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Phytochemical and Nutritional Evaluation of Shea Tree Organs

***[1]Uduakobong Ime Idio, [1]Egwim Nkechinyere Nneka, [1]Samuel Anna Florence, [2]Olusegun-Awosika Bukunmi Damilola, [1]Esew Onyeyirichi, [1]Ogabidu Okpokwu Alexander, [1]Abe Ayotunde Sunday, [1]Iyeh Francis and [1]Odeke Evelyn Hope**

[1]National Research Institute for Chemical Technology, Zaria, Kaduna-State.
[2]Adeyemi Federal University of Education, Ondo, Ondo-State.

*Corresponding authors' email: udyjesuchit81@yahoo.com Phone: +2347031691431

ABSTRACT

Vitellaria paradoxa (shea tree) is an economically important species in sub-Saharan Africa, but its vegetative parts are less characterized than the commercially valuable shea butter. The qualitative phytochemical profile, proximate composition and physicochemical properties of stem bark, leaves, kernel shell and traditionally processed shea butter were comparatively evaluated. Plant materials were gathered, identified, air-dried and analyzed according to standard AOAC procedures. Qualitative phytochemical screening showed the presence of alkaloids, tannins, saponins, flavonoids, steroids, terpenoids, cardiac glycosides and deoxy sugars in most organs, but not anthraquinones. The leaves had the highest phytochemical intensity, especially terpenoids (+++), while the shell had the lowest diversity. The results of proximate analysis showed that there was a significant difference between the different parts of the plant, with stem bark having the highest ash content (25.10%), shell having the highest crude fibre (54.61%), and leaves having the highest carbohydrate (48.33%), protein (6.41%) and lipid (2.59%) content. Physicochemical evaluation revealed that processing decreased acid value (18.23 to 8.43 mg KOH/g), free fatty acid content (9.12% to 4.22%) and slightly increased peroxide value (4.29 to 6.11 meq O_2/kg). The iodine value was not affected, suggesting that the fatty acid unsaturation was not affected. The results showed that there is a considerable variation in the phytochemical and nutritional composition of the different organs and that the traditional clarification process enhances the hydrolytic quality of shea butter. The present study offers scientific evidence for the medicinal and nutritional applications of various organs of *V. paradoxa* and emphasizes their potential for sustainable bioresource applications.

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INTRODUCTION

The shea tree, *Vitellaria paradoxa* C.F. Gaertn (Sapotaceae), is one of the most economically and culturally important plant species in the Sudano-Sahelian region of sub-Saharan Africa (Ojo *et al.,* 2021). The tree is widespread from Senegal to Uganda, playing a key role in traditional agroforestry parkland systems and livelihoods of millions of rural households (Nkoulou *et al*., 2024). The vegetative parts of the tree (stem bark, leaves, and kernel shell) are still relatively underutilized and undercharacterized nutritionally and phytochemically, despite the global interest in the shea kernel and its extracted fat, which is commercially known as shea butter (Lawrence *et al.,* 2023). The secondary metabolome of *V. paradoxa* is known to be pharmacologically rich, with polyphenols, triterpenoids, alkaloids, saponins, flavonoids, and cardiac glycosides being found in different proportions in various plant parts (Mohammed *et al.,* 2024; Sale *et al.,* 2023). The distribution of these secondary metabolites in the various anatomical parts of the tree (stem bark, leaves, and kernel shell) has been poorly studied in a single comparative context (Nestor *et al*., 2024). The knowledge of organ-specific phytochemical distribution is crucial for the selection of plant material for traditional and standardized therapeutic preparations and for the identification of underutilized plant fractions that could be used in circular bioeconomy frameworks (Saady *et al*., 2026). The nutritional value, bioactive matrix and suitability as raw material for extract preparation are also important, and are related to the proximate composition of these plant parts. Moisture content has been reported to affect the stability of thermolabile bioactive compounds during storage, while ash content is a measure of the mineral density of the tissue and may be a sign of the presence of essential cofactors for the synthesis of bioactive compounds by enzymes (Nuhu *et al*., 2021).

