Applied Science, Computing and Energy, 2026, 4(5), 706-721

GC-MS Characterization and Phytochemical Determination of *Buchholzia coriacea* Seeds: Insights into Their Ethnomedicinal Potential

Chidi P. Njoku*, Maryclaret N. Nwaodu, Benedict C. Anyanwu, Bright C. Onyekwere, Ijeoma S. Okoro, Sampson D. Umoh, and Anita K. Williams

Received: 18 April 2026/Accepted: 10 July 2026/Published: 28 July 2026

Abstract:*Buchholzia coriacea seeds are widely used in African traditional medicine for the management of various ailments, giving the plant the common name "wonderful kola." This study evaluated the quantitative phytochemical composition and GC–MS profile of the ethanolic extract of B. coriacea seeds to identify its major bioactive constituents and provide chemical evidence supporting its ethnomedicinal use. Standard phytochemical methods and gas chromatography–mass spectrometry (GC–MS) were employed for the analyses. Quantitative phytochemical analysis revealed the presence of tannins (7.12%), alkaloids (3.26%), saponins (2.41%), phenolics (1.93%), and flavonoids (1.23%), with tannins being the predominant phytochemical. GC–MS analysis identified eleven volatile and semi-volatile compounds, of which cis-9-octadecenoic acid (26.84%), 2-methyl-pyrrolidine-2-carboxylic acid (24.30%), and 5-hydroxymethylfurfural (17.97%) were the major constituents. Published literature indicates that many of these compounds are associated with antioxidant, antimicrobial, anti-inflammatory, cardioprotective, and neuroprotective activities. The diversity of the identified phytochemicals and GC–MS constituents suggests that the medicinal properties of B. coriacea seeds may result from the combined action of multiple bioactive compounds. This study provides chemical evidence supporting the traditional use of B. coriacea seeds and identifies them as a promising source of bioactive secondary metabolites for further pharmacological and phytochemical investigations*

Keywords: *Buchholzia coriacea Seeds, extract, medicinal values*

Chidi P. Njoku*
Department of Chemistry, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
Email: chidi.njoku@alvanikoku.edu.ng
https://orcid.org/0009-0004-3043-8334

Maryclaret N. Nwaodu
Department of Chemistry, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
Email: maryclaret.nwaodu@alvanikoku.edu.ng
https://orcid.org/0009-0001-1659-0610

Benedict Chinonye Anyanwu
Department of Chemistry, Kingsley Ozumba Mbadiwe University, Ideato Imo State, Nigeria.
Email: anyanwubenedict5@gmail.com
https://orcid.org/0009-0001-1659-0610

Bright C. Onyekwere
Department of Pure & Industrial Chemistry, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.
Email: brightonyekwere@gmail.com
https://orcid.org/0009-0007-7622-9636

Ijeoma S. Okoro
Department of Chemistry, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria
Email: okoro.ijeoma@uam.edu.ng
https://orcid.org/0000-0002-9225-7596

Sampson D. Umoh
Department of Chemistry, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria.

Also available @ https://doi.org/10.5281/zenodo.21759632

Email: sampson.umoh@uam.edu.ng
https://orcid.org/0000-0003-4781-0054

Anita K. Williams
Department of Chemistry,
University of Lagos, Lagos State, Nigeria.
Email: akwilliams@unilag.edu.ng
https://orcid.org/0000-0001-8802-5947

1.0 Introduction

Medicinal plants play vital roles in primary healthcare, particularly in developing countries with limited access to conventional medicines, and serve as important sources of bioactive compounds for pharmaceutical research and therapeutic development. More than 70% of people in developing countries utilize traditional medicines to treat microbial infections, metabolic and neurological disorders, inflammatory conditions, and other diseases (World Health Organization, 2021; Anyanwu *et al*., 2021). This reliance has stimulated scientific interest in the phytochemical and pharmacological evaluation of medicinal plants and the identification of novel therapeutic agents (Njoku *et al*., 2025a; Wang *et al*., 2025). Antimicrobial resistance, adverse effects, limited accessibility, and the high cost of some conventional medicines further underscore the need to investigate local medicinal plants as sources of bioactive compounds (Abdallah *et al*., 2023; Ekor, 2014). Although numerous medicinal plants exhibit promising pharmacological properties, relatively few have undergone comprehensive phytochemical characterization and pharmacological validation. Systematic studies are therefore needed to identify the specific constituents responsible for their therapeutic effects and validate traditional medicinal claims (Wang *et al*., 2025).

Buchholzia coriacea Engl., commonly known as "wonderful kola," is a medicinal plant widely used by traditional herbal practitioners in Nigeria. It is an evergreen shrub of the family Capparaceae, distributed across tropical West and Central Africa, including Nigeria, Cameroon, Ghana, Gabon, the Central African Republic, and Angola (Erhirhie *et al*., 2015). The plant has smooth, dark green to blackish-brown bark and was named after R. W. Buchholz, a German explorer who first collected it in Cameroon in the late nineteenth century (Burkill, 1985; Feng & Iheanacho, 2025). In Nigeria, its seeds are consumed raw or cooked to enhance memory and vitality.

Phytochemical investigations have reported alkaloids, tannins, saponins, cardiac glycosides, steroids, carbohydrates, and phenolic compounds in *B. coriacea*. These metabolites may contribute to its antimicrobial, antioxidant, anti-inflammatory, and antidiabetic activities (Nwankwo *et al*., 2018). The plant has also been associated with antimicrobial, antimalarial, antihypertensive, antidiabetic, antioxidant, anti-inflammatory, anti-ulcer, antiparasitic, hypolipidemic, neuroprotective, and anticancer effects (Izah *et al*., 2018; Njoku *et al*., 2025b). Traditionally, its seeds have been used to manage fever, cough, asthma, diabetes, ulcers, rheumatism, headaches, gastrointestinal disorders, helminthic infections, sinusitis, catarrh, smallpox, scabies, chest pain, boils, syphilis, earache, gonorrhoea, and impotence (Izah *et al*., 2018).

Despite these reported therapeutic applications, previous studies have largely focused on broad phytochemical classes, preliminary screening, crude extract bioassays, or ethnobotanical observations. Consequently, the individual compounds underlying the biological activities and ethnomedicinal uses of *B. coriacea* remain insufficiently characterized. Detailed chemical investigations are therefore necessary to establish links between specific bioactive constituents and their therapeutic relevance.

Gas Chromatography-Mass Spectrometry (GC-MS) is a reliable and versatile technique for characterizing volatile and semi-volatile constituents in complex plant extracts. It separates extract components before introducing them into a mass spectrometer,

where their mass spectra are compared with reference spectra in libraries such as the National Institute of Standards and Technology (NIST) library. Compounds are tentatively identified through their mass spectral fragmentation patterns and retention indices, with authentic standards used where available (Torres Flores *et al*., 2026). GC-MS enables rapid detection of phytochemicals and supports the interpretation of their potential pharmacological activities and ethnomedicinal applications. Although widely applied in natural products research, comprehensive GC-MS characterization of *B. coriacea* seeds remains limited, particularly studies integrating compound identification, quantitative phytochemical evaluation, and ethnomedicinal interpretation.

