Nutritional Quality and Palatability: Effects of Traditional Processing Methods on *Vernonia amygdalina* (Bitter Leaf)

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ABSTRACT

Background: *Vernonia amygdalina, a widely consumed African leafy vegetable with recognized nutritional and therapeutic value, requires household debittering processing. The debittering impacts on nutrient and antinutrient composition remain poorly characterized.*

Objective: *This study evaluated the comparative effects of common processing methods on nutritional quality, antinutrient profile, and palatability of V. amygdalina.*

Methodology: *Fresh leaves obtained from Bodija Market, Ibadan, were pooled and assigned to five treatment groups: unprocessed control, squeeze-washed (with and without salt), palm oil–treated squeeze-washing, and potash-blanched followed by squeeze-washing (300 g each). Squeeze-washing was continued until bitterness was appreciably reduced. Samples were analysed for proximate composition, micronutrient content, and antinutritional factors using standard AOAC methods after oven-drying and milling. Data were analysed using one-way ANOVA at $p \leq 0.05$.*

Results: *Processing significantly affected nutrient profiles of Vernonia amygdalina. Potash-blanched leaves retained the highest potassium (2246.9 mg/100 g), iron (13.38 mg/100 g), protein (19.77 g/100 g), and phosphorus (242.68 mg/100 g), while maintaining a vibrant green colour indicative of chlorophyll preservation and high fibre content. Palm oil treatment increased crude fat (11.55 g/100 g) and enhanced vitamin E (621.83 μg/100 g) and β-carotene (3741.9 μg/100 g). Standard squeeze-washing caused notable nutrient losses. All treatments reduced antinutrients, but nutrient retention was higher in potash and palm oil treatments.*

Conclusion: *This study provides novel evidence that palm oil washing and potash blanching outperform standard squeeze-washing, enhancing fat-soluble vitamins and chlorophyll with improved nutrient retention, respectively. Prioritising these methods can optimize the nutritional and health benefits of Vernonia amygdalina.*

Keywords: Bitter leaf; Nutrient retention; Palm oil-washing; Potash-blanching; Squeeze-washing.

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INTRODUCTION

Micronutrient deficiencies remain a major public health concern globally, affecting more than two billion people, particularly in low- and middle-income countries where access to nutrient-dense animal-source foods is limited (1, 2). Such hidden hunger is driven by inadequate intakes of essential vitamins and minerals (2). Dietary diversification has been recognized as a cost-effective and sustainable food-based strategy for combating micronutrient malnutrition (3, 4). In this context, increased consumption of indigenous green leafy vegetables offers an accessible means of improving micronutrient adequacy, enhancing dietary quality, and providing naturally occurring bioactive compounds with functional benefits (5, 6).

African leafy vegetables, such as *Vernonia amygdalina* (bitter leaf), play an important role in traditional diets and local food systems (7). These vegetables are notable for their dense micronutrient profiles, supplying substantial amounts of vitamins, minerals, dietary fiber, and a wide range of phytochemicals such as flavonoids, terpenoids, alkaloids, and phenolic compounds (8). These constituents have been associated with antioxidant, anti-inflammatory, immunomodulatory, and disease-preventive properties (9). As a result, *V. amygdalina* serves not only as a readily available nutrient source but also as a culturally significant functional food with both nutritional and therapeutic value. *Vernonia amygdalina* is widely consumed across West and Central Africa and is valued not only as a culinary ingredient but also for its documented therapeutic properties (10). Despite its nutritional and pharmacological potential, the intense bitterness of the leaves necessitates processing prior to consumption. Traditional household processing techniques such as repeated squeeze-washing using diverse additives are primarily employed to reduce bitterness and enhance palatability. However, these debittering methods can induce substantial physicochemical changes that may affect nutrient concentration, stability, and bioavailability.