Crude fibre content, particularly kernel shell, has been reported to be responsible for sequestration and slow release of phenolic compounds, while the carbohydrate and protein fraction have been reported to be responsible for the mucilaginous and enzymatic properties of leaf and bark preparation respectively (Abubakar *et al.,* 2022). Comparative proximate data for various organs of V. paradoxa are still scattered in the literature, although they are relevant. The physicochemical quality of shea butter is also poorly reported in comparative processing studies. The degree of unsaturation, availability of ester bond, oxidative stability and hydrolytic quality of the fat are represented by key quality parameters such as iodine value, saponification value, peroxide value, acid value and free fatty acid content respectively (Mensah *et al*., 2020; Kolawole *et al.,* 2025). The parameters are greatly affected by post-harvest handling, kernel storage conditions and processing methodology, but the physicochemical changes that occur during the transition from semi-processed to clarified shea butter under traditional processing conditions have not been well documented (Honfo *et al.,* 2020; Tchobo *et al.,* 2022). The present study aimed to fill these gaps in knowledge by comparing the phytochemical, proximate and physicochemical characteristics of *V. paradoxa* stem bark, leaves and kernel shell. We hypothesized that: (i) the distribution of secondary metabolites would differ significantly between plant organs; (ii) the proximate composition would be indicative of the physiological functions of the plant organs; and (iii) the traditional processing would significantly change the physicochemical quality of shea butter compared to the semi-processed product. The results are expected to serve as a scientific reference for the nutritional and phytochemical characterization of *V. paradoxa* and evidence-based utilization of its various plant parts.

MATERIALS AND METHODS

Collection, Authentication, and Preparation of Plant Materials

Fresh leaves, stem bark, and mature nuts of *Vitellaria paradoxa* were collected from farms located in National Research Institute for Chemical Technology, Basawa, Zaria, Kaduna State, in July 2025. The plant was authenticated at the Herbarium department of Ahmadu Beloo University, Zaria, Kaduna State, Nigeria, where a voucher specimen was deposited under voucher number ABUH02709. The plant materials were washed with clean water, air-dried at room temperature (27 ± 2°C) until constant weight was achieved, separately milled into fine powder, and stored in labelled airtight containers until analysis (Yusuf *et al.,* 2020; Danquah *et al.,* 2023). For shea butter preparation, nuts were dehulled, kernels roasted at 110°C for 25 minutes, cooled, and milled into paste. Butter was extracted using the traditional hot-water method by mixing the paste with hot water at 80°C, kneading thoroughly, and allowing the lipid fraction to separate and float. The collected butter was designated as semi-processed shea butter. A portion was further clarified by reheating at 80°C, filtering through muslin cloth, and decanting the clear fat layer, designated as processed shea butter (Ojo and Bello, 2021; Tchobo *et al*., 2022).

Proximate Analysis

Proximate composition of stem bark, leaves, and shell was determined using standard AOAC (2019) official methods. Moisture content was determined by oven drying at 105°C to constant weight; ash content by incineration in a muffle furnace at 550°C; crude lipid by Soxhlet extraction using n-hexane; crude protein by the Kjeldahl method using a nitrogen-to-protein conversion factor of 6.25; and crude fibre by sequential acid and alkali digestion. Carbohydrate content was calculated by difference:

Carbohydrate (%) = 100 − (% moisture + % ash + % crude fibre + % crude lipid + % crude protein). All analyses were performed in triplicate (Adekunle *et al*., 2021; Lawal *et al.,* 2023).

Qualitative Phytochemical Screening

Qualitative phytochemical screening was carried out on aqueous and hydroethanolic extracts of the powdered samples using standard colorimetric and precipitative procedures (Ezeonu and Ejikeme, 2019; Sulaiman and Abubakar, 2022). Alkaloids were detected using Mayer's and Wagner's reagents; tannins by ferric chloride test; saponins by frothing test; flavonoids by alkaline reagent and Shinoda test; steroids and terpenoids by Liebermann–Burchard reaction; anthraquinones by Borntrager's test; and cardiac glycosides by Keller–Killiani test. Results were recorded on a semi-quantitative scale as absent (−), low (+), moderate (++), or high (+++) based on the intensity of visual reaction and precipitate formation (Mohammed *et al.,* 2021; Olamide *et al.,* 2022).

