

CHARACTERIZATION OF BIOACTIVE COMPOUNDS IN THE METHANOLIC LEAF EXTRACT OF *GUIERA SENEGALENSIS* USING GC–MS AND FTIR SPECTROSCOPIC TECHNIQUES

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Abstract

The present study investigates the phytochemical constituents, functional groups, and bioactive compounds present in the methanolic leaf extract of *Guiera senegalensis*. Phytochemical screening, Fourier transform infrared spectroscopy, and gas chromatography mass spectrometry were employed for characterisation. Phytochemical analysis revealed the presence of important secondary metabolites, including alkaloids, flavonoids, tannins, and terpenoids. Infrared analysis indicated the presence of key functional groups, namely O–H at 3235 cm^{-1} , C–H at 2855 cm^{-1} , $\text{C}\equiv\text{C}$ at 2258 cm^{-1} , $\text{C}=\text{C}$ at 1606 cm^{-1} , C–O at 1200 cm^{-1} , and C–N at 1028 cm^{-1} , indicating diverse organic functionalities. Gas chromatography mass spectrometry identified several bioactive compounds, with major constituents including butylated hydroxytoluene at 37.62 percent, n-propyl 11-octadecenoate at 9.45 percent, hexadecanoic acid propyl ester at 9.07 percent, dodecanoic acid propyl ester at 6.46 percent, tetradecanoic acid propyl ester at 3.62 percent, and octadecanoic acid propyl ester at 1.67 percent, among others. The findings confirm that the methanolic leaf extract of *Guiera senegalensis* contains diverse bioactive compounds that may contribute to its medicinal properties and provide a scientific basis for its continued use in traditional medicine.

Keywords: *Guiera senegalensis*, FTIR and GC-MS analysis, bioactive compounds, phytochemicals, functional groups, methanol crude extract

1. Introduction

The analysis of medicinal plants has a long history. The earliest techniques for assessing plant quality were organoleptic, relying on the physical senses of smell, taste, and appearance, and these gradually gave way to more advanced instrumental methods. Traditional medicine has long drawn on higher plants and their extracts for the treatment of disease, a practice that endured until the nineteenth century when developments in chemistry and synthetic organic chemistry introduced new sources of therapeutic agents. Medicinal plants remain a significant natural source of drugs with comparatively few side effects (Santhosh, Velmurugan, and Annadurai, 2015), and they continue to play a major role in the management of disease worldwide.

Plants contain a variety of bioactive compounds that contribute to their medicinal effects, and many modern pharmaceuticals are derived from or inspired by plant compounds. They continue to serve as a basis for the development of new drugs because they house a broad range of bioactive substances, including lipids, phytochemicals, flavours, fragrances, and pigments, and plant extracts are widely used in the food, pharmaceutical, and cosmetics industries (Ahmad et al., 2024). Plants and their extracts constitute the primary source of healthcare for more than seventy five percent of the world's population (Ahmad et al., 2023), and the global revival of interest in herbal products reflects a perception of safety relative to wholly synthetic alternatives.

Guiera senegalensis is one of the medicinal plants used in the treatment and control of disease. It belongs to the family Combretaceae and is widely distributed across the savannah region of west and central Africa, including Senegal, Nigeria, Chad, the Gambia, Mali, Niger, and Mauritania (Anka et al., 2020). It is known locally as Sabara in the Hausa language of northern Nigeria and typically occurs as a shrub or small tree of three to five metres in height, with grey green oval leaves arranged opposite or sub opposite on the stem (Alshafei et al., 2016; Hamadnalla et al., 2020). The plant grows in low rainfall areas and on light dry soils, and its various parts have been employed extensively in traditional medicine, the roots being used in the treatment of conditions such as gonorrhoea, toothache, and stomach ache. The present study characterises the phytochemical and functional group profile of its methanolic leaf extract using complementary spectroscopic techniques.

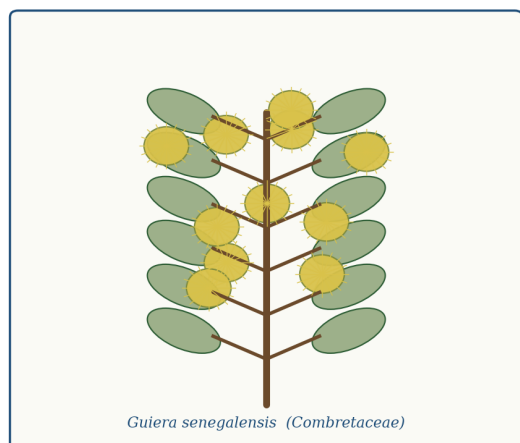


Figure 1. *Guiera senegalensis* (Combretaceae), a savannah shrub of west and central Africa, showing the characteristic globose yellow flower heads and opposite grey green foliage.

