Qualitative and Quantitative Assessment of Phytochemical Constituents in Selected Medicinal Plants from Nigeria

Abstract

The therapeutic potential of medicinal plants is well-recognized globally for their rich phytochemical profiles and pharmacological properties. This study examined the phytochemical composition and therapeutic potential of six (6) selected medicinal plants. Standard extraction and quantitative screening methods were employed, revealing diverse distributions of key bioactive compounds including alkaloids, flavonoids, tannins, phenols, saponins, and terpenoids. *Justicia carnea* excelled in tannins (132.16 mg/g) and cardiac glycosides (137.12 mg/g), alongside notable alkaloids (12.05 mg/g) and phenolics (22.52 mg/g), suggesting strong anti-inflammatory and cardiac-modulatory effects. *Heinsia crinitea* showed high tannins (125.14 mg/g) and TPC (382.22 mg/g), with solid alkaloids (10.13 mg/g) and DPPH activity (129.23), indicating robust antioxidant capacity. *Kalanchoe pinnata* demonstrated elevated alkaloids (18.4 mg/g), tannins (116.78 mg/g), and TPC (216.11 mg/g), positioning it as a versatile candidate for wound healing and immune support. *Aloe vera* led in saponins (10.67 mg/g) and TPC (210.05 mg/g), with substantial alkaloids (13.07 mg/g), supporting its traditional use in skin repair and anti-inflammatory applications. *Vernonia amygdalina* featured high steroids (4.72 mg/g), flavonoids (13 mg/g), and alkaloids (9.89 mg/g), with moderate TPC (67.52 mg/g) and DPPH (73.22), aligning with its antimicrobial and antimalarial properties. *Ocimum gratissimum* exhibited balanced profiles, including TPC (27.16 mg/g) and DPPH (68.4), highlighting potential for respiratory and immune-modulatory benefits. These results highlight the pharmacological value of these compounds, and other metabolites, which drive antioxidant, antimicrobial, anti-inflammatory, and immune-enhancing activities. This analysis validates traditional uses through scientific evidence, paving the way for advanced extraction techniques, safety evaluations, and industrial applications.

Keywords: Medicinal plants; Phytochemical analysis; Bioactive compounds; Therapeutic potential; Antioxidant activity

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1. Introduction

Medicinal plants have played a crucial role in human health for thousands of years, serving as foundational sources for traditional medicine systems across diverse cultures (Ugboko *et al.,* 2020). The therapeutic efficacy of these plants is primarily attributed to their rich array of phytochemical constituents, often referred to as secondary metabolites, which exert distinct biological effects on living organisms (Oyedepo, 2018; Adesanya *et al.,* 2023). These bioactive compounds include, but are not limited to, alkaloids, flavonoids, saponins, tannins, steroids, terpenoids, and phenols, each contributing to the plants' pharmacological potential, such as antimicrobial, antioxidant, anti-inflammatory, analgesic, and antidiabetic activities (Anbessa *et al.,* 2024). For instance, lignanamides isolated from *Solanum melongena* L. have demonstrated anti-inflammatory effects by inhibiting nitric oxide production (Yang *et al.,* 2019). Similarly, a natural compound (LCA) from *Litsea cubeba* inhibits osteoclast differentiation by suppressing Akt and MAPK pathways (Yu *et al.,* 2020). The traditional use of these plants, often passed

down through generations, highlights a deep indigenous knowledge base concerning their applications in managing various diseases (Mangalik and Susandarini, 2025).

Globally, it is estimated that about 80% of the population in developing countries relies on traditional medicine, primarily herbal remedies, for their healthcare needs. This high dependence stems from several factors including accessibility, affordability, and cultural trust in herbal practices (Dubale *et al.,* 2025). The increasing interest in natural remedies is partly due to growing awareness of the side effects associated with synthetic pharmaceuticals, which has driven researchers to explore the therapeutic potential of plant-derived compounds. Additionally, in many developing nations, traditional medicine remains integral to cultural heritage and daily health practices, often coexisting with modern medicine systems (Mbuni *et al.,* 2020). Countries such as China and India have taken significant steps to integrate herbal medicines into national healthcare frameworks, recognizing their importance and potential.

In Nigeria, a country with immense biodiversity and a rich ethnomedical heritage, medicinal plants continue to play a vital role in primary healthcare, particularly among rural populations (Lawal, 2025; Rafiu *et al.,* 2025). Traditional medical practitioners in Nigeria utilize a wide range of plant species for the prevention, treatment, and management of numerous acute and chronic conditions (Rafiu *et al.,* 2025). The sustained interest in herbal medicine, both from practical and scientific standpoints, highlights the necessity of understanding the chemical basis of their purported medicinal properties (Oyedepo, 2018). Studies have identified the presence of various bioactive constituents such as alkaloids, saponins, flavonoids, phenols, and tannins in Nigerian medicinal plants (Ogbuagu *et al.,* 2022; Enin *et al.,* 2023; Olise and Enweani-Nwokelo, 2023; Umeh *et al.,* 2024; Adebiyi, 2025).