Previous investigations of *B. coriacea* have established its phytochemical composition and medicinal properties; however, comprehensive studies combining quantitative phytochemical determination, GC-MS characterization of individual bioactive constituents, and assessment of their pharmacological relevance remain scarce. To the best of our knowledge, no previous study has comprehensively integrated quantitative phytochemical determination, GC-MS characterization of the ethanolic seed extract, and interpretation of the identified compounds in relation to the documented ethnomedicinal uses of *B. coriacea*.

Therefore, this study aimed to quantitatively determine the phytochemical constituents of the ethanolic seed extract of *B. coriacea*, characterize its volatile and semi-volatile compounds using GC-MS, and relate the identified constituents to their documented pharmacological activities and ethnomedicinal applications. The findings provide scientific evidence supporting the traditional medicinal use of *B. coriacea* seeds, enhance knowledge of their phytochemical composition, and identify bioactive compounds with potential pharmaceutical and nutraceutical applications. They also establish a basis for future compound isolation, pharmacological evaluation, and drug development from this important African medicinal plant.

2.0 Materials and Methods

2.1 Materials

Fresh seeds of *Buchholzia coriacea* (wonderful kola) were used for this study. The materials included distilled water, a stainless-steel knife, an electric grinder, an amber-coloured airtight sample container, beakers, measuring cylinders, 50 and 250 mL volumetric flasks, a 250 mL separating funnel, crucibles, Whatman No. 1 filter paper, a water bath, a laboratory oven, a mechanical shaker, an analytical balance, a UV–Visible spectrophotometer, a Heidolph rotary evaporator, a Shimadzu GC–MS QP2010 system, micropipettes, and standard laboratory glassware. Compound identification was performed using the National Institute of Standards and Technology (NIST14) Mass Spectral Library.

2.1.1 Chemicals and Reagents

Analytical-grade ethanol, acetic acid (20% in ethanol), concentrated ammonium hydroxide, Mayer's reagent, Dragendorff's reagent, diethyl ether, *n*-butanol, 5% aqueous sodium chloride solution, tannic acid standard, Folin–Denis reagent, Folin–Ciocalteu reagent, saturated sodium carbonate solution (Na_2CO_3), 80% aqueous methanol, hydrochloric acid (HCl), magnesium turnings (Shinoda reagent), ferric chloride ($FeCl_3$), potassium ferrocyanide [$K_4Fe(CN)_6 \cdot 3H_2O$], and catechol standard were used. All chemicals and reagents were of analytical (Analar) grade).

2.2 Collection and Identification of Plant Material

Fresh seeds of *Buchholzia coriacea* (wonderful kola) were collected from a family garden at Ihitte-Ubi, Isiala-Oparanadim, Ahiazu Mbaise Local Government Area, Imo State, Nigeria. The plant material was identified and authenticated by Dr Catherine Evans-Kemka, Department of Biology, Alvan Ikoku Federal

University of Education, Owerri, Nigeria, using standard botanical procedures. A voucher specimen (A.I.F.U.E.-KEMKA 032-2026) was deposited in the university herbarium for future reference.

2.3 Preparation of Plant Material

The freshly collected seeds were washed thoroughly with distilled water to remove adhering dirt and other extraneous materials. The seeds were then sliced into small pieces using a stainless-steel knife and air-dried at room temperature for seven days. The dried material was subsequently pulverized into a fine powder using an electric grinder. The powdered sample was transferred into a clean, airtight, amber-coloured container and stored at room temperature until extraction.

2.4 Extraction Procedure

A 512 g portion of the powdered *Buchholzia coriacea* seeds was macerated in 500 mL of analytical-grade ethanol for 48 h, with intermittent shaking to enhance the extraction of soluble constituents. The mixture was filtered through Whatman No. 1 filter paper, and the resulting filtrate was concentrated under reduced pressure at 45 °C using a Heidolph rotary evaporator. The concentrated extract yielded 58 g of crude extract, corresponding to an extraction yield of 11.3%.

$$Extraction\ yield = \frac{Wt_{crude}}{Wt_{Initial}} \times 100 \qquad (1)$$

where Wt_{crude} the weight of crude is sample and $Wt_{Initial}$ is the initial weight of the sample.

2.5 GC–MS Analysis

Gas chromatography–mass spectrometry (GC–MS) analysis of the ethanolic seed extract of *Buchholzia coriacea* was carried out at the National Research Institute for Chemical Technology (NARICT), Zaria, Kaduna State, Nigeria, using a Shimadzu GC–MS QP2010 system equipped with a fused-silica capillary column. The analysis was performed under electron ionization (EI) mode at 70 eV. Helium (99.99 % purity) was used as the carrier gas at a constant flow rate of 1.50 mL min^{-1}. The injector and interface temperatures were maintained at 250 °C, while the ion-source temperature was maintained at 200 °C.

The oven temperature was initially maintained at 60 °C for 2 min and subsequently programmed according to the instrument method to achieve adequate separation of the constituents within a total run time of 24 min. An appropriate aliquot of the ethanolic extract was injected into the GC–MS system under the specified operating conditions. The mass spectra of the separated constituents were acquired over the appropriate mass-to-charge (*m/z*) scan range. The compounds were tentatively identified by comparing their mass spectra and retention times with reference spectra in the National Institute of Standards and Technology (NIST14) Mass Spectral Library.

2.6 Quantitative Phytochemical Analysis

Quantitative phytochemical analyses of the powdered *Buchholzia coriacea* seeds or its ethanolic extract, as applicable to each analytical procedure, were carried out in triplicate using established standard methods. The phytochemicals determined included alkaloids, saponins, tannins, flavonoids, and total phenolic compounds.

2.6.1 Determination of Alkaloids

Alkaloid content was determined using the method of Harborne (1985), as modified by Longbap *et al.* (2018). Five grams of the powdered sample were extracted with 20% acetic acid in ethanol for 4 h and subsequently filtered. The filtrate was concentrated to approximately one-quarter of its original volume. Concentrated ammonium hydroxide was then added dropwise to the concentrated filtrate until precipitation was complete. The resulting precipitate was collected, dried to constant weight, and weighed. The alkaloid content was calculated using Equation (2).

$$\%\ \text{Alkaloid} = \frac{Weight\ of\ alkaloid\ extract}{Weight\ of\ plant\ sample} \times 100 \qquad (2)$$

2.6.2 Determination of Saponins

Saponin content was determined according to the method of Obadoni and Ochuko (2001). Twenty grams of the powdered sample were dispersed in 100 mL of 20% aqueous ethanol and heated in a water bath at 55 °C for 4 h with continuous stirring. The mixture was filtered, and the residue was re-extracted with 200 mL of 20% aqueous ethanol. The combined filtrates were concentrated to approximately 40 mL and transferred into a 250 mL separating funnel. Twenty millilitres of diethyl ether were added to the concentrated extract, and the mixture was shaken vigorously. The ether layer was discarded, while the aqueous layer was retained. This purification step was repeated, after which the aqueous fraction was extracted with 60 mL of *n*-butanol. The *n*-butanol extract was washed twice with 10 mL portions of 5% aqueous sodium chloride solution and then evaporated to dryness in a water bath. The residue was dried in a laboratory oven to constant weight, and the percentage saponin content was calculated using Equation (3).

$$\% \text{ Saponin} = \frac{\text{Weight of saponin extract}}{\text{Weight of original sample}} \times 100 \quad (3)$$

2.6.3 Determination of Tannins

Tannin content was determined using the spectrophotometric method described by Gupta *et al.* (2013). Briefly, 0.5 g of the powdered sample was mixed with 50 mL of distilled water and stirred for 1 h. The mixture was filtered into a 50 mL volumetric flask and made up to volume with distilled water. A 5 mL aliquot of the filtrate was transferred into a test tube, followed by the addition of 2 mL of 0.1 M ferric chloride ($FeCl_3$) prepared in 0.1 M hydrochloric acid and 0.008 M potassium ferrocyanide [$K_4Fe(CN)_6 \cdot 3H_2O$]. The absorbance was measured at 395 nm using a UV–Visible spectrophotometer. Tannin concentration was determined from a calibration curve prepared using tannic acid as the reference standard.