Source: Authors' botanical illustration.

2. Materials and Methods

2.1 Sample Collection and Preparation

The leaves of *Guiera senegalensis* were collected from Dan Dalama town in the Dawakin Tofa Local Government Area of Kano State, Nigeria. The plant sample was authenticated at the Biological Laboratory of Ahmadu Bello University, Zaria, and a voucher specimen was deposited for future reference. The collected leaves were washed thoroughly with distilled water to remove adhering particles and air dried under shade at room temperature for two weeks in the Chemistry Laboratory of Federal University Lokoja. The dried leaves were pulverised into a fine powder using a laboratory mortar and pestle, and the powder was stored in an airtight glass container under dry conditions until extraction.

2.2 Extraction Procedure

Two hundred grams of the powdered leaf sample was extracted using 700 mL of analytical grade methanol, a solvent to sample ratio of 3.5 to 1 by volume to mass. Extraction was carried out by maceration for ten days with continuous agitation to enhance solvent penetration and phytochemical recovery. The mixture was filtered through Whatman filter paper, and the filtrate was concentrated by evaporation under shade at room temperature to obtain the crude methanol extract. The dried extract was weighed and the percentage extraction yield was calculated according to Equation 1.

$$\text{Extraction yield (\%)} = (W_{\text{extract}} / W_{\text{sample}}) \times 100 \quad (1)$$

where W_{extract} is the weight of the dried extract in grams and W_{sample} is the weight of the powdered sample used. The crude extract was stored in an airtight container at low temperature until further analysis.

2.3 Spectroscopic Analysis

Functional groups were determined by Fourier transform infrared spectroscopy using a Happ-Genzel spectrophotometer at the Multi-user Research Laboratory of Ahmadu Bello University, Zaria. Spectra were recorded across the range of 4000 to 650 cm^{-1} , and absorption bands were interpreted on the basis of characteristic functional group frequencies. The methanol extract was further analysed using a gas chromatography mass spectrometry system, a Clarus 500 Perkin Elmer analyser, at the same laboratory, with a total run time of 45 minutes. Compounds were identified from their retention times and from comparison of their mass spectra with the National Institute of Standards and Technology library database, and each compound was reported together with its retention time, peak area percentage, molecular formula, and molecular weight. Because butylated hydroxytoluene is commonly used as a synthetic antioxidant additive, a methanol solvent blank was analysed under identical conditions to check for possible contamination, and the identification of this compound was accepted on the basis of the library match score and spectral agreement.

3. Results and Discussion

3.1 Phytochemical Screening

The preliminary phytochemical screening of the methanol leaf extract (Table 1) revealed the presence of flavonoids, tannins, terpenoids, and alkaloids, while steroids, cardiac glycosides, saponins, and phenols were not detected. The occurrence of these metabolites indicates a chemically diverse profile capable of contributing to several biological activities. The detection of flavonoids suggests significant antioxidant potential, since these compounds readily donate electrons and neutralise reactive oxygen species, conferring protection against oxidative stress. The presence of tannins indicates potential antimicrobial and protective effects through their ability to interact with proteins and disrupt microbial membranes, while the occurrence of alkaloids, which are nitrogen containing compounds known to interact with biological receptors and enzymes, points to antimicrobial, analgesic, and protective activities. The presence of terpenoids further suggests antioxidant, anti inflammatory, and antimicrobial actions, and the combined occurrence of these classes implies a synergistic interaction that may enhance the overall efficacy of the extract.

The absence of steroids, cardiac glycosides, saponins, and phenols does not diminish the medicinal value of the extract but indicates that the observed activities are predominantly associated with the metabolites that were detected. Variations of this kind are commonly influenced by the extraction solvent, plant maturity, environmental conditions, and geographical location, and the use of methanol may have favoured the recovery of certain polar and moderately polar compounds while limiting others. The profile obtained provides a scientific basis for the traditional use of the plant in the management of respiratory, gastrointestinal, and microbial conditions, consistent with ethnopharmacological reports (Rasheed-Jada et al., 2025; Taha et al., 2026; Abubakar et al., 2023).