Despite several studies on the nutritional composition of fresh untreated *V. amygdalina*, there remains limited systematic evidence on how commonly practiced household processing methods can influence its rich nutritional profile. Such information is essential for impactful dietary counselling, formulation of nutrition-sensitive interventions, and the promotion of indigenous vegetables for improved dietary quality. This study evaluated the effects of four commonly practiced traditional processing methods on the proximate composition, micronutrient content, and antinutrient profile of *Vernonia amygdalina*, with the aim of identifying techniques that optimize nutrient retention while achieving effective debittering to support evidence-based recommendations for enhancing its nutritional value.

MATERIALS AND METHODS

Sample Collection and Preparation

Fresh young leaves of *V. amygdalina* were randomly purchased from sellers at the Bodija (7.4358°N latitude and 3.9192°E) popular food market in Ibadan, Oyo State, Nigeria. The leaves, which were pooled and thoroughly mixed, were washed to remove extraneous materials, drained, and sorted. The composite sample was then divided into five treatment samples (samples A–E) of approximately 300g each. Sample A: Fresh, untreated control; Sample B: Squeeze-washed without additives; Sample C: Squeeze-washed with sodium chloride (15 g table salt); Sample D: Squeeze-washed with palm oil; and Sample E: Blanched in potash (kaun) for 10 minutes and subsequently squeeze-washed. Two tablespoons of palm oil and 2g of Potash were added to subsamples D and E, respectively. Squeeze-washing was conducted manually until foaming subsided and bitterness was appreciably reduced. Portions of the Squeeze-washed samples were taken and kept for moisture and Vitamin analysis, while the remaining portions were oven-dried at 60°C, milled into powder, and stored in airtight containers for proximate and other chemical analysis.

Proximate Analysis

The moisture content of the samples was measured using an air oven set at 105°C for 4 hours (Plus 11 Sanyo Gallenkamp PLC, UK). Crude protein was quantified through the micro-Kjeldahl method (11), while crude fat was extracted via Soxhlet extraction (11) and expressed as grams per 100 g of sample. Ash content was determined by incinerating 5 g of each sample in a muffle furnace at 550°C for 4 hours (11). Total carbohydrates were calculated by difference. The gross energy content was assessed using a ballistic bomb calorimeter (Cal 2k – Eco, TUV Rheinland Quality Services, South Africa)

Mineral Analysis

The potassium and sodium levels in the samples were measured using a Jenway digital flame photometer (PF-P7 model). Calcium, magnesium, iron, and zinc concentrations were analyzed with an atomic absorption spectrophotometer (Perkin-Elmer Model 403, Norwalk, CT, USA) following digestion with concentrated nitric acid, according to (11) procedures. All analyses were performed in triplicate to ensure accuracy.

Vitamin Analysis

Vitamin A was extracted with chloroform and quantified by UV absorbance at 328 nm against a standard curve of vitamin A acetate. Thiamine (B1) was extracted by acid hydrolysis, treated with sodium acetate and acid potassium chloride, and measured at 285 nm on a fluorescent UV spectrophotometer, with comparison to standard thiamine solutions. Riboflavin (B2) was extracted with HCl and dichloroethene, heated, filtered, and measured at 460 nm, using standard riboflavin for quantification. Niacin (B3) was extracted with water, and its absorbance at 385 nm was compared with standard solutions. Pyridoxine (B6) was extracted with ammonium chloride, chloroform, and ethanol, filtered, and quantified at 415 nm against standard solutions. Cyanocobalamin (B12) was extracted with water, reduced with sodium dithionite, and measured at 445 nm relative to standard cyanocobalamin solutions. Ascorbic acid (Vitamin C) was determined by titration with 2,6-dichlorophenol-indophenol dye to a faint pink endpoint.

Antinutrient Analysis

Oxalate was quantified after extracting the samples in water for about three hours. Standard oxalic acid solutions and sample extracts were read at 420 nm on a Spectronic 20 spectrophotometer, and oxalate concentration was estimated from the calibration curve. Phytate was determined by titration with ferric chloride (12). Trypsin inhibitory activity was measured using casein as substrate, with absorbance taken at 280 nm and compared to trypsin standards (13). Tannin content was analyzed by extracting samples in an acetone–acetic acid mixture for five hours and reading absorbance at 500 nm against tannic acid standards (14). Saponin concentration was determined by comparing sample absorbance at 380 nm with that of saponin standards (13).