2.6.4 Determination of Flavonoids

Flavonoid content was determined according to the method of Odeyemi *et al.* (2023). Ten grams of the powdered sample were repeatedly extracted with 100 mL of 80% aqueous methanol at room temperature. The extract was filtered into a pre-weighed crucible and evaporated to dryness in a water bath. The resulting residue was subsequently dried to constant weight, and the flavonoid content was calculated using equation 4,

$$\% \text{ Flavonoids} = \frac{(\text{Weight of crucible+residue}) - (\text{Weight of crucible}) \times 100}{\text{Weight of analysed sample}} \quad (4)$$

2.6.5 Determination of Total Phenolic Content

Total phenolic content was determined using the method of Madhu *et al.* (2016). Appropriate concentrations of the ethanolic extract were mixed with 0.4 mL of Folin–Ciocalteu reagent diluted 1:10 (v/v). After 5 min, 4.0 mL of 20% sodium carbonate solution was added, and the volume was made up to 10 mL with distilled water. The reaction mixture was allowed to stand at room temperature for 90 min, after which its absorbance was measured at 750 nm using a UV–Visible spectrophotometer. A calibration curve was prepared using catechol as the reference standard. The total phenolic content was expressed as milligrams of catechol equivalent per gram of dry extract (mg CE g^{-1}).

2.7 Data analysis

The experimental data were analyzed using Microsoft Excel and GraphPad Prism version 8. All quantitative determinations were performed in triplicate, and the results were expressed as mean ± standard deviation (SD). Statistical significance was considered at $p < 0.05$.

3.0 Results and Discussion

The GC–MS analysis of the ethanolic seed extract of *Buchholzia coriacea* identified eleven compounds, as presented in Table 1. The corresponding chromatogram is shown in Fig. 1, the mass spectra of the major identified

constituents are presented in Fig. 2, while the chemical structures of the identified compounds are shown in Fig. 3. The three most abundant constituents were cis-9-octadecenoic acid (oleic acid; 26.84%), 2-methylpyrrolidine-2-carboxylic acid (24.30%), and 5-hydroxymethylfurfural (5-HMF; 17.97%).

The GC–MS profile indicates that the ethanolic seed extract contains fatty acids, fatty acid derivatives, heterocyclic compounds, and oxygenated organic compounds. These constituents may contribute to the biological properties associated with *B. coriacea*; however, the biological activity of the crude extract cannot be attributed to any single compound solely on the basis of its detection by GC–MS. The observed biological effects may result from the combined actions and possible interactions of several constituents.

Previous phytochemical investigations of *B. coriacea* have reported the presence of secondary metabolites, including alkaloids, tannins, flavonoids, saponins, and phenolic compounds, mainly through qualitative phytochemical screening (Nwankwo *et al*., 2018; Ojo *et al*., 2021). The present GC–MS analysis complements these earlier findings by providing information on individual volatile and semi-volatile constituents detectable under the analytical conditions employed. Differences in chemical composition among studies may arise from several factors, including geographical origin, environmental conditions, plant maturity, plant part examined, extraction solvent, extraction procedure, sample preparation, and instrumental conditions.

Cyclopentenedione derivatives constitute a group of biologically active secondary metabolites reported in higher plants, fungi, algae, cyanobacteria, and bacteria. Members of this class have been associated with various biological activities, including antifungal, antibacterial, anti-inflammatory, cytostatic, and enzyme-inhibitory effects (Sevcíková *et al*., 2014). Cyclopentenedione-containing compounds have been identified from several natural sources and are therefore of interest as potentially bioactive natural products. If the compound identified in the present GC–MS analysis corresponds to a cyclopentenedione derivative, its presence may contribute to the biological potential of the extract. Nevertheless, such an inference should be regarded as tentative because detection by GC–MS does not establish its specific contribution to the biological activity of the crude extract.

Tetrazoles and their derivatives have attracted considerable attention because of their diverse pharmacological properties and their importance as structural motifs in medicinal chemistry. Reported biological activities of tetrazole derivatives include antimicrobial, antihypertensive, anti-inflammatory, analgesic, anticonvulsant, antifungal, anticancer, antidiabetic, and antimycobacterial effects (Jaiswal *et al.* 2024 ; Shende & Mahapatra, (2019). Szulczyk *et al.* (2021), for example, reported antimicrobial activity for a series of synthesized tetrazole derivatives with low cytotoxicity toward normal cell lines. The detection of a tetrazole-containing compound in *B. coriacea* seed extract may therefore be of pharmacological interest. However, the presence of such a compound alone cannot be used to conclude that the seeds are responsible for antihypertensive, analgesic, or anticonvulsant effects in traditional medicine. Such biological effects would require direct experimental validation using the isolated compound or a suitably characterized extract.

2-Methylpyrrolidine-2-carboxylic acid was the second most abundant constituent detected in the ethanolic seed extract, accounting for 24.30% of the total chromatographic area, with a retention time of 8.292 min. Pyrrolidine-containing compounds have been reported to possess various biological activities, including antibacterial activity, depending on their molecular structures and substitution patterns (Bhat *et al*., 2023). The relatively high abundance of 2-methylpyrrolidine-2-

carboxylic acid in the present extract makes it a potentially important constituent of the GC–MS profile. Its presence may contribute to the biological properties of the extract; however, antibacterial activity cannot be attributed specifically to this compound solely on the basis of its GC–MS detection.

5-Hydroxymethylfurfural (5-HMF) was another major constituent detected in the ethanolic seed extract, accounting for 17.97% of the total chromatographic area and exhibiting a retention time of 8.662 min. 5-HMF is an oxygen-containing furan derivative that can be formed during the thermal degradation and dehydration of carbohydrates. It has attracted considerable scientific interest because of its reported biological and pharmacological activities. Safo *et al.* (2004) reported the potential antisickling activity of 5-HMF, particularly its ability to interact with haemoglobin and increase its oxygen affinity, thereby reducing the tendency of sickle haemoglobin to polymerize under deoxygenated conditions. Subsequent studies have investigated several other biological properties of 5-HMF, including antioxidant, anti-inflammatory, anti-hypoxic, anti-ischemic, cytoprotective, and anti-proliferative effects (Pagare *et al*., 2024). The relatively high abundance of 5-HMF in the present extract is therefore noteworthy. Nevertheless, its detection by GC–MS does not demonstrate that *B. coriacea* seeds possess antisickling activity or that 5-HMF is responsible for any particular traditional medicinal application of the plant. Such conclusions require targeted biological assays and, preferably, isolation and structural confirmation of the compound.