Physicochemical Analysis of Shea Butter

Semi-processed and processed shea butter samples were analyzed for iodine value, saponification value, peroxide value, acid value, and free fatty acid content following official AOAC (2019) methods for fats and oils. The iodine value was determined by the Wijs method; saponification value by refluxing fat with alcoholic KOH and back-titrating with standard hydrochloric acid; peroxide value iodometrically; and acid value by titration against standard KOH solution. Free fatty acid content was calculated from the acid value and expressed as percentage oleic acid. All determinations were carried out in triplicate (Mensah *et al.,* 2020; Kolawole *et al.,* 2025).

Statistical Analysis

All determinations were carried out in triplicate, and results were expressed as mean ± standard deviation (SD). Data were analyzed using one-way analysis of variance (ANOVA), and mean separation was performed using Duncan's New Multiple Range Test at $p < 0.05$ using SPSS version 23.0 (IBM Corp., Armonk, NY, USA) (Bello Adeyemi, 2022; Usman *et al.,* 2021).

RESULTS AND DISCUSSION

Table 1: Qualitative Phytochemical Screening of Shea Butter Tree (*Vitellaria paradoxa*) Parts

S/No	Phytochemical	Stem/Bark	Leaves	Shell
1	Alkaloids	+	+	-
2	Tannins	++	+	+
3	Saponins	+	+	-
4	Flavonoids	+	++	+
5	Steroids	+	++	+
6	Anthraquinones	-	-	-
7	Cardiac Glycosides	+	+	+
8	Terpenoids	++	+++	++
9	Deoxy sugars	+	+	+

Key: "–" = Not Detected. "+" = Present (Low Abundance). "++" = Moderately Abundant. "+++" = Highly Abundant

The phytochemical screening (Table 1) showed that alkaloids and saponins were present in the stem bark and leaves but absent in the shell. Tannins, flavonoids, steroids, cardiac glycosides, terpenoids, and deoxy sugars were detected across most plant parts, while anthraquinones were not detected in any sample. The leaves exhibited the highest phytochemical intensity, with strong (+++) presence of terpenoids and moderate (++) levels of flavonoids and steroids. The stem bark showed moderate (++) tannins and terpenoids. The shell displayed a comparatively limited profile, lacking alkaloids and saponins and showing mainly low (+) to moderate (++) abundance of other constituents.

Table 2: Physicochemical Properties of Semi-Processed and Processed Shea Butter

Parameter	Semi-Processed	Processed	Reference Range
Iodine Value (g I_2/100g)	47.68 ± 0.04	47.94 ± 0.02	52–65
Saponification Value (mg KOH/g)	183.3 ± 1.5	196.2 ± 0.1	170–200
Peroxide Value (meq O_2/kg)	4.29 ± 0.01	6.11 ± 0.01	≤ 10
Acid Value (mg KOH/g)	18.23 ± 0.01	8.43 ± 0.02	≤ 4.0
Free Fatty Acid (%)	9.12 ± 0.01	4.22 ± 0.01	≤ 2.0

Table 3: Other Properties of Semi-Processed and Processed Shea Butter

Parameter	Semi-Processed	Processed
Iodine Value (g I_2/100g)	23.84 ± 0.02	23.97 ± 0.01
Saponification Value (mg KOH/g)	183,3 ± 0.15	196.2 ± 0.01
Peroxide Value (meq O_2/kg)	4.29 ± 0.01	6.11 ± 0.01
Acid Value (mg KOH/g)	18.23 ± 0.01	8.43 ± 0.02
Free Fatty Acid (%)	9.12 ± 0.01	4.22 ± 0.01

Note: Values are Expressed as Mean ± Standard Deviation

Table 2 shows that the iodine value remained nearly unchanged between semi-processed (47.68 ± 0.04 g I_2/100 g) and processed (47.94 ± 0.02 g I_2/100 g) shea butter. The saponification value increased from 183.3 ± 1.5 to 196.2 ± 0.2 mg KOH/g after processing. The peroxide value increased from 4.29 ± 0.01 to 6.11 ± 0.01 meq O_2/kg. In contrast, the acid value decreased from 18.23 to 8.43 mg KOH/g, and the free fatty acid content decreased from 9.12% to 4.22% following processing.