Table 1. Preliminary phytochemical screening of the leaf of *Guiera senegalensis*.

Phytochemical	Result
Flavonoids	+
Tannins	+
Terpenoids	+
Alkaloids	+
Steroids	–
Cardiac glycosides	–
Saponins	–
Phenols	–

Note: + indicates presence and – indicates absence.

3.2 Fourier Transform Infrared Spectroscopy

The infrared analysis of the methanol leaf extract (Table 2, Figure 2) revealed several characteristic absorption bands corresponding to functional groups commonly associated with biologically active secondary metabolites. The broad and intense band at 3235 cm^{-1} was assigned to O–H stretching vibrations, indicating hydroxyl bearing compounds such as alcohols and polyhydroxylated metabolites; these groups participate in hydrogen bonding and contribute substantially to antioxidant potential. The strong peaks at 2926 cm^{-1} and 2855 cm^{-1} were attributed to C–H stretching of

alkane chains, while the medium band at 2258 cm^{-1} reflects $\text{C}\equiv\text{C}$ stretching characteristic of an alkyne functionality. The strong absorption at 1699 cm^{-1} was assigned to C=O stretching, suggesting aldehydes, ketones, esters, or carboxylic acids, all of which are reactive moieties that frequently mediate antioxidant, antimicrobial, and anti inflammatory interactions.

The strong band at 1606 cm^{-1} was assigned to C=C stretching of alkenes, indicating unsaturated organic compounds, while the medium band at 1513 cm^{-1} corresponds to aromatic ring stretching and points to the presence of aromatic phytochemicals. The bands at 1341 cm^{-1} and 1442 cm^{-1} were assigned to C–O stretching associated with ester functionalities, and the strong band at 1200 cm^{-1} to C–O stretching of ether linkages. The band at 1028 cm^{-1} was attributed to C–N stretching, indicating amine bearing compounds; this observation is consistent with the alkaloids detected during the preliminary screening. Collectively, the simultaneous occurrence of hydroxyl, carbonyl, alkene, aromatic, ester, ether, and amine groups demonstrates the chemical complexity of the extract and provides complementary evidence for the presence of flavonoids, alkaloids, terpenoids, and other oxygenated metabolites (Awwalu et al., 2022; Sahoo and Umashankara, 2022).

Table 2. Infrared spectroscopic profile of the methanol crude extract of *Guiera senegalensis* leaf.

S/N	Wavenumber (cm^{-1})	Bond	Intensity	Functional Group
1	3235	O–H stretch	Strong	Alcohol
2	2926	C–H stretch	Strong	Alkane
3	2855	C–H stretch	Strong	Alkane
4	2258	$\text{C}\equiv\text{C}$ stretch	Medium	Alkyne
5	1699	C=O	Strong	Carbonyl
6	1606	C=C	Strong	Alkene
7	1513	C=C–C	Medium	Aromatic ring
8	1442	C–O	Medium	Ester
9	1341	C–O	Strong	Ester
10	1200	C–O	Strong	Ether
11	1028	C–N	Strong	Amine

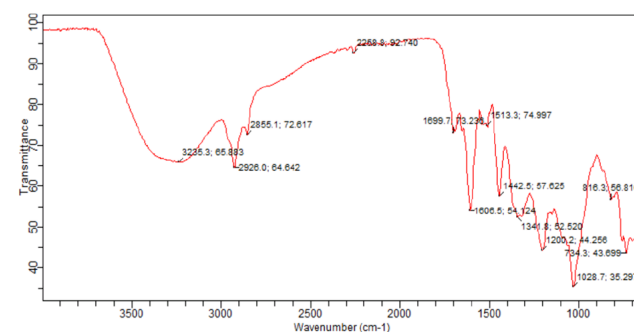


Figure 2. Infrared spectrum of the methanol crude extract of *Guiera senegalensis* leaf, showing the characteristic absorption bands listed in Table 2.

Source: Authors' laboratory analysis.

