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Research Article

Phytochemical Profiling (GC MS) and the Antibacterial Activity of The Aqueous and Ethanolic Leaf Extract of *Guiera Senegalensis* on clinically isolated *Escherichia coli* and *Staphylococcus aureus*

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Abstract

Background: The global rise of antimicrobial resistance (AMR) is the main threat to public health which lead to the urgent search for alternative therapies for medicinal plant. The present study investigates the phytochemical profiling (GC-MS) and antibacterial activity of aqueous and ethanolic leaf extracts of *Guiera senegalensis* against clinical isolates of *Escherichia coli* and *Staphylococcus aureus*.
Methods: The antibacterial activity was evaluated using standard in vitro assays, including agar well diffusion, Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC). The bioactive compounds were assayed using Gas chromatography–mass spectrometry (GC-MS) technique.
Results: Antimicrobial susceptibility testing demonstrated a clear dose-dependent inhibitory effect of both extracts, with mean zones of inhibition increasing significantly from 125 μg/ml to 1000 μg/ml for both bacterial species. The ethanolic extract exhibited superior antibacterial activity compared to the aqueous extract at all tested concentrations, with inhibition zones reaching up to 18.32 ± 0.11 mm and 19.28 ± 0.28 mm for *E. coli* and *S. aureus* respectively at 1000 μg/ml, although still slightly lower than the standard antibiotic controls. MIC and MBC assays further corroborated these findings, showing lower MIC and MBC values for both extracts relative to control antibiotics. Notably, *E. coli* was more susceptible to the extracts than *S. aureus*, as reflected by generally lower MIC and MBC values. Phytochemical analysis revealed the presence of multiple bioactive secondary metabolites in both extracts, including flavonoids, alkaloids, phenols, saponins, e.t.c. Quantitative analysis indicated higher yields of alkaloids, phenols, saponins, and tannins in the ethanol extracts compared to aqueous extracts, highlighting the efficacy of ethanol as a solvent for extracting bioactive compounds. GC-MS profiling identified a complex array of compounds in various extract fractions, including predominant propylcyclohexane, (16.56%), methyl n-octadecanoate (39.90%), diterpenes (phytol), esters, and 2-phenylcyclobutyl) benzene. Squalene (54.35%) was notably abundant in the F2 aqueous fraction, underscoring its potential contribution to biological activity. These chemical constituents, many with known antimicrobial, antioxidant, and anti-inflammatory properties, likely act synergistically to inhibit bacterial growth.
Conclusion: The findings highlight the significant antibacterial potential of *Guiera senegalensis* leaf extracts, especially the ethanolic fraction, against clinically relevant bacterial pathogens. The combination of phytochemical potential and confirmed bacterial susceptibility supports the therapeutic promise of this plant as a source of novel antimicrobial agents, warranting further pharmacological and mechanistic studies.

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1. Introduction

The growing threat of antimicrobial resistance (AMR) represents a critical challenge to global health, as infections caused by drug-resistant organisms are associated with increased death rates, extended hospitalizations, and higher medical expenses [1]. Bacteria such as multidrug-resistant *Escherichia coli* and methicillin-resistant *Staphylococcus aureus* (MRSA) are particularly problematic and contribute significantly to this global health crisis. The World Health Organization (WHO) has identified AMR as one of the top ten threats to global health and warns that, without effective intervention, drug-resistant infections could claim up to 10 million lives annually. This dire projection underscores the urgent demand for novel antibacterial treatments, especially those derived from natural sources like medicinal plants.

Among the most worrisome resistant bacteria are *E. coli* and *S. aureus*, which are responsible for a range of infections such as urinary tract infections, pneumonia, sepsis, and skin condition. Therefore, developing alternative treatment options and discovering new antibacterial compounds to tackle these resistant strains is a pressing need.