Table 4: Mean Proximate Composition (%) of Shea Butter Tree (*Vitellaria paradoxa*) Parts

S/No	Parameter	Stem/Bark (%)	Leaves (%)	Shell (%)
1	Moisture Content	12.73 ± 0.12^c	11.20 ± 0.01^c	8.30 ± 0.01^b
2	Ash Content	25.10 ± 0.10^d	11.40 ± 0.02^c	11.35 ± 0.02^c
3	Crude Fibre	39.33 ± 0.05^e	20.06 ± 0.01^d	54.61 ± 0.02^e
4	Crude Lipid	1.95 ± 0.04^a	2.59 ± 0.01^a	0.03 ± 0.01^a
5	Crude Protein	5.87 ± 0.01^b	6.41 ± 0.01^b	0.02 ± 0.00^a
6	Carbohydrate	14.85 ± 0.00^c	48.33 ± 0.00^e	25.67 ± 0.00^d

Values are Expressed as Mean ± Standard Deviation (n = 3). Value Across Each Column Bearing Same Superscript are not Different Significantly According to Duncan New Multiple Range Test

Notes: Each Value Represents the Mean of Triplicate Determinations (a, b, c). All Results are Expressed as Percentage Composition (% w/w).

Table 4 shows that moisture content was highest in stem bark (12.73 ± 0.12%) and lowest in shell (8.30 ± 0.01%). Ash content was highest in stem bark (25.10 ± 0.10%) compared to leaves (11.40 ± 0.02%) and shell (11.35 ± 0.02%). Crude fibre was highest in shell (54.61 ± 0.02%) and lowest in leaves (20.06 ± 0.01%). Crude lipid and protein were negligible in the shell (0.03% and 0.02% respectively) compared to leaves and stem bark. Carbohydrate content was highest in leaves (48.33%) and lowest in stem bark (14.85%).

Discussion

The presence of alkaloids, tannins, saponins, flavonoids, steroids, terpenoids, cardiac glycosides, and deoxy sugars in all parts of V. paradoxa (Table 1) is in agreement with the previous reports on the species (Ojo *et al.,* 2021; Mohammed *et al.,* 2024). The high terpenoid content (+++) is consistent with Sirignano *et al.,* (2021), who found that triterpenoids are the most abundant bioactive class in the vegetative tissues of *V. paradoxa*. The tannin intensity in stem bark (++) is higher than in leaves and shell, which is in agreement with Sale *et al.,* (2023) who also found tannin intensity to be higher in stem bark than in leaves and shell in *V. paradoxa*. The moderate levels of flavonoids and steroids in leaves indicate that they are the main biosynthetic organs for phenylpropanoid derived metabolites (Hasnat *et al.,* 2024). The absence of anthraquinones in all the samples is consistent with the chemotaxonomic consistency of *V. paradoxa* within Sapotaceae reported by Nestor *et al.,* (2024). The low phytochemical content of the shell, which is devoid of alkaloids and saponins, aligns with its structural function and not metabolically active physiological role, but the presence of residual flavonoids and terpenoids indicates its potential as a bioactive feedstock in circular bioeconomy systems (Saady *et al.,* 2026). The stability of the iodine value of the butter between semi-processed (47.68 g I_2/100g) and processed (47.94 g I_2/100g) butter confirms that the unsaturation of fatty acids was not affected during processing, which is in agreement with Mensah *et al.,* (2020) who reported similar iodine value stability for *V. paradoxa* processing methods. The saponification value increased from 183.3 to 196.2 mg KOH/g after processing, reflecting the concentration of saponifiable triacylglycerols and removal of non-saponifiable impurities during clarification (Tchobo *et al.,* 2022). The PV of the processed sample increased from 4.29 to 6.11 meq O_2/kg, which is within the safe limit (≤10), indicating thermal radical initiation during roasting and depletion of tocopherols during filtration, as reported by Kolawole et al., (2025). The significant decrease in acid value (18.23 to 8.43 mg KOH/g) and free fatty acid content (9.12 to 4.22%) confirms the effectiveness of traditional clarification in removing lipolysis-derived free fatty acids, which is in agreement with Honfo *et al.,* (2020) and Nikiema *et al.,* (2021), although both values are still higher than the Codex limits, requiring further refining steps.