Despite the widespread traditional use and documented efficacy of many Nigerian medicinal plants, there remains a significant gap in the comprehensive qualitative and quantitative assessment of their phytochemical profiles particularly for *Justicia carnea, Heinsia crinitea, Kalanchoe pinnata, Aloe vera, Vernonia amygdalina, and Ocimum gratissimum*. In order to bridge this gap, this research aims to conduct a thorough investigation into the phytochemical constituents of these medicinal plants from Nigeria, employing both qualitative and quantitative analytical techniques. The study seeks to generate reliable data that will enhance understanding of the bioactive compounds present in these plants, support their traditional applications, and potentially contribute to the development of novel therapeutic agents.

2. Materials and Methods

2.1 Study Area Description

The study area is Uyo which is the capital city of Akwa Ibom State in Nigeria (**Figure 1**). It is characterized by a diverse population and a mix of residential, commercial, and industrial areas. The current metro area population of Uyo is 1,457,000 a 4.59 % increase from 2024 (Udousoro *et al.,* 2025). The area lies in the humid tropical rainforest zone of southern Nigeria, being distinguished by high annual rainfall with an average of 3868.91 mm, warm temperatures of 27°C (Usoh, 2025), and abundant vegetation.

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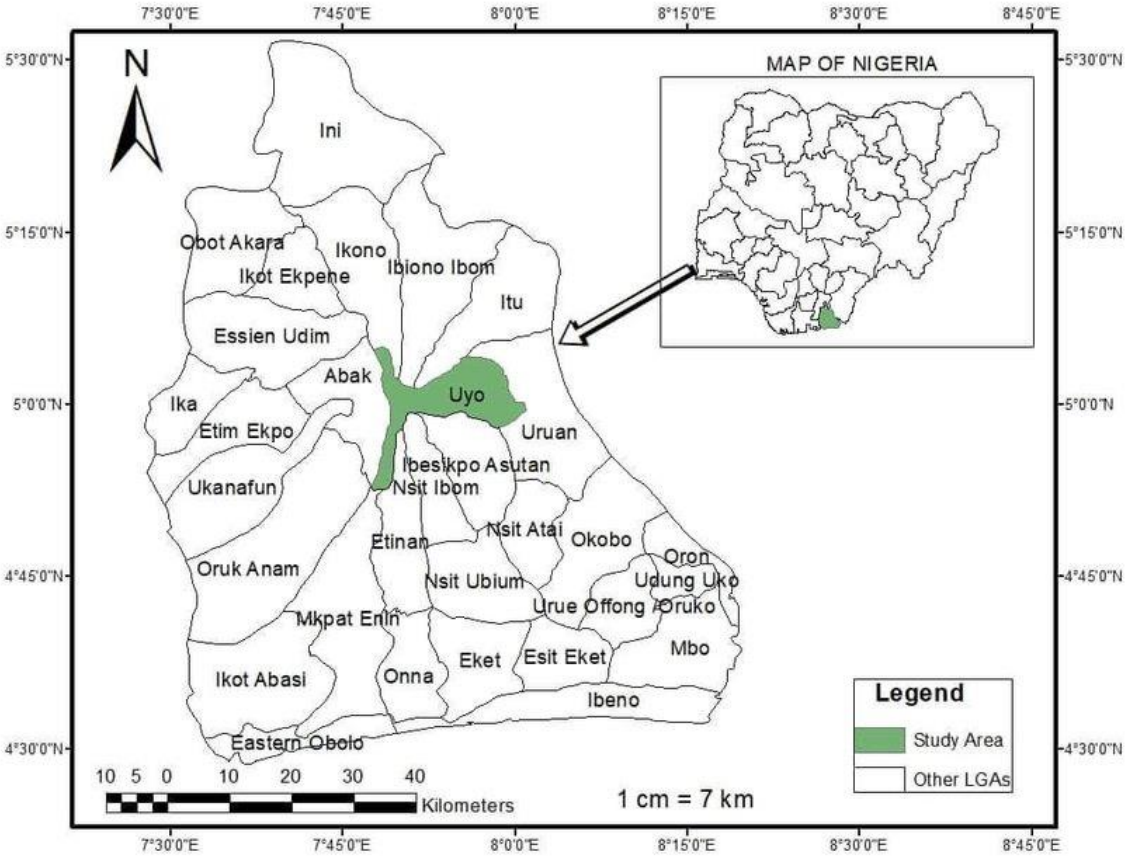

Figure 1: The map of the study area, state in Nigeria.