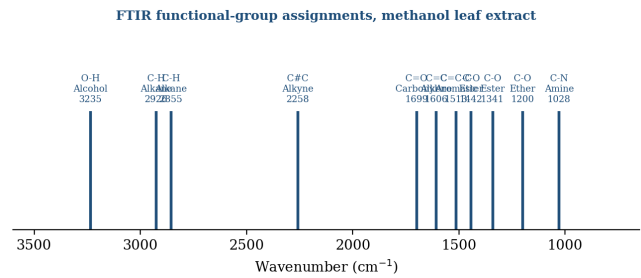


Figure 3. Summary map of the assigned infrared bands and their associated functional groups across the 3600 to 650 cm⁻¹ region.
Source: Authors' computation.

3.3 Gas Chromatography Mass Spectrometry

The gas chromatography mass spectrometry analysis (Table 3, Figures 4 and 5) revealed a chemically diverse composition of volatile and semi volatile organic compounds, comprising terpenoids, fatty acid esters, hydrocarbons, aldehydes, and aromatic compounds. The reconstructed total ion chromatogram (Figure 4) and the representative mass spectrum (Figure 5) together summarise the distribution of constituents by retention time and relative abundance. Among the identified compounds, butylated hydroxytoluene was the most abundant, representing approximately 37.62 percent of the total detected compounds. Its exceptionally high relative abundance makes it the principal constituent of the extract, and because it is a recognised antioxidant whose activity arises from its ability to donate hydrogen atoms to free radicals and interrupt oxidative chain reactions, its predominance implies a substantial antioxidant capacity that may protect cellular components against lipid peroxidation and related oxidative damage.

The presence of fatty acid esters, including dodecanoic acid propyl ester, tetradecanoic acid propyl ester, hexadecanoic acid propyl ester, n-propyl 11-octadecenoate, and octadecanoic acid propyl ester, further enriches the profile. These compounds combine long hydrocarbon chains with oxygen bearing functional groups that may mediate membrane interactions and biological activity. The relatively high abundance of hexadecanoic acid propyl ester at 9.07 percent and of n-propyl 11-octadecenoate at 9.45 percent indicates that lipid derived metabolites constitute a substantial proportion of the extract, and such compounds may contribute to antimicrobial activity through interaction with microbial membranes while supporting antioxidant mechanisms. The detection of D-limonene, although present at a low concentration, is noteworthy because monoterpenes frequently contribute to the aroma, chemical defence, and biological activity of medicinal plants (Lin et al., 2024).

The identification of long chain hydrocarbons such as tetratetracontane, 1-octadecene, 1-nonadecene, 1-docosene, and 1-tetracosene demonstrates the occurrence of aliphatic constituents that, although generally stable, may influence the physicochemical properties of the extract and the stability of its bioactive components. The presence of the aldehyde heptadecanal adds further chemical complexity through its reactive carbonyl functionality. Taken together, the constituents indicate a multifunctional composition in which different metabolites may act independently or synergistically, a pattern consistent with the broad pharmacological spectrum attributed to the plant (Atia et al., 2025; Olivia et al., 2021; Ahmad et al., 2024).

Table 3. Gas chromatography mass spectrometry profile of the methanol crude extract of *Guiera senegalensis* leaf.

Peak	R/T (min)	Area (%)	Compound	Formula	Reported Activity
1	6.2632	0.29	D-Limonene	C ₁₀ H ₁₆	Organic herbicide
2	6.9039	0.18	Nonanoic acid, propyl ester	C ₁₂ H ₂₄ O ₂	Antifeedant
3	19.4106	37.62	Butylated hydroxytoluene	C ₁₅ H ₂₄ O	Antioxidant, antimicrobial
4	23.5723	6.46	Dodecanoic acid, propyl ester	C ₁₃ H ₂₆ O ₂	Antimicrobial
5	25.9079	0.17	Tetratetracontane	C ₄₄ H ₉₀	Antioxidant, antimicrobial
6	27.8967	3.62	Tetradecanoic acid, propyl ester	C ₁₇ H ₃₄ O ₂	Food enhancer
7	29.4862	1.60	Dibutyl phthalate	C ₁₆ H ₂₂ O ₄	Antimicrobial
8	31.8536	9.07	Hexadecanoic acid, propyl ester	C ₁₉ H ₃₈ O ₂	Antioxidant, antimicrobial
9	33.1824	0.27	Heptadecanal	C ₁₇ H ₃₄ O	Antioxidant
10	34.9982	9.45	n-Propyl 11-octadecenoate	C ₂₁ H ₄₀ O ₂	Surfactant, softening agent
11	35.4809	1.67	Octadecanoic acid, propyl ester	C ₂₁ H ₄₂ O ₂	Antioxidant, antimicrobial
12	38.8366	0.24	1-Octadecene	C ₁₈ H ₃₆	Antioxidant
13	38.8689	0.15	1-Nonadecene	C ₁₉ H ₃₈	Antimicrobial
14	40.0569	0.18	1-Docosene	C ₂₂ H ₄₄	Lubricant
15	41.4040	3.00	1-Tetracosene	C ₂₄ H ₄₈	Antioxidant