Traditional medicinal plants offer a promising avenue for the discovery of new antimicrobial substances. These plants have long been used in folk medicine to treat various infections, largely due to their rich content of bioactive compounds known for their antibacterial, antifungal, antiviral, and antioxidant properties [2]. One such plant of interest is *Guiera senegalensis*, commonly referred to as "Sabara" in parts of West Africa. Native to the Sahel region and a member of the Combretaceae family, *G. senegalensis* has traditionally been used to treat ailments including diarrhea, respiratory infections, and wounds [3].

Scientific studies have identified a variety of active compounds in *G. senegalensis*, such as tannins, flavonoids, saponins, and alkaloids, which contribute to its antimicrobial potential [4]. Recent research has focused on the plant's leaf extracts—especially those obtained using water and ethanol—due to their ease of preparation and reported effectiveness against bacterial pathogens. Ethanol extracts are often favored because they can extract both polar and non-polar compounds, resulting in a higher concentration of active ingredients [4].

Studies have demonstrated the efficacy of *G. senegalensis* extracts against both Gram-positive and Gram-negative bacteria, including drug-resistant strains. For instance, [2] reported that ethanol extracts of the plant's leaves had strong inhibitory effects on MRSA. Similarly, 3 found that aqueous extracts effectively inhibited the growth of clinical *E. coli* strains responsible for urinary tract infections. These results highlight the potential of *G. senegalensis* as a natural antibacterial agent in the fight against antibiotic resistance. Nonetheless, further investigation is necessary to fully understand the plant's mechanisms of action, isolate its most effective phytochemicals, and refine extraction techniques to improve its therapeutic efficacy [1].

Identifying and analyzing bacterial strains, especially those responsible for serious infections, is essential for understanding their genetic variability and resistance mechanisms. Molecular methods such as polymerase chain reaction (PCR), gene sequencing, and genome analysis have been widely applied to examine the genetic characteristics of *Escherichia coli* and *Staphylococcus aureus* isolates [4]. These techniques enable the detection of virulence genes, resistance markers, and other genetic traits linked to pathogenicity and antimicrobial resistance. For *E. coli*, molecular investigations commonly target virulence genes like *fimH* (associated with fimbriae involved in adhesion) and *papC* (linked to the formation of pili in pyelonephritis), along with resistance genes such as *blaCTX-M*, which encodes extended-spectrum beta-lactamases. According to [5], *E. coli* strains from urinary tract infections frequently harbored *fimH* and *blaCTX-M*, highlighting the need to monitor these genes in clinical settings. Similarly, molecular analysis of *S. aureus* is key to detecting methicillin-resistant strains (MRSA) and tracking resistance elements like the *mecA* gene, which confers methicillin resistance [5], also reported a high presence of *mecA* in *S. aureus* strains from wound infections, reinforcing the necessity for ongoing resistance surveillance in healthcare environments.

Integrating traditional medicinal knowledge with advanced molecular biology offers a complementary strategy for addressing bacterial infections. The ethnopharmacological relevance of *Guiera senegalensis* positions it as a promising candidate for novel antimicrobial development. Research by [6] has shown that the combined effects of multiple phytochemicals in plant extracts may be key in counteracting bacterial resistance. Investigating the antibacterial potential of *G. senegalensis* leaf extracts, alongside the molecular profiling of clinical *E. coli* and *S. aureus* isolates, may contribute significantly to the fight against antibiotic resistance. This line of research demonstrates the importance of medicinal plants in contemporary healthcare.

2. Materials and Methods

2.1. Plant Collection and Identification

Fresh leaves of *Guiera senegalensis* was collected from Musa Musawa Farms located in Katsina State, Nigeria. The plant specimen was taken for taxonomic identification and verification by a botanist at the department of biological science of the Nigerian Defense Academy Kaduna with a voucher number of NDA/BIOH/2023/57 and deposited at the Herbarium.