2.2 Collection of Samples

Fresh leaves of the selected medicinal plants were collected within the streets of Nwanibia road in Uyo. The leaves were taken from healthy and mature plants. Each sample was placed in a clean, labeled polythene bag to avoid cross-contamination. The plants were then deposited at the herbarium laboratory in the Botany Department, University of Uyo, for identification by a qualified taxonomist. The scientific names, English/Ibibio or Efik names, the Family, Herbarium numbers of the plant samples investigated and their GPS coordinates are presented in **Table 1** and the pictures of the studied plants in **Figure 2**.

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Table1: The scientific, English/Ibibio or Efik names, herbarium number and GPS coordinate of the studied samples.

Scientific name	English/local name	Family	Herbarium number	Latitude	Longitude
Heinsia crinita	Bush apple (Atama)	*Rubiaceae*	PETER UYYH4722	5.048983N	7.980914E
Kalanchoe pinnata	Cathedral bell (Nndudub)	*Crassulaceae*	PETER UYYH4721	5.032963N	7.975592E
Justicia carnea	Brazilian plume (Mfang ibok iyip)	*Acanthaceae*	PETER UYYH4723	5.032795N	7.975182E
Aloe vera (L.) Burn. F	Aloe vera	*Asphodecease*	UYYH4723	5.027352N	7.983639E
Vernonia amygdalina	Bitter leaf	*Asteraceae*	UUPH NO. 30[j]	5.0339N	7.9239E

Figure 2: Pictures of the medicinal plant samples used in this study

2.3 Preparation and Extraction of Samples

The leaves of the harvested plant samples were destalked, washed with tap water before washing with distilled water to remove further impurities, sliced, and air dried at room temperature. The dried leave were ground into fine powder using stainless steel blender and stored in well labelled Ziploc bag for analysis.

A 10-30 g sample of the powdered leaves were extracted with 80% ethanol as a solvent, and the extract was filtered using No. 1 Whatman filter paper and stored at 4ºC in a tightly sealed labelled container for phytochemicals analysis.

2.4 Qualitative analysis

2.4.1 Test for Alkaloids

2 ml of extract was treated with 2 drops of Mayer's reagent (Potassium iodide + distilled water), along the sides of the test tube. A creamy white or yellow precipitate was taken as confirmatory evidence for the presence of alkaloids.

2.4.2 Test for Flavonoids

A. Using Alkaline reagent test: 1 mL of extract was treated in 2 mL of 2% NaOH solution. An intense yellow colour, became colourless on the addition of few drops of dilute hydrochloric acid indicating the presence of flavonoids.

B. Lead acetate test: 1 mL of extract was treated with 2 drops of 10% lead acetate solution. A yellow precipitate indicated the presence of flavonoids.

C. Ferric chloride test: 2 mL of extract was added to 2 drops of 5% ferric chloride solution. A green precipitate indicated the presence of flavonoids.

2.4.3 Test for Saponin

0.5 gm of extract was shaken with 2 mL of water. Formation of foam persisted for 10 minutes indicates the presence of saponins.

2.4.4 Test for Tannins

2 mL of the extract was added to a few drops of 1% lead acetate. A yellowish precipitate indicated the presence of tannins.

2.4.5 Test for Phenolic compounds

A. Lead acetate test: Plant extract was dissolved in 5 mL of distilled water and 3 mL 10% lead acetate solution was added to it. A white precipitate indicated the presence of phenols.

B. Ferric chloride test: 1 mL of extract was added to 2 drops of 5% ferric chloride solution. A dark green or bluish black precipitate indicated the presence of phenols.

2.4.6 Test for Terpenes

5 mL of extract was dissolved in 2 mL of acetic anhydride in a test tube and then in 2mL chloroform. The solution was under laid with 3 mL of concentrated sulphuric acid (boiled on water bath). A grey coloured solution indicated the presence of terpenoids.

2.4.7 Test for Anthocyanins

2 mL of extract was dissolved in 2 mL of HCl, a few mL of ammonia was added to the solution. A pink-red solution which turns blue-violet after the addition of ammonia indicated the presence of anthocyanins.

2.4.8 Test for Anthraquinones

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10 mg of extract was dissolved in isopropyl alcohol and 2 mL of 10% Conc. Ammonium hydroxide solution was added. Formation of red colour after 2 minutes indicated the presence of anthraquinones.

2.4.9 Test for Cardiac Glycosides: Using Keller Killian's test

1 mL of filtrate was dissolved in 1.5 mL of glacial acetic acid containing one drop of 5% $FeCl_3$ solution in a test tube. The mixture was under laid with 2 mL of concentrated sulphuric acid (along the side of the test tube). A blue coloured solution in acetic acid layer indicated the presence of cardiac glycosides.

