural changes in plant tissues during heating, which could influence the extractability or distribution of the mineral within the sample matrix. Similar reductions in zinc content following cooking treatments have been reported by Onyeike *et al*. (2003), who observed decreased zinc levels in cooked vegetables compared with raw samples.

The relatively higher copper content observed in roasted samples may be associated with the concentration effect resulting from moisture loss during heating. Roasting removes water from plant tissues and may also cause the breakdown of cellular structures, potentially releasing minerals that were previously bound within the plant matrix. As a result, the measured copper concentration in the roasted samples may appear higher on a dry-weight basis. In addition, unlike blanching, roasting does not involve water contact, thereby eliminating the possibility of mineral loss through leaching. Previous studies have similarly reported that dry-heat processing methods may retain higher levels of certain minerals compared with hydrothermal treatments (Wang *et al*., 2011).

Table 2: Vitamin Composition of *Bryophyllum Pinnatum* leaves as affected by processing methods

Treatment	Vitamin A	Vitamin C	Vitamin B1	Vitamin B2	Vitamin B3
			mg/100g		
T1	1.33^{e}	214.28e	17.30^{e}	0.34^{e}	0.020^{d}

T2	3.19[a]	291.98[a]	25.99[a]	0.51[b]	0.050[b]
T3	3.00[b]	259.76[b]	23.51[b]	0.46[c]	0.040[c]
T4	2.63[c]	244.09[c]	22.95[c]	0.54[a]	0.070[a]
T5	1.44[d]	229.31[d]	20.93[d]	0.44[d]	0.037[c]
Sig.	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Mean values followed by the same letter (s) along the column are statistically similar at $p<0.05$: T1 = Water blanching, T2 = Shade drying, T3 = Sun drying, T4 = Roasting, T5 = Fresh leaves.

The vitamin content of *Bryophyllum pinnatum* leaves was strongly influenced by the processing method (Table 2). Shade-dried leaves (T2) retained the highest concentrations of vitamin A (3.19 mg/100 g), vitamin C (291.98 mg/100 g), and vitamin B1 (25.99 mg/100 g). This preservation is likely due to the low-temperature, indirect dehydration conditions of shade drying, which reduce thermal and oxidative degradation compared with sun drying, roasting, or blanching. Shade drying limits exposure to UV light and extreme heat, thereby maintaining both heat- and light-sensitive vitamins (Khatoniar *et al*., 2019; Idowu *et al*., 2022).

Sun-dried leaves (T3) retained moderate levels of vitamins, slightly lower than shade-dried samples. The reduction in vitamin content compared with shade drying may be attributed to prolonged exposure to sunlight and fluctuating temperatures**,** which can accelerate oxidative degradation of sensitive compounds such as vitamin C and carotenoids (Fratianni *et al*., 2024).

Roasted leaves (T4) displayed comparatively higher vitamin B2 (0.54 mg/100 g) and vitamin B3 (0.07 mg/100 g) than other treatments, but lower levels of vitamin C (244.09 mg/100 g) and vitamin A (2.63 mg/100 g). The high heat involved in roasting can partially degrade heat-sensitive

vitamins**,** such as vitamin C and carotenoids, while dry-heat processing may improve the extractability of more stable vitamins like B2 and B3 by breaking down cell walls and releasing bound compounds (Wang *et al*., 2011).

Water-blanched samples (T1) recorded the lowest levels of most vitamins, particularly vitamin A (1.33 mg/100 g) and vitamin C (214.28 mg/100 g), likely due to leaching into the blanching water and thermal degradation. Vitamins that are water-soluble or heat-sensitive are particularly vulnerable to such losses during hydrothermal treatment (Verma *et al*., 2017).

Fresh leaves (T5), used as the control, exhibited lower concentrations of all vitamins compared with shade-dried samples, indicating that controlled processing can enhance the apparent concentration and bioavailability of vitamins, particularly through moisture removal and cell wall disruption. However, excessive heat or water contact, as in roasting and blanching, can counteract these benefits by inducing nutrient losses (Omah *et al*.,2022).

These findings demonstrate that shade drying is the most effective method for preserving both water-soluble and fat-soluble vitamins in *Bryophyllum pinnatum*, while water blanching results in the greatest losses. Roasting, although beneficial for certain B-vitamins, compromises heat- and oxidation-sensitive vitamins. This is consistent with previous studies on leafy vegetables, where low-temperature drying methods preserved nutritional quality more effectively than high-heat or hydrothermal treatments (Huang *et al*., 2016; Joshi and Mehta, 2010; Khatoniar *et al*., 2019).

Conclusion and Recommendation

This study demonstrates that traditional processing methods profoundly influence the nutritional quality of *B. pinnatum* leaves. Shade drying emerges as the optimal method for preserving both

mineral and vitamin content, offering a simple, accessible technique suitable for traditional and small-scale commercial applications. The preservation efficacy of shade drying likely results from: (i) removal of moisture without thermal stress or leaching; (ii) minimization of photodegradation; and (iii) reduction of oxidative reactions through gradual dehydration.

Pan-roasting, while suboptimal for vitamins A and C, offers advantages for B-vitamin preservation, suggesting potential for product-specific applications. Conversely, blanching generally resulted in nutrient losses and cannot be recommended for nutrient preservation purposes.

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