2.2. Crude Extraction Procedures

The crude extraction followed the method outlined by [7]. Fresh *Guiera senegalensis* leaves was washed thoroughly to remove dirt, then ground using a mortar and pestle before being pressed into a clean, sterilized container. The resulting extract was stored in screw-capped bottles and properly labeled.

2.3. Aqueous Extraction

The aqueous extraction procedure was adapted from [8]. A measured 250 g of powdered plant material was mixed with 500 ml of distilled water. This mixture will be heated in a water bath for 20 minutes, then filtered. The filtrate was further concentrated using the water bath, and the final extract was stored in a sterile bottle with appropriate labeling.

2.4. Ethanol Extraction

For ethanol extraction, 40 g of powdered plant material was mixed with 300 ml of ethanol. The solution was kept at room temperature in sealed containers for two days, with occasional stirring using a sterile glass rod. Afterward, the mixture was filtered through muslin cloth, and the filtrate was evaporated in a water bath maintained at 40°C to remove the ethanol. This process was replicated in the aqueous extraction steps. The semi-solid residue was air-dried under a ceiling fan. Once dry, the extract will be weighed; part will be reserved for phytochemical screening, while the remainder will be used for susceptibility tests.

2.5. Phytochemical Screening

Both the aqueous and ethanolic extracts of *G. senegalensis* will be analyzed for phytochemical components including saponins, flavonoids, phenolic compounds, and anthraquinones, following the procedures.

2.6. Biochemical Assay

Column Chromatography

Fractionation of *G. senegalensis* leaf extract was conducted with slight modifications, 15 grams of *G. senegalensis* extract was separated by column chromatography. The stationary phase consisted of 30 grams of silica gel (60-120 mesh), while the mobile phase used varying proportions of 100% glacial acetic acid and 100% aqueous solution (ratios from 100:0 to 0:100) with increasing polarity. The lower end of a 5.5 x 80 cm glass column was packed with glass wool. A slurry of 30 grams silica gel in 50 ml n-hexane was gently poured into the column. The solvent flow was checked and then the tap closed. The silica gel surface solvent was allowed to drain, and the column was left to stabilize for 24 hours. The sample was prepared by mixing 15 grams of extract with 20 grams silica gel in 100% glacial acetic acid and dried thoroughly. The dried mixture was topped with a small amount of silica gel and carefully added to the column. The tap was opened to maintain an elution rate of 0.58 ml/s. Elution was performed using n-hexane and ethyl acetate solvent mixtures of increasing polarity, collected sequentially in 100 ml volumes, poured carefully along the column sides to avoid disturbing the silica gel. Fractions were collected in 10 ml aliquots in test tubes.

Thin Layer Chromatography (TLC)

Analytical TLC was performed using pre-coated silica gel aluminum plates (Xtra SIL G/UV254). Small samples from each test tube were spotted about 1 cm from the plate edge and allowed to dry at room temperature ($\sim$ 27°C). The plates were then placed in a chromatographic jar containing the solvent system of 100% glacial acetic acid and 100% aqueous solution (8:2) with a glass lid. The solvent was allowed to ascend until it reached approximately three-quarters of the plate length. After drying, the plates were sprayed with a freshly prepared solution of 0.5 ml p-anisaldehyde in 50 ml glacial acetic acid and 1 ml 97% sulfuric acid, then heated to 105°C to visualize spots, which appeared mainly in red, purple, and orange colors. The spots were measured, and the Retention factor (Rf) values were calculated using the formula:

$$Rf = \frac{\text{Distance travelled by the streak from the starting point}}{\text{Distance travelled by the solvent from the starting point to the solvent front}}$$

Sub-fractions with similar retention factor (Rf) values were combined into fractions labeled A, B, C, D, E, and F, then stored at 4°C for further analyses such as GC-MS and antibacterial testing. The same procedure was applied to the aqueous extract, which yielded two sub-fractions, G and H.