2.5 Quantitative Analysis

2.5.1 Determination of Total Alkaloids

2 g of the plant powder was weighed into the beaker and 100 mL of 20% acetic acid in ethanol was added to the plant sample. The mixture was covered and allowed to stand for 4 hours. The mixture was then filtered and the extract was allowed to become concentrated in a water bath till it reaches a quarter of the original volume. Concentrated NH_4OH was added until the precipitation was complete. The whole solution was allowed to settle the precipitate was collected and washed with dilute NH_4OH and then filtered. The residue is alkaloid which was then dried and weighed. The alkaloid content was calculated and expressed as a percentage of the weight of the sample analysed (**Equ. 1**).

Calculation:

$$\%\text{Weight of alkaloid} = \frac{\text{weight of filter paper with residue} - \text{weight of filter paper}}{\text{Weight of sample analysed}} \times 100 \qquad \text{(Equ. 1)}$$

2.5.2 Determination of Flavonoid

5 g of plant sample was repeatedly extracted with 100 mL of 70% aqueous methanol at room temperature. The whole solution was then filtered through the filter paper and the filtrate was later placed in a water bath and the solution was allow to evaporate into dryness. The sample was then weighed. The flavonoid content was calculated and expressed as a percentage of the weight of the sample analysed using **Equ. 2**.

$$\%\text{Weight of flavonoids} = \frac{\text{weight of filter paper with residue} - \text{weight of filter paper}}{\text{Weight of sample analysed}} \times 100 \qquad \text{(Equ. 2)}$$

2.5.3 Determination of Saponins

Exactly 2 g of each sample were put into a conical flask and 150 mL of 20% aqueous ethanol was added to the sample. The sample were heated over a hot water bath for 4 hours with continuous stirring at about 55°C. The mixture was filtered and the residue re-extracted with another 100 mL of 20% aqueous ethanol. The combined extracts were reduced to 40 mL over water bath at about 90°C. The concentrated is then transferred into a 250 mL separating funnel and acetone was added to the extract and vigorously shaken, then kept to precipitate, filtered and then weighed. The saponins content was calculated and expressed as a percentage of the weight of the sample analysed using **Equ. 3.**

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$$\%\text{Weight of saponin} = \frac{\text{weight of filter paper with residue} - \text{weight of filter paper}}{\text{Weight of sample analysed}} \times 100 \qquad \text{(Equ. 3)}$$

2.5.4 Determination of Total Phenolic compounds

The total phenolic content was determined using the Folin–Ciocalteu method.1 g of dried powdered sample was extracted with 20 mL of 70% methanol, shaken for 2 hours, centrifuged at 3500 rpm for 10 minutes, filtered, and made up to 50 mL with solvent.

Gallic acid was used to prepare standards (0–100 µg/mL). For each standard or sample, 0.5 mL was mixed with 2.5 mL of 10% Folin–Ciocalteu reagent, allowed to stand for 5 minutes, then 4.0mL of 7.5% sodium carbonate was added. The mixture was incubated for 30 minutes at room temperature in the dark, and absorbance was measured at 505 nm using a spectrophotometer against a blank.

A calibration curve (absorbance vs. garlic acid concentration) was used to calculate results, expressed as milligrams garlic acid equivalents per gram dry weight (mg GAE·g^{-1} DW) using (**Equ. 4**)

$$\text{TPC (mg GE/g DW} = \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \times \frac{\text{Conc. of standard}}{\text{weighing of sample}} \times df \times 100 \qquad \text{(Equ. 4)}$$

2.5.5 Antioxidant Scavenging Assay

The antioxidant activity of the methanol leaf extracts of the plant samples were evaluated using 1, 1- diphenyl-2-picryl hydrazyl (DPPH) assay methods, various concentration of extract in µg/mL (50, 100,150, 200, 250, 300 µg/mL) was used. 1 mL of each extract (at varying concentration was added in methanol to 1 mL of 0.004% methanol solution of DPPH and was shaken vigorously, and allowed to stand for 30 minutes at room temperature in the dark. The absorbance of the solution was measured at 517 nm was recorded using a UV-Vis Spectrophotometer. Method was repeated for blank (methanol without sample) and for the control (methanol plus BHT) and IC_{50} for the various concentrations were calculated as follows (**Equ. 5**):

$$\text{Antioxidant scavenging activity} = \frac{A_{control} - A_{Sample}}{A_{Control}} \times 100 \qquad \text{(Equ. 5)}$$

Where, $A_{control}$ is the mixture of methanol and DPPH solution, and A_{sample} is the mixture of sample extract and DPPH solution.