Statistical Analysis

Analyses were performed in triplicate ($n = 3$), and results are expressed as mean ± SD. One-way ANOVA was conducted using SPSS version 29 to assess differences among processing methods, with $p < 0.05$ considered statistically significant.

RESULTS

Proximate Composition of *Vernonia amygdalina* Leaf

Table 1 shows the effects of traditional processing on the proximate and energy profiles of *V. Amygdalina*. Data show significant protein and fiber losses during squeeze-washing, whereas potash-blanching (sample e) maximized nutrient retention. Palm oil-washing (sample d) significantly increased crude fat and gross energy (509 kcal/100g).

Table 1: Proximate Composition of *Vernonia amygdalina* Leaf (G/100 G Dry Weight)

Parameter	A	B	C	D	E
Crude protein	26.48±0.10^{a}	15.37±0.11^{b}	14.78±0.11^{c}	13.87±0.10^{d}	19.77±0.11^{e}
Crude fat	4.21±0.04^{a}	2.25±0.02^{b}	2.14±0.03^{c}	11.55±0.03^{d}	3.46±0.03^{e}
Crude fiber	12.52±0.04^{a}	5.33±0.03^{b}	5.41±0.03^{c}	3.72±0.05^{d}	9.83±0.04^{e}
Ash	7.96±0.02^{a}	5.83±0.04^{b}	5.49±0.03^{c}	7.21±0.04^{d}	6.81±0.03^{e}
Carbohydrates	44.96±0.03^{a}	64.46±0.13^{b}	65.09±0.18^{c}	58.38±0.42^{d}	55.41±0.0^{9e}
G. E (kcal/100g)	372±0.00^{a}	331±0.00^{b}	329±0.00^{c}	509±0.00^{d}	347±0.00^{e}

Sample E = V. amygdalina leaf blanched in potash (10 mins) Values with the same superscript on the same row are not significantly different (p> 0.05); Values are means of three determinations (n = 3); G.E = Gross Energy; Sample A = Fresh V. amygdalina leaf; Sample B = V. amygdalina leaf processed by squeeze washing only; Sample C = V. amygdalina leaf processed with salt (NaCl); Sample D = V. amygdalina leaf processed with palm oil, then squeeze washed

Mineral Composition of *Vernonia amygdalina* Leaf

Table 2 shows the mineral concentrations (mg/100g) following various treatments. Extensive leaching of iron and potassium occurred in squeeze-washed samples (b, c, d). Potash-blanching (sample e) served as the most effective method for mineral preservation, particularly for iron (13.38 mg/100g) and phosphorus.

Vitamin Composition of *Vernonia amygdalina*

Table 3 shows the vitamin stability across processing methods. Vitamin C showed high sensitivity to mechanical washing, while potash-blanching (sample e) achieved the highest retention (23.77 mg/100g). Palm oil (sample d) significantly enhanced fat-soluble beta-carotene and vitamin E levels.

Table 2: Mineral Composition of *Vernonia amygdalina* Leaf (Mg/100 G Dry Weight)

Parameter	A	B	C	D	E
Sodium	170.36 ±0.60a	162.03±0.96b	1625.4 ±1.51c	66.38 ±1.51d	85.13±0.97e
Potassium	2747.20±1.28a	1890.40±2.26b	1098.10±1.01c	507.57±0.70d	2246.9±1.58e
Calcium	801.72±1.57a	729.15±0.12b	705.11±0.02c	500.11±1.94d	586.41±1.55e
Magnesium	358.37±0.81a	233.96±0.50b	218.72±0.25c	245.23±0.81d	185.45±0.59e
Phosphorus	299.34±0.87a	111.02±0.81b	186.09±0.88c	80.69±0.16d	242.68±0.65e
Iron	50.04±0.02a	7.63±0.01b	5.73±0.03c	5.39±0.01d	13.38±0.04e
Zinc	0.95±0.04a	0.68±0.01b	0.62±0.01c	1.08±0.01d	0.85±0.02e
Copper	2.05±0.03a	1.65±0.03b	1.15±0.02c	1.73±0.01d	1.78±0.02e
Manganese	11.36±0.01a	9.56±0.05b	7.63±0.04c	4.26±0.02d	7.36±0.05e