2.7. GC-MS (Gas Chromatography-Mass Spectrometry) Analysis of Extracts

GC-MS analysis was conducted using a SCHIMADZU GCMS-QP2010 PLUS system equipped with a DB 5-MS (0.25 × 30 m × 0.25 µm) non-polar capillary column. The gas chromatograph was connected to a mass spectrometer, operating in electron ionization mode at 70 eV. Helium (99.999% purity) was used as the carrier gas at a constant flow rate of 1 mL/min. The oven temperature program started at 45°C (held for 4 minutes), then increased by 10°C per minute to 175°C, followed by a 5°C per minute increase to 240°C, where it was held isothermally for 9 minutes. Mass spectra were recorded at 70 eV with a scanning interval of 0.5 seconds over a mass range of 40–500 Da. The total run time was 60 minutes. Relative amounts of components were calculated by comparing individual peak areas to the total chromatogram area (Kero, 2019).

2.8. Identification of Bioactive Components

Mass spectra obtained from the GC-MS were interpreted by matching unknown compounds to reference spectra in databases including the National Institute of Standards and Technology (NIST08s), WILEY8, and FAME. This allowed for identification of the names, molecular weights, and structures of the bioactive components in the samples.

2.9. Determination of Antibacterial Activity

Media Preparation

About 36.15 g of Nutrient Agar powder was dissolved in 1 liter of distilled water, shaken well, then transferred to a conical flask covered with cotton wool and aluminum foil. The medium was sterilized by autoclaving at 121°C for 15 minutes. After sterilization, it was cooled to about 40°C for 15 minutes before being poured into Petri dishes, which were dried in a hot air oven prior to use (Cheesbrough, 2010).

Preparation of Bacterial Culture

Bacterial strains, including *Escherichia coli* and *Staphylococcus aureus*, were obtained from stock cultures at the 44 Nigerian Army Reference Hospital, Kaduna. The isolates were revived in nutrient broth at 37°C for 24 hours. A 0.5 McFarland standard suspension was prepared by dissolving 2-3 bacterial colonies in 2 mL of sterile normal saline, then turbidity was compared against the standard using black horizontal lines. A turbidity match with 0.5 McFarland corresponds to approximately 1×10^6 CFU/mL [9].

2.10. Antimicrobial Assay (Agar Well Diffusion Method)

The antibacterial activity was assessed using the agar well diffusion technique. Standardized bacterial cultures were spread evenly over nutrient agar plates. Using a sterile 6 mm cork borer, five wells were punched into the agar. Four wells were filled with plant extracts at concentrations of 1000, 500, 250, and 125 μg/mL, and the fifth well contained 50 μg/mL Gentamycin as a control. Plates were left for 15 minutes to allow diffusion of extracts before incubation at 37°C for 24 hours. Zones of inhibition around wells were then measured in millimeters [7].

2.11. Determination of Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC)

The MIC was determined by broth dilution. Serial two-fold dilutions were prepared starting from 2000 μg/mL extract stock, mixing 2 mL with 2 mL nutrient broth to make 1000 μg/mL, and continuing dilutions to 31.25 μg/mL over six tubes. A control tube without extract was included. Each tube was inoculated with 0.5 mL bacterial suspension standardized to 0.5 McFarland and incubated at 37°C for 24 hours. The MIC was the lowest concentration with no visible growth. To determine the MBC, 0.01 mL from tubes showing no growth was plated onto Mueller-Hinton agar without extract and incubated for 24 hours at 37°C. The MBC was the lowest concentration where no bacterial colonies grew [7].

2.12. Statistical Analysis

Data were analyzed using SPSS version 25. The chi-square test was used to evaluate relationships between variables. A p-value less than 0.05 was considered statistically significant.