3. Results and Discussions

3.1 Qualitative Assessment of Phytochemical Constituents in Selected Medicinal Plants

The qualitative assessment of phytochemical constituents in the selected medicinal plants reveals a diverse array of bioactive compounds, with varying intensities across species (**Table 2**). These plants consistently demonstrate the presence of major phytochemical classes such as alkaloids, flavonoids, tannins, phenolic compounds, saponins, and glycosides, which contribute significantly to their therapeutic potential. Specifically, *Justicia carnea* is noted for

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containing significant flavonoids, alkaloids, and phenolic compounds, aligning with its traditional applications for antioxidant and anti-inflammatory activities (Andrew et al., 2024). *Heinsia crinitea* also exhibits flavonoids, alkaloids, tannins, and phenolics, suggesting potential antioxidant and antimicrobial properties, although it notably lacks terpenoids and anthocyanins. *Kalanchoe pinnata* presents a broad spectrum of phytochemicals, particularly saponins and flavonoids, which are implicated in wound healing and anti-inflammatory effects (Adodo et al., 2024). *Aloe vera* is rich in phenolic compounds and glycosides, consistent with its extensive use in dermatological treatments and as an anti-inflammatory agent (Goyani, 2025). *Vernonia amygdalina* demonstrates strong qualitative reactions for alkaloids, tannins, and flavonoids, which are associated with its documented antimalarial and anticancer properties (Erhabor & Erhabor, 2024). *Ocimum gratissimum* shows a diverse phytochemical profile, including terpenoids and phenolics, contributing to its antimicrobial and antioxidant activities (Adodo et al., 2024).

Table 2: Qualitative assessment of phytochemical constituents in the selected medicinal plants

Phytochemicals	***Justicea carnea***	***Heinsia crinitea***	***Kalanchoe pinnata***	***Aloe vera***	***Vernonia amygdalina***	***Ocimum gratissimum***
Cardiac glycoside	+	+	+	+	+	+
flavonoids	+	+	+	+	+	+
Phenolic compounds	+	+	+	+	+	+
Tannins	+	+	+	+	+	+
Phytosterols	+	+	+	+	+	+
Terpenoids	+	–	+	–	+	+
Quinones	–	+	+	–	+	+
Anthraquinones	+	+	+	+	+	+
Anthocyanins	–	–	–	–	+	+
Coumarins	+	+	+	–	+	+
Reducing sugar	+	+	+	–	+	+
Amino acids	+	+	+	+	+	+
Protein	–	+	+	+	–	–
Steroids	+	+	+	+	+	+
Saponins	+	+	+	+	+	+
Alkaloids	+	+	+	+	+	+
Triterpenoids	–	–	+	+	+	+
Diterpenoids	–	+	+	–	+	+

Intensity (key): *+ (Present); – (Absent)*

Comparing these findings with other global and African studies reveals both consistencies and unique insights. The widespread presence of alkaloids, flavonoids, tannins, and saponins in the Nigerian plants aligns with reports from Ethiopia, where medicinal plants are similarly rich in these compounds, demonstrating antibacterial activity and antioxidant potential. For example, a study on selected medicinal plants in the Dibatie district, Metekel zone, western Ethiopia,

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highlighted the therapeutic efficacy of these plants due to their diverse phytochemicals, echoing the findings in Nigerian species (Anbessa *et al.,* 2024). This suggests a common evolutionary pressure or ecological niche that favours the biosynthesis of these secondary metabolites in African flora.

The absence of some specific compounds, such as terpenoids, quinones, anthocyanins and protein in these plant species, warrants further consideration. While many plant species are recognized for their diverse phytochemical profiles contributing to various biological activities (Rani *et al.,* 2023; Lin *et al.,* 2025), the specific absence of certain compounds highlights the critical importance of detailed species and subspecies analysis. Phytochemical profiles can vary significantly even within the same genus or species due to genetic, environmental, and developmental factors (Ahadi et al., 2023; Feng et al., 2024). For instance, salal berries (*Gaultheria shallon Pursh.*) demonstrate significant changes in proanthocyanidin and anthocyanin content during fruit development (Ferguson et al., 2018). Similarly, the composition of storage proteins, minor proteins, and amino acids varies across different faba bean cultivars (Xiao et al., 2025). This variation highlights that general classifications may not capture the full complexity of a plant's biochemical makeup.

Terpenoids are a diverse group of natural compounds responsible for aromas, essential oils, and various biological defense functions in many plants, as seen in species like *Rhus chinensis* (Li et al., 2024), *Lepidium apetalum* (Lin et al., 2025), and multiple *Cannabis* strains (Benes et al., 2024); therefore, their absence in *Heinsia crinitea and Aloe vera* may indicate distinct metabolic pathways or alternative defense strategies. Anthocyanins, the pigments that produce red purple and blue coloration and provide strong antioxidant activity, also vary widely across plant species including Sorbus fruits, Chinese cherry, and bilberry liqueurs (Medic et al., 2023; Liu et al., 2024; Siniawska et al., 2025), so their absence in *Justicea carnea, Heinsia crinitea, Kalanchoe pinnata and Aloe vera* suggests that other phytochemicals determine its coloration and antioxidant properties, potentially influencing its industrial applications where natural pigments are valued. Proteins are essential to nearly all biological processes and occur in great diversity across plants and microorganisms (Xiao et al., 2025). Therefore, the reported absence of proteins in *Justicea carnea, Vernonia amygdalina and Ocimum gratissimum is* highly unlikely and more likely reflects very low protein concentrations or limitations in the extraction or detection methods used, since plants naturally contain structural, enzymatic, and storage proteins in their tissues.