Values with the same superscript on the same row are not significantly different (p> 0.05); Values are means of three determinations (n = 3)

Table 3: Vitamin Composition of *Vernonia amygdalina* (Mg/100 G Dry Weight)

Parameter	A	B	C	D	E
β-Carotene (μg/100)	3568.6±0.31a	2986.7±0.40b	2977.7±0.25c	3741.9±0.30d	3124.9±0.36e
Vitamin B1	0.34±0.03a	0.24±0.03b	0.21±0.03bc	0.18±0.02c	0.29±0.02d
Vitamin B2	0.18±0.03a	0.11±0.02be	0.09±0.02bc	0.06±0.02cd	0.15±0.03ae
Vitamin B6	0.05±0.00a	0.04±0.00b	0.03±0.00c	0.02±0.00d	0.04±0.00e
Vitamin E (μg/100)	567.53±0.25a	389.90±0.30b	386.80±0.36c	621.83±0.35d	521.70±0.20e
Vitamin C	28.34±0.03a	15.28±0.07b	13.89±0.03c	11.29±0.03d	23.77±0.02e

Values with the same superscript on the same row are not significantly different (p> 0.05); Values are means of three determinations (n = 3)

Antinutrient Composition of *Vernonia amygdalina*

Table 4 shows the impact of processing on antinutritional factors. All methods significantly reduced phytates, oxalates, and saponins. Mechanical squeeze-washing (samples b–d) was more effective at reducing trypsin inhibitors than potash-blanching (sample e).

Table 4: Antinutrient Composition of *Vernonia amygdalina* (Mg/100 G Dry Weight)

Parameter	A	B	C	D	E
Phytate	0.95±0.00a	0.05±0.00b	0.05±0.00c	0.02±0.00d	0.08±0.00e
Oxalate	0.07±0.00a	0.03±0.00b	0.02±0.00c	0.01±0.00d	0.05±000e
Saponin	0.38±0.00a	0.17±0.00b	0.17±0.00c	0.10±0.00d	0.24±0.01e
Trypsin inhibitor	16.35±0.04a	0.58±0.03b	0.46±0.03c	0.21±0.03d	13.42±0.05e

Values with the same superscript on the same row are not significantly different (p> 0.05); Values are means of three determinations (n = 3)

DISCUSSION

This study confirms that the nutrient, vitamin, mineral, and antinutrient composition of *Vernonia amygdalina* leaves is strongly influenced by processing, consistent with recent evidence highlighting substantial nutrient variability following household and traditional processing methods (15). The findings reinforce the growing understanding that even minor variations in processing, such as differences in washing duration, temperature, pH, or use of additives, can significantly alter the nutritional profile of leafy vegetables.

Protein, fat, fiber, and ash contents were variably affected across the different treatment methods. Water- and salt-based washing typically led to reductions in protein and soluble minerals, possibly due to leaching and thermal degradation. This pattern aligns with previous postharvest studies in bitter leaf, which similarly reported significant loss of soluble nutrients into the cooking medium as processing intensity increases (16, 17). Squeezed washing with palm oil showed comparatively better preservation of fat and fat-soluble constituents. This is consistent with the observations of (15), confirming the importance of preserving lipid-soluble phytochemicals in *Vernonia amygdalina* for its nutritional and medicinal benefits. This may be attributed to the formation of hydrophobic interactions that reduce solute movement across cell membranes, thereby limiting leaching. The stabilising effect of lipid coatings on plant tissues has been previously documented, particularly in studies demonstrating enhanced retention of carotenoids and other lipophilic bioactive compounds when oil is incorporated into processing steps (18).