The GC–MS profile also showed a substantial representation of fatty acids and fatty acid derivatives. These compounds constitute an important class of natural products and participate in several physiological and biochemical processes. Fatty acids such as oleic acid and palmitic acid have been investigated for antioxidant, anti-inflammatory, antimicrobial, cardiometabolic, and other biological properties. Their occurrence in *B. coriacea* seeds may therefore contribute to the biological potential of the seed extract. However, the presence of these compounds should not be interpreted as evidence that they are solely responsible for the ethnomedicinal properties of *B. coriacea*. Biological effects of a crude plant extract generally reflect the combined actions of multiple constituents, including possible synergistic or antagonistic interactions.

Hexadecanoic acid (palmitic acid) was detected among the constituents of the ethanolic seed extract. Palmitic acid is a saturated fatty acid commonly found in plants and other biological materials. Studies have reported various biological properties of palmitic acid and its derivatives, including antimicrobial and antioxidant-related activities, although these effects depend on concentration, experimental model, and chemical context (Ghfil *et al*., 2025). The presence of palmitic acid in *B. coriacea* seeds may therefore contribute to the overall biological properties of the extract. However, its detection alone does not establish that the compound is responsible for the traditional use of the seeds against fungal infections. Further biological evaluation would be required to establish such a relationship.

Methyl-(11E)-octadecenoate, a fatty acid methyl ester, was also identified among the constituents of the ethanolic seed extract. Fatty acid methyl esters and related lipid derivatives have been investigated for several biological activities, including anti-inflammatory, antimicrobial, hepatoprotective, and other pharmacological effects (Sudha *et al*., 2013; Parthipan *et al*., 2015). The occurrence of methyl-(11E)-octadecenoate in *B. coriacea* seeds may therefore contribute to the biological profile of the extract. However, claims linking this specific compound to the traditional treatment of cardiovascular disease or arthritis

should be regarded as tentative unless supported by direct pharmacological evidence.

Cis-9-Octadecenoic acid, commonly known as oleic acid, was the most abundant compound detected in the ethanolic seed extract, accounting for 26.84% of the total chromatographic area, with a retention time of 21.280 min. Oleic acid is a monounsaturated omega-9 fatty acid that occurs widely in plant oils, particularly olive oil. It is an important dietary fatty acid and has been extensively investigated in relation to lipid metabolism, cardiovascular health, inflammation, and other physiological processes. Its occurrence as the predominant constituent of the *B. coriacea* seed extract suggests that lipid-derived constituents may represent an important component of the chemical profile of the seeds. The high relative abundance of oleic acid may contribute to some of the biological properties associated with the seed extract. However, its presence should not, by itself, be used to establish a specific therapeutic effect or to directly explain the ethnomedicinal use of *B. coriacea* for cholesterol management. Such a relationship requires appropriate nutritional, pharmacological, or clinical evidence.

9-(Z)-Octadecenamide, commonly known as oleamide, is a fatty acid amide derived from oleic acid. Oleamide has attracted considerable interest because of its association with sleep regulation and its interactions with several neurotransmitter and receptor systems. It has been reported to influence various central nervous system pathways, including those involving dopamine, acetylcholine, serotonin, γ-aminobutyric acid (GABA), cannabinoid, and vanilloid systems (Akanmu *et al*., 2007). The detection of oleamide in the ethanolic seed extract of *B. coriacea* is therefore of potential pharmacological interest, particularly in relation to neuroactive properties. Nevertheless, the presence of oleamide does not provide sufficient evidence to conclude that the seeds possess cognitive-enhancing or sleep-modulating effects. Further pharmacological studies would be required to determine whether oleamide contributes meaningfully to the biological effects of the extract.

Overall, the GC–MS analysis revealed a chemically diverse profile of the ethanolic seed extract of *Buchholzia coriacea*, with oleic acid, 2-methylpyrrolidine-2-carboxylic acid, and 5-HMF representing the major detected constituents. The occurrence of fatty acids, fatty acid derivatives, heterocyclic compounds, and other oxygen-containing constituents provides a possible chemical basis for some of the biological properties associated with the plant. Nevertheless, the relationship between the identified compounds and the ethnomedicinal applications of *B. coriacea* should be interpreted cautiously. GC–MS profiling provides evidence of the presence of chemical constituents but does not, on its own, establish their pharmacological activities or demonstrate that individual compounds are responsible for particular therapeutic effects. Further studies involving isolation, structural confirmation using authentic standards and complementary spectroscopic techniques, and targeted biological assays would be necessary to establish such relationships.

The phytochemical analysis of the ethanolic seed extract of *Buchholzia coriacea*, as presented in Table 2 and Figure 3, revealed the presence of alkaloids, tannins, saponins, flavonoids, and phenolics in varying concentrations. Among the quantified phytochemicals, tannins exhibited the highest concentration (7.12%), followed by alkaloids (3.26%), saponins (2.41%), phenolics (1.93%), and flavonoids (1.23%). The relatively high tannin content suggests that tannins may contribute to the biological properties of the seed extract, given their well-documented antioxidant, antimicrobial, and wound-healing activities (Nasseri *et al*., 2019). However, the quantitative predominance of tannins alone does not establish that they are primarily responsible for the medicinal effects of *B. coriacea*, and further bioactivity-guided

studies would be required to determine their specific contribution

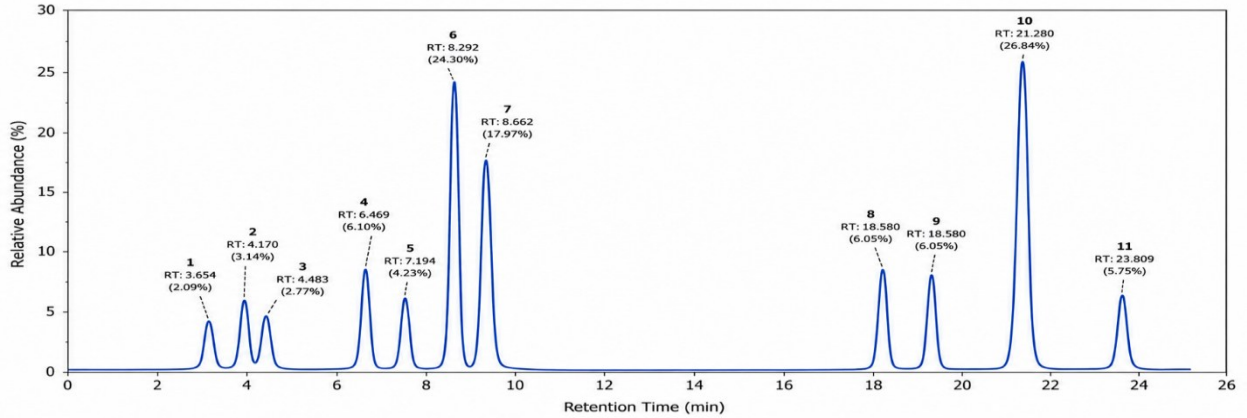


Fig. 1. GC-MS chromatogram of ethanolic extract of seeds of *Buccholzia coriacea*