The emphasis on qualitative analysis in this study, while foundational, sets the stage for more rigorous quantitative assessments. The pharmaceutical industry and researchers are increasingly interested in the precise quantification of active compounds to standardize herbal medicines and develop new drugs (Kibibi, 2025). The future of medicinal plants in combating emerging infectious diseases, for example, relies heavily on understanding their phytochemical properties and mechanisms of action against pathogens. The detailed qualitative insights from this study provide a strong basis for targeted quantitative research using techniques such as Gas Chromatography-Mass Spectrometry (GC-MS) or Ultra-Performance Liquid Chromatography-Quadrupole Time-of-Flight Mass Spectrometry (UPLC-QTOF-MS), which are instrumental in achieving detailed phytochemical profiling and global semi-quantitation.

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Ultimately, the present qualitative assessment of these Nigerian medicinal plants contributes significantly to the ethnobotanical landscape by confirming the presence of numerous therapeutically relevant phytochemicals. This study provides a crucial step towards validating traditional uses and lays the groundwork for future quantitative studies, drug discovery, and the development of evidence-based herbal therapies, ensuring quality control and efficacy of plant-derived medicines.

3.2 Quantitative Assessment of Phytochemical Constituents in Selected Medicinal Plants

The quantitative assessment of phytochemical constituents across these medicinal plants revealed significant variations in the concentrations of bioactive compounds, correlating with their traditional therapeutic applications. *Heinsia crinitea* led in terpenoids at 13.56 mg/g, followed by *Kalanchoe pinnata* (11.04 mg/g), *Vernonia amygdalina* (8.1 mg/g), and *Ocimum gratissimum* (0.52 mg/g). Terpenoids underpin anti-inflammatory, antimicrobial, and anticancer effects (Degu et al., 2024). For alkaloids, *Kalanchoe pinnata* topped the list at 18.4 mg/g, with *Aloe vera* (13.07 mg/g), *Justicia carnea* (12.05 mg/g), *Heinsia crinitea* (10.13 mg/g), and *Vernonia amygdalina* (9.89 mg/g) following; *Ocimum gratissimum* trailed at 1.54 mg/g (**Table 3**). These compounds drive analgesic, antimalarial, and anti-inflammatory activities (Degu et al., 2024).

Saponin levels varied widely, peaking in *Aloe vera* (10.67 mg/g), *Heinsia crinitea* (7.02 mg/g), *Kalanchoe pinnata* (8.25 mg/g), *Justicia carnea* (6.81 mg/g), and *Vernonia amygdalina* (6.54 mg/g), while *Ocimum gratissimum* registered just 2.1 mg/g. Saponins support anti-inflammatory, cholesterol-lowering, and immune-modulating properties (Zhang et al., 2023). Flavonoids were highest in *Kalanchoe pinnata* (17.16 mg/g) and *Vernonia amygdalina* (13 mg/g), with *Heinsia crinitea* (8.88 mg/g), *Justicia carnea* (7.5 mg/g), *Aloe vera* (3.26 mg/g), and *Ocimum gratissimum* (1.21 mg/g) lower (**Table 3**). As potent antioxidants, flavonoids confer anti-inflammatory, antiviral, and anticancer benefits (Degu et al., 2024), notably enhancing *Vernonia amygdalina's* medicinal value (Ugbaja et al., 2021).

Tannins reached exceptional levels in *Justicia carnea* (132.16 mg/g), *Heinsia crinitea* (125.14 mg/g), and *Kalanchoe pinnata* (116.78 mg/g), contrasting sharply with *Aloe vera* (25.66 mg/g), *Ocimum gratissimum* (3.05 mg/g), and *Vernonia amygdalina* (1.2 mg/g). Their astringent, antioxidant, and antimicrobial roles are well-documented (Brahmam et al., 2024). C-glycosides dominated in *Justicia carnea* (137.12 mg/g), far exceeding *Heinsia crinitea* (1.65 mg/g), *Kalanchoe pinnata* (0.15 mg/g), *Vernonia amygdalina* (0.08 mg/g), *Aloe vera* (0.06 mg/g), and *Ocimum gratissimum* (0.04 mg/g) (**Table 3**); these exhibit cardiotonic, anti-inflammatory, and antimicrobial effects.