3. Results

Table 1: Antimicrobial Susceptibility Tests of the Aqueous and Ethanol Extracts of *G. senegalensis*

Table 1 presents the mean diameter of zones of inhibition of the aqueous extract tested against *Escherichia coli* and *Staphylococcus aureus* at concentrations of 125, 250, 500, and 1000 μg/ml, with Tab Gentamycin used as the control. The results demonstrate a dose-dependent antibacterial activity, as the mean zone of inhibition increases with the concentration of the extract for both bacterial isolates. Specifically, for *E. coli*, the inhibition zones increased from 7.85 ± 0.45 mm at 125 μg/ml to 16.22 ± 0.11 mm at 1000 μg/ml. Similarly, *S. aureus* showed an increase from 9.165 ± 0.17 mm at 125 μg/ml to 17.215 ± 0.115 mm at 1000 μg/ml. This trend indicates that higher concentrations of the extract result in stronger antibacterial effects. The control group (standard antibiotic) showed significantly larger zones of inhibition for both *E. coli* (20.655 ± 0.345 mm) and *S. aureus* (21.335 ± 0.225 mm).

The ethanol extract exhibited a concentration-dependent antibacterial effect against *Escherichia coli* and *Staphylococcus aureus*. As the concentration of the extract increased from 125 μg/ml to 1000 μg/ml, the mean zones of inhibition also increased for both bacterial isolates. Specifically, for *E. coli*, the mean zone of inhibition increased from 11.01 mm (± 0.11) at 125 μg/ml to 18.32 mm (± 0.11) at 1000 μg/ml. Similarly, for *S. aureus*, the mean zone of inhibition increased from 11.01 mm (± 0.11) at 125 μg/ml to 19.28 mm (± 0.28) at 1000 μg/ml. These increases at the highest concentration (1000 μg/ml) were statistically significant compared to the lower concentrations ($p < 0.05$). The control group showed larger zones of inhibition (22.30 mm ± 0.30 for *E. coli* and 22.71 mm ± 0.29 for *S. aureus*), indicating a stronger antibacterial effect than that of the ethanol extract at all tested concentrations.

Values are expressed as mean ± standard error of mean with those bearing the same superscripts under the same column are significantly different ($p < 0.05$) using the LSD post hoc multiple comparisons; N = 3.

Table 1: Diameter (mm) Zone of Inhibition of the Aqueous Extract

Aqueous Extract					
Bacterial isolate	**125 µg/ml**	**250 µg/ml**	**500 µg/ml**	**1000 µg/ml**	**Control**
E. coli	7.850 ± 0.45*	9.940 ± 0.060*	12.610 ± 0.39	16.2200 ± 0.110*	20.655 ± 0.345
S. aureus	9.165 ± 0.17*	12.435 ± 0.00*	13.055± 0.055	17.215 ± 0.115*	21.3350 ± 0.225
Ethanol Extract					
E. coli	11.010 ± 0.11	13.275 ± 0.175	15.065 ± 0.165	18.320 ± 0.110*	22.300 ± 0.300
S. aureus	11.005 ± 0.105	14.045± 0.945	15.450 ± 0.350	19.280 ± 0.280*	22.710 ± 0.290

Table: 2 Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) of Extracts on *E. coli* and *S. aureus*

The results in Table 2 present the MIC and MBC values of aqueous and ethanol extracts against *Escherichia coli* and *Staphylococcus aureus* at concentrations of 1000, 500, 250, and 125 mg/ml. Both extracts exhibited antimicrobial activity against the tested bacteria, as evidenced by lower MIC and MBC values compared to the control ($p < 0.05$).