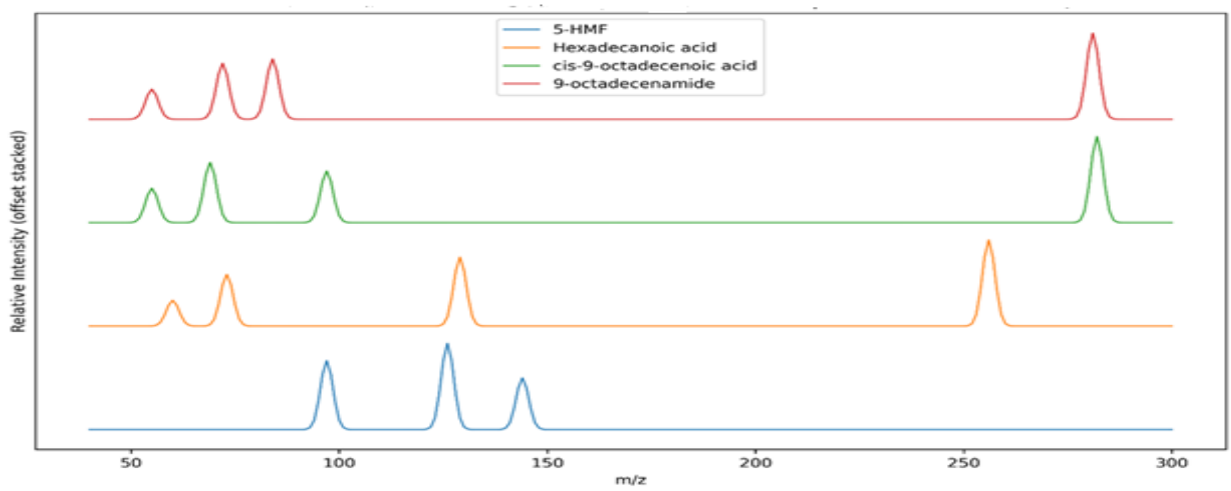


Fig. 2. GC-MS Mass Spectra of three major compounds (stacked layout)

The alkaloid content of the ethanolic seed extract of *Buchholzia coriacea* was quantified as 3.26%. This finding is consistent with the detection of alkaloid-related compounds in the GC–MS profile, particularly compound 4, identified as 2-[2-(4-methylfurazan-3-yloxy)ethyl]-2H-tetrazol-5-ylamine, and compound 6, identified as 2-methylpyrrolidine-2-carboxylic acid. However, the quantitative phytochemical assay and GC–MS analysis provide different types of information; therefore, the quantitative alkaloid content should not be interpreted as a direct measurement of the concentrations of these two individual GC–MS-detected compounds. Alkaloids constitute an important class of secondary metabolites with diverse pharmacological activities, including antimalarial, antiasthmatic, anticancer, cholinomimetic, vasodilatory, antiarrhythmic, analgesic, antibacterial, and antihyperglycaemic effects (Lu *et al*., 2012; Awuchi, 2019).

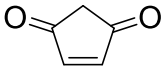
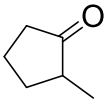
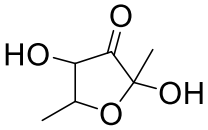
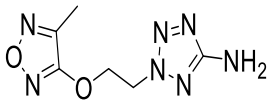
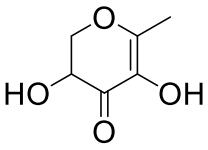
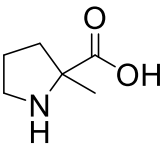
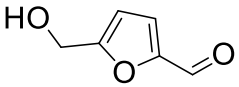
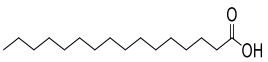
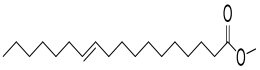
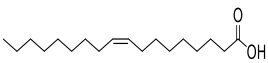
The occurrence of alkaloids in the seeds of *B. coriacea* is consistent with previous reports of the ethnomedicinal use of the plant in the management of conditions such as asthma, cough, bacterial infections, and malaria (Shende & Mahapatra, 2019). Nevertheless, the present phytochemical findings alone do not

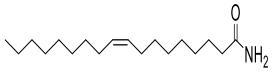
establish that the detected alkaloids are responsible for these specific therapeutic effects.

The phytochemical profile obtained in the present study is broadly consistent with previous reports on *B. coriacea*, which have identified similar classes of secondary metabolites, although variations in their concentrations have been reported. Such differences may arise from variations in extraction solvents and procedures, geographical location, climatic conditions, plant maturity, sample preparation, and analytical methods (Ojo *et al*., 2021; Nwankwo *et al*., 2018).

Saponins are structurally diverse plant-derived glycosides associated with a broad range of biological activities. They have been reported to exhibit antiprotozoal and molluscicidal effects, partly through interactions with membrane sterols that increase membrane permeability and may ultimately cause cellular disruption (Zhong *et al*., 2022).

Table 1. Compounds Detected from GC-MS Analysis of *Buchholzia coriacea* Seed

Peak	Compound Name	Molecular Formula	Molecular Weight	Retention Time	Area Percentage	Chemical Structure
1	2-cyclopentene-1,4-dione	$C_5H_4O_2$	96	3.654	2.09	
2	2-methylcyclopentanone	C_6H_{10}	98	4.170	3.14	
3	2,4-dihydroxy-2,5-dimethyl-3(2H)-furan	$C_6H_8O_4$	144	4.483	2.77	
4	2-[2-(4-methylfurazan-3yloxy)-ethyl]-2H-tetrazol-5-ylamine	$C_6H_9N_7O_2$	211	6.469	6.10	
5	3,5-dihydroxy-6-Methyl-2,3-dihydro-4H-pyran-4-one	$C_6H_8O_4$	144	7.194	4.23	
6	2-methyl-pyrrolidine-2-carboxylic acid	$C_6H_{11}NO_2$	129	8.292	24.30	
7	5-hydroxymethylfurfural	$C_6H_6O_3$	126	8.662	17.97	
8	Hexadecanoic acid	$C_{16}H_{32}O_2$	256	18.580	6.05	
9	Methyl-(11E)-octadecenoate	$C_{19}H_{36}O_2$	296	18.580	6.05	
10	cis-9-octadecenoic acid	$C_{18}H_{34}O_2$	282	21.280	26.84	