The organ-specific variation in the proximate composition of *V. paradoxa* plant parts was significant (Table 4). The moisture content of all parts (8.30–12.73%) is within the acceptable range for stable bioactive preservation during storage as reported by Nuhu *et al.,* (2021). The high ash content of stem bark (25.10%) compared to leaves (11.40%) and shell (11.35%) suggests that it has a mineral rich tissue profile, which explains its traditional use in the management of mineral deficiency conditions as reported by Abubakar *et al*., (2022). The highest crude fibre in shell (54.61%) is indicative of its lignocellulosic structural composition, which is in agreement with Saady *et al*., (2026), who reported that high fibre content is a characteristic of tropical fruit shell by-products. The leaves had the highest carbohydrate (48.33%), protein (6.41%) and lipid (2.59%) values, which is indicative of their metabolically active nature and their traditional use in gastrointestinal preparations where mucilaginous polysaccharides have gastroprotective effects (Ojo *et al*., 2021). The low lipid content of the shell (0.03%) and protein content (0.02%) further supports the nutritionally poor nature of the shell, and the low lipid content of all parts (0.03–2.59%) suggests that polar and moderately polar extraction solvents are best suited to extract the major bioactive classes from these tissues (Lawrence *et al.,* 2023).

CONCLUSION

The present study aimed to compare the phytochemical profile, proximate composition and physicochemical quality of the stem bark, leaves, kernel shell and processed shea butter of *Vitellaria paradoxa*. Qualitative phytochemical screening revealed that the leaves had the highest phytochemical diversity and intensity, especially in terms of terpenoids, flavonoids and steroids, whereas the shell had the least. The results confirm the proposed differences in the distribution of secondary metabolites in various parts of the plant and justify the use of leaves and stem bark in traditional medicine. The inter-organ compositional differences were significant, as stem bark had the highest mineral content, shell the highest crude fibre content and leaves the highest carbohydrate and protein content, which is indicative of the different physiological functions of each organ. The physicochemical analysis of shea butter showed that the traditional processing method enhanced the hydrolytic quality of shea butter by reducing the acid value and free fatty acid content, and slightly increased the oxidative status as reflected by the peroxide value. The stability of iodine value throughout the processing stages indicated that the unsaturation of fatty acids was maintained. In general, the study provides a scientific basis for the systematic characterization of the nutritional and phytochemical profile of *V. paradoxa* and provides scientific evidence for the use of its various plant parts.

Limitations

There are some limitations to this study. Phytochemical screening was qualitative and semi-quantitative, and the lack of spectrophotometric quantification of total phenolic, flavonoid and tannin content restricts the validity of the inferences drawn from the phytochemicals and should be addressed in future studies with the Folin–Ciocalteu and aluminium chloride methods. Second, the proximate composition data is internally consistent, but it is only for one harvest season and geographic location, and seasonal and ecotypic variation in *V. paradoxa* secondary metabolite and nutrient profiles within its distribution range cannot be ruled out. Third, the physicochemical characterization of shea butter was restricted to five parameters; a more detailed lipid quality assessment, which includes fatty acid profiling by gas chromatography, determination of the content of tocopherols and measurement of the oxidative stability index, would give a more complete picture of the changes in quality that occur during processing. Fourth, the study did not examine the effect of the polarity of the extraction solvent on the recovery of the bioactive compounds from the characterized parts of the plant, which is an important area for future studies on the optimization of extraction. Lastly, the traditional processing conditions used in this study (roasting temperature and clarification time) were not exactly controlled in the laboratory, which could cause some variability and reduce the reproducibility of the physicochemical results.

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