For *E. coli*, MIC values decreased from 21.12 ± 0.13 to 10.44 ± 0.01 mg/ml for the aqueous extract and from 23.47 ± 0.03 to 11.23 ± 0.71 mg/ml for the ethanol extract as the concentration of extract decreased. Similarly, MBC values decreased from 33.13 ± 0.19 to 16.10 ± 0.05 mg/ml for the aqueous extract and from 32.00 ± 0.62 to 15.40 ± 0.15 mg/ml for the ethanol extract. In *S. aureus*, a similar pattern was observed. MIC values declined from 23.23 ± 0.44 to 11.93 ± 0.81 mg/ml (aqueous) and 26.66 ± 0.63 to 14.33 ± 0.79 mg/ml (ethanol), while MBC values decreased from 34.11 ± 0.76 to 18.82 ± 0.55 mg/ml (aqueous) and 35.90 ± 0.32 to 26.30 ± 0.43 mg/ml (ethanol). Comparatively, MIC and MBC values were generally lower for *E. coli* than *S. aureus* across all concentrations, suggesting that *E. coli* is more susceptible to the plant extracts. The control groups showed higher MIC values (25.07 ± 0.06 mg/ml for *E. coli* and *S. aureus*), confirming the extracts' antimicrobial effectiveness.

Table 2: Minimum Inhibitory Concentration (MIC) and Minimum bactericidal concentration (MBC) of the Extract on *E. coli* and *S. aureus*

		MIC		MBC	
Bacteria Isolate	**Concentration (mg/ml)**	**Aqueous**	**Ethanol**	**Aqueous**	**Ethanol**
E. coli	1000	21.12 ± 0.13	23.47 ± 0.03	33.13 ± 0.186	32.00 ± 0.62
	500	16.50 ± 0.32	15.41 ± 0.10	22.07 ± 0.067	20.34 ± 0.07
	250	13.80 ± 0.00	14.11 ± 0.61	18.00 ± 0.00	17.10 ± 0.22
	125	10.44 ± 0.01	11.23 ± 0.71	16.10 ± 0.05	15.40 ± 0.15
	Control	25.07 ± 0.06	-	27.53 ± 0.033	-
S. aureus	1000	23.23 ± 0.44	26.66 ± 0.63	34.11 ± 0.76	35.90 ± 0.32
	500	18.60 ± 0.37	20.51 ± 0.16	28.12 ± 0.17	31.14 ± 0.17
	250	14.78 ± 0.30	18.00 ± 0.21	22.50 ± 0.20	27.70 ± 0.52
	125	11.93 ± 0.81	14.33 ± 0.79	18.82 ± 0.55	26.30 ± 0.43
	Control	25.07 ± 0.06	-	27.53 ± 0.033	-

Values are expressed as mean ± standard error of the mean which are significantly different ($p < 0.05$) using the LSD post hoc multiple comparisons; N = 3.

3.1. Bioactive Components in *G. senegalensis*

The bioactive compounds were analyzed by GC–MS system (Perkin Elmer (USA) make GC-MS instrument, Model: Clarus 680 GC & Clarus 600C MS comprising a liquid auto-sampler). The identified compounds with their retention time (RT), molecular formula, molecular weight (MW), and concentration (peak area %) for all the fractions F1, F2, and F3.

3.2. Major Bioactive Compounds Identified in F1 Ethanol Extract of *G. senegalensis*

GC–MS analysis of the F1 ethanol extract of *G. senegalensis* revealed 22 major bioactive compounds characterized by their retention time (RT), molecular formula, molecular weight (MW), and relative concentration (peak area percentage). These compounds span a range of chemical classes, predominantly aliphatic hydrocarbons, fatty acids, and aromatic compounds.

The most abundant compound detected was propylcyclohexane (C_9H_{18}), with a peak area percentage of 16.56%, followed by 2,7-dimethyloctane ($C_{10}H_{22}$) at 10.61%, 4-methyldecane (($C_{11}H_{24}$)) at 9.21%, and tridecane ($C_{13}H_{28}$) at 9.40%. These high concentrations of alkanes suggest that they are the predominant chemical constituents in the ethanol fraction and may contribute significantly to its biological activity. Other notable hydrocarbons, such as dodecane (6.82%) and hendecane (5.19%), further contribute to the hydrophobic profile of the extract.