11	9-(Z)-octadecenamide	$C_{18}H_{35}NO$	281	5.75	

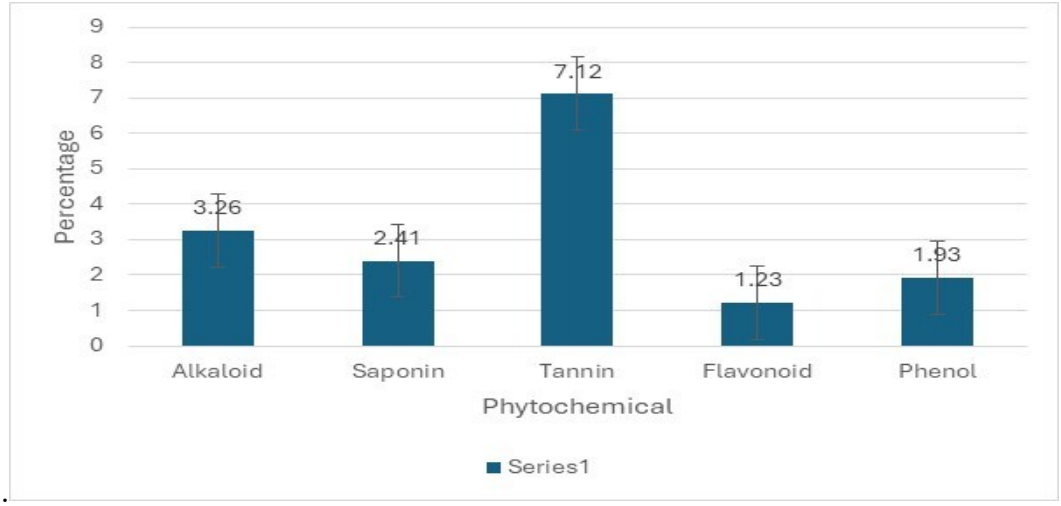


Fig. 3: Bar chart showing the percentage composition of phytochemicals in Buchholzia coriacea ethanolic seed extract

Saponins have also demonstrated hypoglycaemic effects through mechanisms that may include enhancement of insulin sensitivity and inhibition of carbohydrate-metabolizing enzymes such as α-glucosidase and α-amylase (Shen *et al*., 2023). In addition, their antioxidant activities have been associated with free-radical scavenging and modulation of endogenous antioxidant defence systems, including superoxide dismutase and catalase. Antifungal and antiviral effects have also been reported and may involve disruption of microbial membranes and interference with viral replication (Vyshnavi *et al*., 2023). Furthermore, saponins may exert anti-inflammatory effects through modulation of pro-inflammatory cytokines, including tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), and associated signaling pathways such as nuclear factor kappa B (NF-κB) (Shen *et al*., 2023). The detection of saponins at 2.41% in the present study is therefore consistent with the reported biological activities of this class of phytochemicals and with the ethnomedicinal applications of *B. coriacea*. Shende and Mahapatra (2019) reported traditional uses of the plant for conditions including worm infestation, diabetes, cough, and certain skin-related conditions. However, the present findings do not establish a direct causal relationship between the quantified saponin content and these traditional therapeutic applications.

Tannins possess several biological properties that may be relevant to wound healing, including astringent, antimicrobial, and antioxidant activities. These properties may promote tissue contraction, reduce microbial burden, and support processes involved in tissue repair (Okwu & Josiah, 2006; Agyare *et al*., 2022). The relatively high tannin content observed in the present study (7.12%) indicates that tannins constitute a major quantified phytochemical component of the seed extract. This finding is consistent with reports of the traditional use of *B. coriacea* in the management of ulcers and wound-related conditions (Salami *et al*., 2018). Nevertheless, further experimental studies are required to establish whether the tannins in the seed extract directly contribute to the reported wound-healing effects.

Phenolic compounds are widely recognized for their antioxidant and antimicrobial properties and may exert antimicrobial effects through mechanisms involving disruption of cellular membranes, alteration of membrane permeability, and protein denaturation (McDonnell & Russell, 1999; Dagli, 2021). The phenolic content of the *B. coriacea* seed extract was 1.93%. This finding indicates the presence of phenolic constituents that may contribute to the antioxidant and antimicrobial potential of the extract. However, it is important to distinguish between the total phenolic content determined by a phytochemical assay and the concentration of free phenol itself; therefore, the value of 1.93% should not be described as 1.93% phenol unless the analytical method specifically measured phenol. The presence of phenolic constituents may nevertheless contribute to the biological properties associated with *B. coriacea*.

Flavonoids are an important class of plant polyphenols with well-documented antioxidant, antibacterial, and antifungal activities (Panche *et al*., 2016; Farhadi *et al*., 2022). The flavonoid content of the seeds of *B. coriacea* was quantified as 1.23%. The occurrence of flavonoids may contribute to the biological activity of the seed extract through antioxidant and antimicrobial mechanisms. Previous investigations of *B. coriacea* have also reported the presence of flavonoids and other secondary metabolites (Ojo *et al*., 2021). However, the present quantitative result does not by itself establish that flavonoids are responsible for the traditional medicinal applications of the plant.

Overall, the quantitative phytochemical analysis and GC–MS profile demonstrate that the seeds of *B. coriacea* contain a diverse range of phytochemical constituents, including alkaloids, tannins, saponins, phenolics, flavonoids, heterocyclic compounds, oxygenated compounds, fatty acids, fatty acid esters, and amides. The coexistence of these constituents may contribute collectively to the biological properties reported for the plant. However, the present findings establish chemical composition rather than pharmacological efficacy, and the contribution of individual compounds or phytochemical classes to specific biological activities cannot be determined solely from their presence or relative abundance. Further isolation, structural characterization, bioactivity-guided fractionation, and in vitro and in vivo pharmacological studies are therefore required to establish the specific constituents responsible for the reported activities and to evaluate their potential for therapeutic development.

Table 2. Percentage phytochemical content of ethanolic extract of *Buchholzia coriacea* seeds.

Phytochemical	Percentage ± sd ($n = 3$)
Alkaloid	3.26 ± 0.22
Saponin	2.41 ± 0.51
Tannin	7.12 ± 0.36
Flavonoid	1.23 ± 0.46
Phenol	1.93 ± 0.27

4.0 Conclusion

This study investigated the GC–MS profile and quantitative phytochemical composition of the ethanolic extract of *Buchholzia coriacea* seeds. Quantitative phytochemical analysis revealed the presence of alkaloids, saponins, tannins, flavonoids, and phenolics, with tannins occurring at the highest concentration and flavonoids at the lowest. GC–MS analysis identified eleven volatile and semi-volatile compounds belonging to ketones, furan and pyran derivatives, fatty acids, esters, heterocyclic compounds, and amides.

Published literature indicates that many of these compounds are associated with antioxidant, antimicrobial, anti-inflammatory, cardioprotective, and neuroprotective activities. Therefore, the phytochemicals and GC–MS-detected constituents identified in this

study may contribute to the reported ethnomedicinal uses of *B. coriacea*. The diversity of these bioactive constituents suggests that the medicinal properties of the seeds are likely attributable to the combined action of multiple compounds rather than a single active principle.

This study provides chemical evidence supporting the traditional use of *B. coriacea* and identifies the seeds as a promising source of bioactive secondary metabolites with potential pharmaceutical and nutraceutical applications. However, the biological activities inferred in this study require experimental validation.

Further research should focus on the isolation and structural characterization of the identified compounds, as well as in vitro, in vivo, and in silico pharmacological investigations, toxicity assessments, and mechanistic studies to confirm their therapeutic potential. Similar studies on other parts of the plant are also recommended to facilitate the comprehensive utilization of this valuable medicinal species.