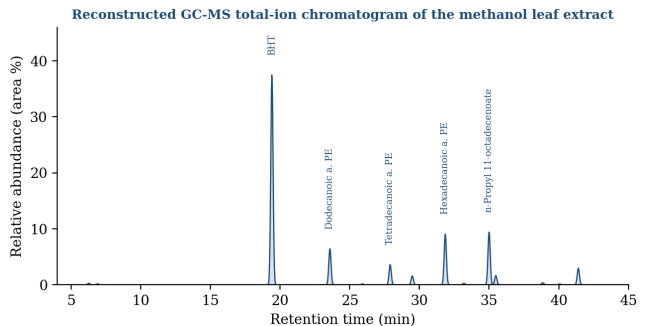


Figure 4. Reconstructed total ion chromatogram of the methanol leaf extract derived from the retention times and peak areas of Table 3, with the principal constituents labelled.
Source: Authors' computation.

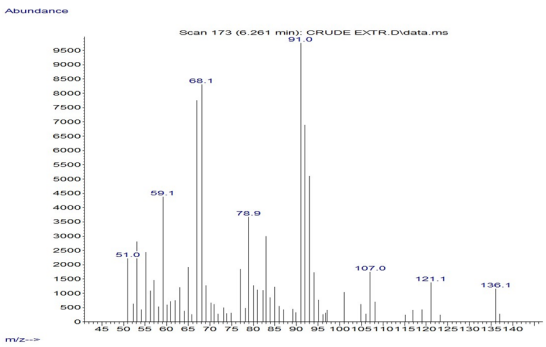


Figure 5. Representative mass spectrum from the gas chromatography mass spectrometry analysis of the extract.
Source: Authors' laboratory analysis.

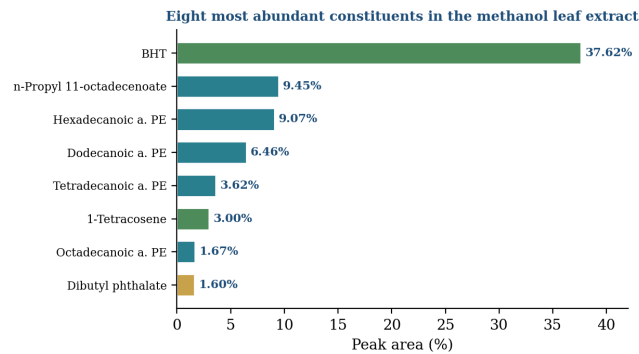


Figure 6. The eight most abundant constituents of the methanol leaf extract by peak area, dominated by butylated hydroxytoluene and the fatty acid esters.

Source: Authors' computation.

GC-MS compound-class distribution

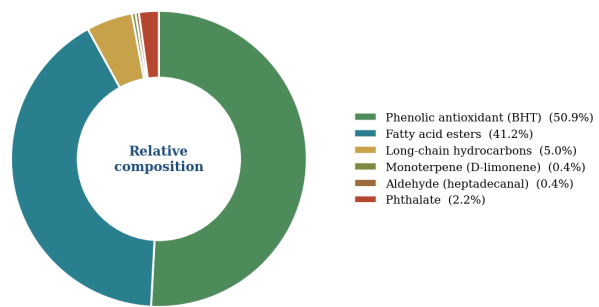


Figure 7. Distribution of the detected constituents by compound class, showing the predominance of the phenolic antioxidant fraction and the fatty acid esters.

Source: Authors' computation.