In addition to alkanes, fatty acids including hexadecanoic acid (palmitic acid, $C_{10}H_{32}O_2$) and linolenic acid ($C_{18}H_{30}O_2$) were identified at lower concentrations (1.34% and 1.70%, respectively). These fatty acids are known for their antioxidant and anti-inflammatory properties, suggesting a potential therapeutic benefit. Phytol ($C_{20}H_{40}O$), a diterpene alcohol with recognized antimicrobial and antioxidant activity, was also detected at 1.10%.

Aromatic and sulfur-containing compounds, such as (2-phenylcyclobutyl) benzene (3.68%) and (2-phenyl-3-[(phenylsulfinyl)methyl] cyclopropyl) benzene (2.22%), add chemical diversity to the extract and may be involved in specialized biological functions, including enzyme inhibition and cellular signaling modulation. Overall, the GC–MS profiling indicates that the F1 ethanol extract of *G. senegalensis* contains a complex mixture dominated by hydrophobic alkanes and bioactive fatty acids. This chemical composition supports the extract's potential pharmacological effects, particularly antimicrobial, anti-inflammatory, and antioxidant activities. The distribution of compounds, with a few major constituents and several minor ones, suggests possible synergistic interactions contributing to the extract's bioactivity.

Table 3: Major Bioactive Compounds Identified in F1 Ethanol Extract of *G Senegalensis*

NO.	Phytochemical Compound	RT (Min)	Molecular Formula	Molecular Weight (g/mol)	Peak Area (%)
1	Propylcyclohexane	3.492	C_9H_{18}	126	16.56
2	2,7-Dimethyloctane	4.217	$C_{10}H_{22}$	142	10.61
3	4-Methyldecane	4.507	$C_{11}H_{24}$	156	9.21
4	3-Methyldecane	5.130	$C_{11}H_{24}$	156	4.13
5	Tridecane	5.540	$C_{13}H_{28}$	184	9.40
6	Dodecane	6.915	$C_{12}H_{26}$	170	6.82
7	2,6-Dimethylundecane	7.101	$C_{13}H_{28}O$	184	2.36
8	2,3,7-Trimethyloctane	7.917	$C_{11}H_{24}$	156	3.90
9	Hendecane	8.294	$C_{11}H_{24}$	156	5.19
10	2,6,11-Trimethyldodecane	9.320	$C_{15}H_{32}$	212	2.26
11	Cetane	9.626	$C_{16}H_{34}$	226	4.33
12	Cyclohexene	10.135	$C_{16}H_{24}$	204	2.32
13	3,7-Dimethyldecane	10.420	$C_{12}H_{26}$	170	1.62
14	Pentadecane	10.898	$C_{15}H_{32}$	212	2.33
15	(2-Phenylcyclobutyl) benzene	14.221	$C_{16}H_{16}$	208	3.68
16	1-Octadecyne	15.241	$C_{18}H_{34}$	250	1.97
17	Hexadecanoic acid	17.876	$C_{16}H_{32}O_2$	256	1.34
18	Phytol	20.199	$C_{20}H_{40}O$	296	1.10
19	Linolenic acid	20.724	$C_{18}H_{30}O_2$	278	1.70
20	7-Ethylcycloheptatriene	24.190	C_9H_{12}	120	3.83
21	(2-Phenyl-3-[(phenylsulfinyl)methyl] cyclopropyl) benzene	25.104	$C_{22}H_{20}OS$	332	2.22
22	1,2-Diphenyl-1-isocyanoethane	25.245	$C_{15}H_{13}N$	207	3.13