5.0 References

Abdallah, E. M., Alhatlani, B. Y., de Paula Menezes, R., & Martins, C. H. G. (2023). Back to nature: Medicinal plants as promising sources for antibacterial drugs in the post-antibiotic era. *Plants, 12*(17), 3077.https://doi.org/10.3390/plants12173077

Agyare, C., Boakye, Y. D., Bekoe, E. O., Hensel, A., Dapaah, S. O., & Appiah, T. (2022). African medicinal plants with wound healing properties. *Journal of Ethnopharmacology, 288*, 114993. https://doi.org/10.1016/j.jep.2021.114993

Akanmu, M. A., Adeosun, S. O., & Ilesanmi, O. R. (2007). Neuropharmacological effects of oleamide in male and female mice. *Behavioural Brain Research, 182*(1), 88–94. https://doi.org/10.1016/j.bbr.2007.05.006

Anyanwu, B. C., Otuokere, I. E., Echeme, J. O., Akoh, O. U., Njoku, C. P., Ohenhen, O. N., & Ikeadim, O. C. (2021). Isolation and characterization of a secondary metabolite from the aerial parts of *Launaea taraxacifolia*. *Journal of Chemical Society of Nigeria, 46*(4). https://doi.org/10.46602/jcsn.v46i4.644

Awuchi, C. G. (2019). The biochemistry, toxicology, and uses of the pharmacologically active phytochemicals: Alkaloids, terpenes, polyphenols, and glycosides. *Journal of Food and Pharmaceutical Sciences, 7*(3), 131–150. https://doi.org/10.22146/jfps.666

Bhat, A. A., Tandon, N., Singh, I., & Tandon, R. (2023). Structure-activity relationship (SAR) and antibacterial activity of pyrrolidine based hybrids: A review. *Journal of Molecular Structure, 1283*, 135175.https://doi.org/10.1016/j.molstruc.2023.135175

Burkill, H. M. (1985). *The useful plants of West Tropical Africa* (2nd ed., Vol. 1). Royal Botanic Gardens, Kew.

Daglia, M. (2012). Polyphenols as antimicrobial agents. *Current Opinion in Biotechnology, 23*(2), 174–181.

Ekor, M. (2014). The growing use of herbal medicines: Issues relating to adverse reactions and challenges in monitoring safety. *Frontiers in Pharmacology, 4*, 177. https://doi.org/10.3389/fphar.2013.00177

Erhirhie, E. O., Ben-Azu, B., Moke, E. G., Emuesiri, C. P., & Omonjiaho, I. A. (2015). Ethnopharmacological review of *Buchholzia coriacea*. *International Journal of Advances in Pharmacy, Biology and Chemistry, 4*(1), 149–155.

Feng, X., & Iheanacho, C. O. (2025). Potential clinical relevance of *Buchholzia coriacea*: In vitro antimicrobial characteristics of the methanol leaf extract. *BMC Complementary Medicine and Therapies, 25*(1), 309. https://doi.org/10.1186/s12906-025-05057-9

Ghfil, Z. A. H. A., Aboalhur, F. J., Mshachal, M. A., & Alobaidi, A. A. A. (2025). Antioxidant and antifungal activities of n-hexadecanoic acid extracted from algae. *South Asian Research Journal of Pharmaceutical Sciences, 7*(4), 125–127.

Gupta, M., Thakur, S., Sharma, A., & Gupta, S. (2013). Qualitative and quantitative analysis of phytochemicals and pharmacological value of some dye yielding medicinal plants. *Oriental Journal of Chemistry, 29*(2), 475–481. https://doi.org/10.13005/ojc/290211

Harborne, J. B. (1985). *Phytochemical methods: A guide to modern techniques of plant analysis* (2nd ed.). Chapman and Hall.

Longbap, B. D., *et al*. (2018). Phytochemical screening and quantitative determination of phytochemicals in leaf extracts of *Hannoa undulata*. *International Journal of Medicinal Plants and Natural Products, 4*(2), 32–38. https://doi.org/10.20431/2454-7999.0402005

Lu, J. J., Bao, J. L., Chen, X. P., Huang, M., & Wang, Y. T. (2012). Alkaloids isolated from natural herbs as the anticancer agents. *Evidence-Based Complementary and Alternative Medicine, 2012*, 485042. https://doi.org/10.1155/2012/485042

Izah, S. C., Uhunmwangho, E. J., & Eledo, B. O. (2018). Medicinal potentials of *Buchholzia coriacea* (wonderful kola). *Medicinal Plant Research, 8*(5), 27–42. https://doi.org/10.5376/mpr.2018.08.0005

Jaiswal, S., Verma, K., Dwivedi, J., & Sharma, S. (2024). Tetrazole derivatives in the management of neurological disorders: Recent advances on synthesis and pharmacological aspects. *European Journal of Medicinal Chemistry, 271*, 116388. https://doi.org/10.1016/j.ejmech.2024.116388

Longbap, B. D., *et al*. (2018). Phytochemical screening and quantitative determination of phytochemicals in leaf extracts of *Hannoa undulata*. *International Journal of Medicinal Plants and Natural Products, 4*(2), 32–38. https://doi.org/10.20431/2454-7999.0402005

Lu, J. J., Bao, J. L., Chen, X. P., Huang, M., & Wang, Y. T. (2012). Alkaloids isolated from natural herbs as anticancer agents. *Evidence-Based Complementary and Alternative Medicine, 2012*, 485042. https://doi.org/10.1155/2012/485042

Madhu, M., Sailaja, V., Satyadev, T. N. V. S. S., & Satyanarayana, M. V. (2016). Quantitative phytochemical analysis of selected medicinal plant species by using various organic solvents. *Journal of Pharmacognosy and Phytochemistry, 5*(2), 25–29.

McDonnell, G., & Russell, A. D. (1999). Antiseptics and disinfectants: Activity, action, and resistance. *Clinical Microbiology Reviews, Clinical Microbiology Reviews, 12*(1), 147–179. https://doi.org/10.1128/CMR.12.1.147.

Mohammed, J. H. (2016). Biological activities importance of tetrazole derivatives. *European Academic Research, 3*(12), 12796–12804.

Nasseri, M. A., Behravesh, S., Allahresani, A., *et al*. (2019). Phytochemical and antioxidant studies of *Cleome heratensis* (Capparaceae) plant extracts. *Bioresources and Bioprocessing, 6*, 5. https://doi.org/10.1186/s40643-019-0240-1

Njoku, C. P., Ekpewu-Ovie, R. A., Odiba, I. O., Nwosu, M. J., & Igara, C. E. (2025a). Isolation and structure elucidation of Buchholzcine A, a novel steroidal cyanoformamide from the stem bark of Buchholzia coriacea Engler (Capparaceae). *Communication in Physical Sciences,* 12(4), 1290–1299. https://dx.doi.org/10.4314/cps.v12i4.11

Njoku, C. P., Onyekwere, B. C., Uchegbu, R. I., & Igara, C. E. (2025b). Isolation and characterization of Buchholztrienone A, a

novel trienone glycosidic polyketide from the stem bark of Buchholzia coriacea Engler (Capparaceae). *Communication in Physical Sciences,* 12(5), 1515–1527. https://doi.org/10.4314/cps.v12i5.7

Nwankwo, C. C., Friday, B. J., & Onwukwe, C. D. (2018). Antimicrobial and antihelmintic effect of wonderful kola (*Buchholzia coriacea*). *International Journal of Biochemistry Research & Review, 24*(4), 1–8. https://doi.org/10.9734/IJBCRR/2018/45656

Obdoni, B. O., & Ochuko, P. O. (2002). Phytochemical studies and comparative efficacy of the crude extracts of some homostatic plants in Edo and Delta States of Nigeria. *Global Journal of Pure and Applied Sciences, 8*(2), 203–208.