3.4 Major Bioactive Compounds and Their Activities

The principal constituents of the extract and their reported biological activities are summarised in Table 4. The predominance of butylated hydroxytoluene, a phenolic antioxidant, together with a substantial complement of fatty acid esters, indicates that antioxidant and antimicrobial mechanisms are likely to dominate the biological behaviour of the extract. Fatty acid esters are known to exhibit antimicrobial, antioxidant, membrane stabilising, and anti inflammatory properties, and their relatively high combined abundance suggests that they may act synergistically with the phenolic and terpenoid fractions to improve the overall therapeutic effectiveness of the extract (Lamba et al., 2023; Park et al., 2024). The monoterpene D-limonene, although present in a smaller proportion, contributes antioxidant, antimicrobial, anti inflammatory, and chemoprotective properties that reinforce the terpenoid signal detected during screening (Lin et al., 2024).

The overall profile demonstrates considerable similarity with previous reports on medicinal plants in which fatty acid esters, terpenoids, aromatic compounds, and hydrocarbon derivatives constitute the major bioactive fractions. The exceptionally high proportion of butylated hydroxytoluene observed here nonetheless suggests a distinctive composition that may be influenced by environmental conditions, geographical location, harvesting period, and extraction methodology, factors that commonly produce differences in metabolite abundance among extracts. The combination of antioxidant, antimicrobial, anti inflammatory, and membrane protective constituents supports the long standing use of

the plant in traditional medicine for the management of infectious and inflammatory disorders, and corroborates reports of significant antibacterial, antifungal, and antioxidant activity (Taha et al., 2026; Abigail et al., 2024; Atia et al., 2025; Ehaimir et al., 2023).

Table 4. Major compounds identified in the *Guiera senegalensis* leaf extract and their reported biological activities.

Compound	Area (%)	Chemical Class	Reported Biological Activities
Butylated hydroxytoluene	37.62	Phenolic antioxidant	Antioxidant, free radical scavenger, antimicrobial, anti inflammatory, preservative
n-Propyl 11-octadecenoate	9.45	Fatty acid ester	Antioxidant, antimicrobial, surfactant, membrane protective
Hexadecanoic acid, propyl ester	9.07	Fatty acid ester	Antioxidant, anti inflammatory, antibacterial, membrane stabilising
Dodecanoic acid, propyl ester	6.46	Fatty acid ester	Antimicrobial, antiviral, antifungal
Tetradecanoic acid, propyl ester	3.62	Fatty acid ester	Antioxidant, antimicrobial
1-Tetracosene	3.00	Long chain hydrocarbon	Antioxidant, antimicrobial potential
Octadecanoic acid, propyl ester	1.67	Fatty acid ester	Antioxidant, antimicrobial
Dibutyl phthalate	1.60	Phthalate derivative	Antimicrobial activity reported in plant extracts
D-Limonene	0.29	Monoterpene	Antioxidant, antimicrobial, anti inflammatory, anticancer
Heptadecanal	0.27	Aldehyde	Antioxidant, antimicrobial

The diversity of compounds identified is consistent with the broad therapeutic applications traditionally associated with the plant and reinforces its value as a source of biologically active natural products. The detection of constituents with established antioxidant and anti infective activity provides additional support for the use of the plant in managing microbial and inflammatory disease, and the coexistence of fatty acid esters with hydrocarbon derivatives may facilitate synergistic interactions that enhance bioavailability, stability, and therapeutic performance (Ehaimir et al., 2023; Magaji et al., 2025). These observations underline the importance of standardised extraction and analytical procedures for ensuring consistency and reproducibility in future phytopharmaceutical formulations.

4. Conclusion

The present study demonstrates that the methanolic leaf extract of *Guiera senegalensis* contains a diverse range of bioactive compounds, including important phytochemicals and functional groups associated with biological activity. The infrared analysis confirmed the presence of hydroxyl, carbonyl, alkene, aromatic, ester, ether, and amine functionalities, while the gas chromatography mass spectrometry analysis revealed a composition dominated by butylated hydroxytoluene together with a substantial complement of fatty acid esters, terpenoids, aldehydes, and long chain hydrocarbons. These findings collectively support the traditional use of the plant in medicinal applications and highlight its potential as a valuable source of natural bioactive compounds for further pharmacological and drug development studies.

4.1 Recommendations

It is recommended that further studies be carried out on the isolation and structural elucidation of the individual bioactive compounds, together with in vitro and in vivo pharmacological evaluation of their activity against various disease causing organisms. Comparative studies based on geographical variation, and mechanistic investigations of antimicrobial and antioxidant activity, would help to establish the spectrum and potency of the extract against different micro organisms and would strengthen the evidence base for its therapeutic application.

Declarations

Conflict of interest. The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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