Anthraquinones appeared in *Kalanchoe pinnata* (1.86 mg/g), *Justicia carnea* (1 mg/g), and *Heinsia crinitea* (0.87 mg/g), but were undetectable (-) in *Aloe vera, Vernonia amygdalina*, and *Ocimum gratissimum*. Steroids peaked in *Vernonia amygdalina* (4.72 mg/g), *Kalanchoe pinnata* (2.11 mg/g), and *Justicia carnea* (1.73 mg/g), with others ranging from 1.07 mg/g *(Heinsia crinitea*) to 0.98 mg/g (*Ocimum gratissimum*). Phenolics were prominent in *Kalanchoe pinnata* (32.56 mg/g), *Justicia carnea* (22.52 mg/g), and *Heinsia crinitea* (21.56 mg/g), dropping to 3.58 mg/g (*Vernonia amygdalina*), 2.4 mg/g (*Ocimum gratissimum*), and

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0.232 mg/g (*Aloe vera*) (**Table 3**). These compounds deliver strong antioxidant, neuroprotective, and anti-inflammatory activity (Nájera-Maldonado et al., 2024).

Total phenolic content (TPC) favoured *Heinsia crinitea* (382.22 mg/g), *Kalanchoe pinnata* (216.11 mg/g), and *Aloe vera* (210.05 mg/g), compared to 67.52 mg/g (*Vernonia amygdalina*), 27.16 mg/g (*Ocimum gratissimum*), and 5.81 mg/g (*Justicia carnea*). DPPH assay results indicated robust antioxidant capacity in *Heinsia crinitea* (129.23), *Justicia carnea* (117.67), *Kalanchoe pinnata* (108.83), *Aloe vera* (85.01), *Vernonia amygdalina* (73.22), and *Ocimum gratissimum* (68.4), where higher values reflect greater activity. *Vernonia amygdalina* had the highest steroid content at 4.72 mg/g, followed by *Kalanchoe pinnata* at 2.11 mg/g, and *Justicia carnea* at 1.73 mg/g while *Heinsia crinitea* (1.07 mg/g), *Aloe vera* (1.04 mg/g) and *Ocimum gratissimum* (0.98 mg/g) showed lower contents. Total flavonoid content (TFC) was highest in *Aloe vera* (108.25 mg/g), *Heinsia crinitea* (103.84 mg/g), and *Kalanchoe pinnata* (101.4 mg/g), with *Vernonia amygdalina* (24.22 mg/g), *Justicia carnea* (20.86 mg/g), and *Ocimum gratissimum* (17.12 mg/g) lower (**Table 3**). TFC indicates the overall flavonoid content, contributing to the plant's antioxidant potential.

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Table 3: Quantitative assessment (mg/g) of phytochemical constituents across various medicinal plants

Parameters	***Justice carnea***	***Heinsia crinitea***	***Kalanchoe pinnata***	***Aloe vera***	***Vernonia amygdalina***	***Ocimum gratissimum***
Terpenoid	6.34	13.56	11.04	8.12	8.1	0.52
Alkaloid	12.05	10.13	18.4	13.07	9.89	1.54
Saponin	6.81	7.02	8.25	10.67	6.54	2.1
Flavonoid	7.5	8.88	17.16	3.26	13	1.21
Tannin	132.16	125.14	116.78	25.66	1.2	3.05
C/glycoside	137.12	1.65	0.15	0.06	0.08	0.04
Anthraquinone	1	0.87	1.86	0.26	-	-
Phenolics	22.52	21.56	32.56	0.232	3.58	2.4
TPC	5.81	382.22	216.11	210.05	67.52	27.16
TFC	20.86	103.84	101.4	108.25	24.22	17.12
DPPH	117.67	129.23	108.83	85.01	73.22	68.4
Steroid	1.73	1.07	2.11	1.04	4.72	0.98

Comparing these findings with other African and global studies reveals both consistencies and variations in phytochemical profiles and their implications for pharmacological activity. For instance, the widespread occurrence of alkaloids, flavonoids, saponins, and tannins in Nigerian medicinal plants aligns with observations reported across other African regions. Studies on species such as *Aspilia africana* and *Sida acuta* have demonstrated considerable variation in their phytochemical profiles. *A. africana* contains substantial levels of alkaloids (8.22 ± 0.40 mg/100 g), saponins (4.20 ± 0.05 mg/100 g), and tannins (2.23 ± 0.03 mg/100 g), whereas *S. acuta* exhibits notable concentrations of flavonoids (0.55 ± 0.02 mg/100 g), saponins (0.28 ± 0.05 mg/100 g), and alkaloids (2.31 ± 0.03 mg/100 g) (Anyanele *et al.,* 2023). Similarly, a 2024 Nigerian investigation of *Bryophyllum (Kalanchoe) pinnatum* leaf extracts reported alkaloid levels ranging from 6.65% to 8.20%, flavonoids from 2.26% to 10.91%, and saponins from 1.24% to 4.95%, depending on the extraction solvent (Nnaebue *et al.,* 2024). These findings are consistent with research from other regions of Africa, where medicinal plants likewise exhibit high levels of these phytochemical constituents, reflecting their broad spectrum of biological activities, including notable antibacterial and antioxidant properties.