Odeyemi, O., Onochie, A. U., Odeyemi, S. O., & Oshim, I. O. (2023). Evaluation of qualitative and quantitative phytochemical constituents of *Napoleona imperialis* stem bark. *GSC Biological and Pharmaceutical Sciences, 24*(1), 202–208. https://doi.org/10.30574/gscbps.2023.24.1.0246

Ojo, O. A., Ojo, A. B., Ajiboye, B. O., Oyinloye, B. E., & Olayide, I. (2021). Phytochemical composition and biological activities of *Buchholzia coriacea*: A review. *Heliyon, 7*(3), e06547. https://doi.org/10.1016/j.heliyon.2021.e06547

Okwu, D. E., & Josiah, C. (2006). Evaluation of the chemical composition of medicinal plants showing wound healing potential. *African Journal of Biotechnology, 5*(4), 357–361.

Pagare, P. P., McGinn, M., Ghatge, M. S., *et al*. (2024). The antisickling agent, 5-hydroxymethyl-2-furfural: Other potential pharmacological applications. *Medicinal Research Reviews,* 44, 2707–2729. https://doi.org/10.1002/med.22062

Panche, A. N., Diwan, A. D., & Chandra, S. R. (2016). Flavonoids: An overview. *Journal of Nutritional Science, 5*, e47. https://doi.org/10.1017/jns.2016.41

Parthipan, B., Suky, M. G. T., Mohan, V. R., *et al*. (2015). GC-MS analysis of phytocomponents in *Pleiospermium alatum* (Wall. ex Wight & Arn.) Swingle (Rutaceae). *Journal of Pharmacognosy and Phytochemistry, 4*(1), 216–222.

Safo, M. K., Abdulmalik, O., Danso-Danquah, R., *et al*. (2004). Structural basis for the potent antisickling effect of a novel class of five-membered heterocyclic aldehydic compounds. *Journal of Medicinal Chemistry, 47*(19), 4665–4676. https://doi.org/10.1021/jm049486l

Salami, A. T., Odukanmi, O. A., Faniyan, O. F., Omayone, T. P., & Olaleye, S. B. (2018). Seeds of Buchholzia coriacea in Diet Mitigate Ischemic Reperfusion-Induced Gastric Ulceration in Experimental Rats. *Journal of dietary supplements*, *15*(6), 842–859. https://doi.org/10.1080/19390211.2017.1404544

Sevcíková, Z., Pour, M., Novák, D., Ulrichová, J., & Vacek, J. (2014). Chemical properties and biological activities of cyclopentenediones: A review. *Mini-Reviews in Medicinal Chemistry, 14*(4), 322–331. https://doi.org/10.2174/1389557514666140306130207

Shen, L., Luo, H., Fan, L., Tian, X., Tang, A., Wu, X., Dong, K., & Su, Z. (2023). Potential immunoregulatory mechanism of plant saponins: A review. *Molecules, 29*(1), 113. https://doi.org/10.3390/molecules29010113

Shende, M., & Mahapatra, D. K. (2019). Buchholzia coriacea: An African plant with pharmacological importance. *International Journal of Medical & Pharmaceutical Sciences,* 9(2), 1-5. http://dx.doi.org/10.31782/IJMPS.2019.9201

Sudha, T., Chidambarampillai, S., & Mohan, V. R. (2013). GC-MS analysis of bioactive components of aerial parts of *Fluggea leucopyrus* Willd. (Euphorbiaceae).

Journal of Applied Pharmaceutical Science, 3(5), 126–130.

Szulczyk, D., Bielenica, A., Roszkowski, P., Dobrowolski, M. A., Olejarz, W., Kmiecik, S., Podsiad, M., & Struga, M. (2021). Synthetic transition from thiourea-based compounds to tetrazole derivatives: Structure and biological evaluation of synthesized new N-(furan-2-ylmethyl)-1H-tetrazol-5-amine derivatives. *Molecules, 26*(2), 323. https://doi.org/10.3390/molecules26020323

Torres Flores, C., Pérez-Campos, E., Pérez-Campos Mayoral, L., Laguna-Barrios, L. Á., Méndez-Rodríguez, K. B., Pérez-Vázquez, F. J., Pérez Campos-Mayoral, E., Lastre-Domínguez, C. M., Jarquín González, E. E., Martínez Cruz, M., Pina Canseco, M. D. S., Mora Guzmán, Z., López Montesinos, K. C., Cabrera-Fuentes, H. A., & Hernández-Huerta, M. T. (2026). From gas chromatography-mass spectrometry (GC-MS) to network pharmacology: System-level insights into the multi-target biological potential of *Flaveria trinervia* (Spreng.) C. Mohr. *Current Issues in Molecular Biology, 48*(2), 160. https://doi.org/10.3390/cimb48020160

Vyshnavi, D. V., Swaroop, S. S., Sudheer, A., Kanala, S. R., Naik, R. M., & Varalakshmi, O. (2023). Plant-derived bioactive saponins and tannins: An overview of their multi-target mechanisms and diverse biological activities. *Pharmacognosy Research, 15*(4), 623–635. https://doi.org/10.5530/pres.15.4.083

Wang, X., Anwar, T., Qureshi, H., El-Beltagi, H. S., Sehar, Z., Solieva, D., Azizov, B., Rebouh, N. Y., Abbasov, M. A., Yakubov, F., & Alomran, M. M. (2025). Plant-based traditional remedies and their role in public health: Ethnomedicinal perspectives for a growing population. *Journal of Health, Population and Nutrition, 44*(1), 300. https://doi.org/10.1186/s41043-0250103 6-5

World Health Organization. (2021). *WHO global report on traditional and complementary medicine*. World Health Organization.

Zhong, J., Tan, L., Chen, M., & He, C. (2022). Pharmacological activities and molecular mechanisms of *Pulsatilla* saponins. *Chinese Medicine, 17*, 59. https://doi.org/10.1186/s13020-022-00613-8

Declarations

Competing Interests

The authors declared no competing interests

Ethical Consideration

Not applicable

Funding

The authors declared no source of funding.

Availability of data and material

All data used in this manuscript are original except those duly acknowledged and cited by the authors.

Authors Contributions

CPN conceptualized the study, conducted collection of sample, prepared the manuscript's first draft, and conducted laboratory analyses. MNN contributed to drafting of the manuscript. BCA contributed to data Analysis and interpretation. BCO contributed to literature search. ISO contributed to drafting of the manuscript. SDU contributed to drafting of the manuscript. AKW contributed to literature search. All authors jointly revised the manuscript and approved the final version for submission.