The alkali-based blanching method (potash treatment) similarly provided better retention of protein, fiber, and ash. The alkaline environment may promote cell wall swelling, reduce protein solubilisation, and enhance stability of structural components (19). Notably, potash-treated leaves retained a vibrant green colouration. This occurs because alkaline conditions slow the conversion of chlorophyll to pheophytin, the brown pigment formed under acidic or high-heat conditions, thereby preserving both leaf colour and chlorophyll-associated nutrients (20). The greenness serves as a practical visual indicator of nutrient retention, particularly of antioxidants and other bioactive compounds, while also enhancing sensory appeal and consumer acceptability (21).

Carbohydrate content appeared relatively stable across treatments, with slight increases in some cases likely reflecting moisture loss rather than true nutrient gain. This is consistent with established evidence that bitter leaf contains modest carbohydrates and contributes minimally to energy intake, yet remains valuable as a source of dietary fiber and therapeutic phytochemicals (15).

Water-soluble vitamins are highly sensitive to processing, with substantial losses observed in treatments involving prolonged squeezed washing. This aligns with the findings of (22) and the previous findings of (17). In contrast, fat-soluble vitamins such as vitamins A and E were comparatively well preserved, particularly in palm oil-assisted or alkali-treated leaves. The retention of green colouration in potash-treated leaves reflects better maintenance of chlorophyll-rich structures, which may protect lipophilic vitamins and other bioactive components from oxidative degradation (20). The greenness, therefore, functions not only as a visual cue but also as a proxy for overall micronutrient preservation, including pigments, carotenoids, and certain antioxidants. Mineral retention showed similar method-dependent patterns. Water- and salt-based washing caused notable losses of calcium, magnesium, potassium, and iron due to leaching into the processing water, which is consistent with the findings of (22, 17).

However, palm oil washing and alkali blanching mitigated these reductions, likely due to decreased solubility of minerals under fat-rich or alkaline conditions. The retention of chlorophyll and leaf colour in potash-treated samples further suggests preservation of plant matrix integrity, which can help maintain functional mineral bioavailability. Overall, these findings underscore that processing method strongly influences both nutrient content and functional quality, with leaf greenness serving as a useful visual and biochemical marker of effective nutrient retention.

Most processing methods effectively reduced antinutrients such as phytates, oxalates, and tannins, improving palatability and safety. This finding corroborated the earlier findings of (23, 24). This study, however, showed that blanching with alkali (kaun) and then squeeze washing preserved relatively more nutrients but retained higher levels of certain antinutrients. Combined with its ability to maintain leaf greenness, this reinforces the importance of balancing sensory quality, nutritional adequacy, and safety when selecting processing methods for *V. amygdalina* and other green leafy vegetables. The green colouration not only indicates chlorophyll stability but may also reflect preservation of bioactive compounds associated with health-promoting effects.

This study uniquely demonstrates how traditional household processing techniques such as squeezed washing with palm oil and potash blanching can differentially shape the nutritional quality, bioactive retention, and palatability of *Vernonia amygdalina* leaves. Our findings reveal that specific additives and processing methods can simultaneously reduce bitterness and preserve macronutrients, fat-soluble vitamins, minerals, and antioxidant compounds. Potash blanching, for example, maintains vibrant leaf greenness, providing a visual cue for nutrient preservation. These insights offer practical guidance for enhancing dietary quality at the household level. To maximize nutritional and functional benefits, squeezed washing with palm oil and alkali blanching are recommended as optimal strategies, supporting the use of *V. amygdalina* as a functional food capable of improving dietary diversity and micronutrient intake in sub-Saharan Africa.

Therefore, promoting optimal processing practices such as potash blanching could enhance dietary contributions of *V. amygdalina*, particularly in communities reliant on leafy vegetables for micronutrient intake. These insights can guide public health nutrition strategies and inform food-based interventions aimed at reducing micronutrient deficiencies.

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CONFLICT OF INTEREST

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