Globally, the identification of diverse phytochemicals across medicinal plants, such as those highlighted in the present study, remains a central theme in ethnopharmacological research. For instance, *Convolvulus scammonia* Linn. (Saqmonia), an important medicinal plant in Unani medicine, is widely recognized for its therapeutic properties, which are closely linked to its rich composition of naturally occurring bioactive constituents (Zahid *et al.,* 2020). The focus on both qualitative and quantitative analyses of medicinal plants, globally and particularly in Africa, is motivated by the need to scientifically validate traditional uses and advance evidence-based herbal therapies. Such analyses are essential for elucidating the chemical basis of therapeutic properties and for ensuring the safety and efficacy of plant-derived medicines (Nwozo *et al.,* 2023).

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Variations in phytochemical intensity and presence across different regions can be attributed to environmental factors, genetic diversity, and cultivation practices. The observations from this study of some specific plant species containing the highest levels of flavonoids and phenols, while others had lower concentrations, illustrates how species-specific differences in composition are influenced by internal plant biochemistry. Such variations are also influenced by soil mineral content, exposure to sunlight, and moisture levels during growth (Nwozo *et al.,* 2023). This aligns with global understanding that environmental stressors can significantly alter secondary metabolite production (Onuchukwu *et al.,* 2025). The presence of cyanogenic glycosides in these plant species, though toxic in excess, highlights the importance of traditional processing methods to mitigate potential risks. Also, the high concentration of flavonoids and phenols in these plant species, consistent with darker pigmentation and higher chlorophyll content in leafy vegetables, supports their strong antioxidant capacity (Agidew, 2022). This protective effect against oxidative stress, which contributes to aging, inflammation, and degenerative diseases, is a well-documented pharmacological action of these compounds globally. Conversely, the absence or lower levels of specific compounds in certain plant species, like the lower level of anthraquinone in *Aloe vera* in this study, despite other *Aloe* species being known for phenolic compounds and their thrombolytic activity, highlights the importance of precise species and even subspecies analysis (Kebede *et al.,* 2021).

Generally, the quantitative and qualitative findings from this study are consistent with a broader scientific understanding of medicinal plants, both within Africa and globally. The observed variations in phytochemical composition and intensity highlight the importance of detailed species-specific analysis. This study lays a crucial groundwork for validating traditional uses, fostering future quantitative studies, and facilitating drug discovery efforts based on Nigeria's rich botanical heritage. Such comprehensive characterization is essential for establishing quality control parameters and maximizing the therapeutic potential of plant-derived medicines.

Conclusion

This study quantitatively assessed phytochemical constituents in six Nigerian medicinal plants (*Justicia carnea*, *Heinsia crinitea*, *Kalanchoe pinnata*, *Aloe vera*, *Vernonia amygdalina*, and *Ocimum gratissimum*), revealing diverse bioactive profiles that validate their traditional therapeutic uses. Key findings include *Justicia carnea*'s exceptional tannins (132.16 mg/g) and C-glycosides (137.12 mg/g); *Heinsia crinitea*'s superior TPC (382.22 mg/g) and DPPH activity (129.23); *Kalanchoe pinnata*'s high alkaloids (18.4 mg/g) and tannins (116.78 mg/g); *Aloe vera*'s leading saponins (10.67 mg/g); *Vernonia amygdalina*'s elevated steroids (4.72 mg/g) and flavonoids (13 mg/g); and *Ocimum gratissimum*'s balanced antioxidants. These concentrations correlate with antioxidant, anti-inflammatory, antimicrobial, and immune-modulating properties.

The research bridges indigenous knowledge with scientific validation, contributing to pharmacognosy by establishing baseline phytochemical data for Nigerian flora and supporting public health through evidence-based promotion of accessible, culturally relevant herbal remedies. This advances sustainable healthcare solutions in resource-limited settings. Limitations include reliance on in vitro extraction methods without in vivo bioavailability

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assessment, potential variability from seasonal/geographical factors, and absence of toxicity profiling or synergistic compound interactions. Future research should prioritize in vivo efficacy trials, clinical safety evaluations, optimized extraction techniques, and sustainable cultivation practices to translate these findings into standardized pharmaceutical and nutraceutical products.

Recommendations

1. Conduct in vivo efficacy trials to validate antioxidant, anti-inflammatory, and antimicrobial activities of high-performing plants like *Heinsia crinitea* and *Justicia carnea*.
2. Perform toxicity profiling and clinical safety evaluations, prioritizing *Kalanchoe pinnata* and *Justicia carnea* due to their elevated alkaloid and glycoside content.
3. Investigate synergistic interactions between major phytochemicals across all six plants using advanced fractionation techniques.
4. Develop optimized extraction protocols to maximize yields of target compounds, such as saponins from *Aloe vera* and steroids from *Vernonia amygdalina*.
5. Establish standardized quality control guidelines for commercial herbal products containing these plants, including minimum TPC/DPPH thresholds.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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