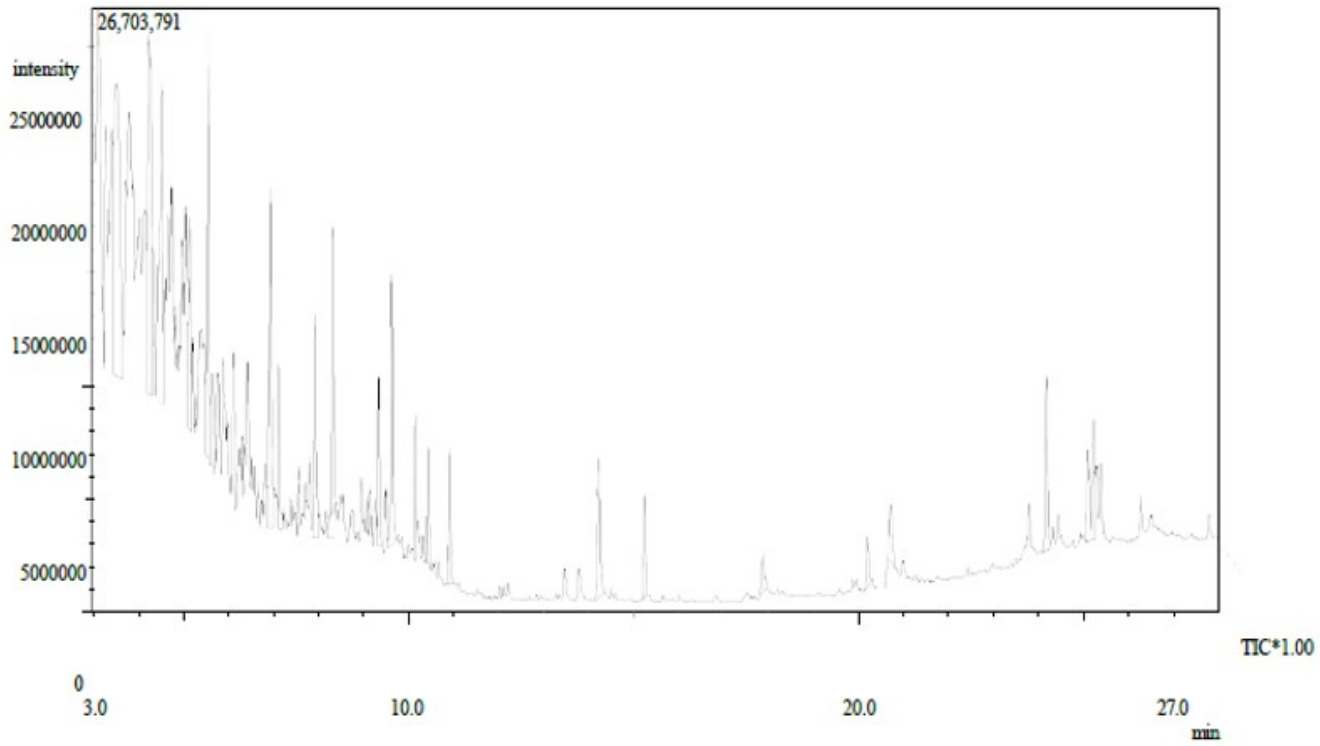

Figure 1: Chromatogram of F1 Ethanol Fraction of Extract of *G. senegalensis*

3.3. Major Bioactive Compounds Identified in F1 Aqueous Fraction of the Plant Extract

Table 4 presents the results of gas chromatography–mass spectrometry (GC–MS) analysis conducted on the F1 aqueous extract of *G. senegalensis*. The result revealed 22 major bioactive compounds characterized by their retention time (RT), molecular formula, molecular weight (MW), and relative concentration (peak area percentage). The most abundant compound detected was methyl n-octadecanoate (peak

area: 39.90%), followed by methyl linolelaidate (24.88%). Additionally, methyl 11-octadecenoate (9.59%) was identified, further supporting the fatty acid-rich profile of the extract. Other notable compounds included diethylene glycol monomethyl ether (5.66%), butyl isobutyrate (4.55%), and glycerol 2-monooleate (3.04%). Several minor compounds such as hexadecanoic acid, oleic acid, and linoleic acid, all essential fatty acids, were also detected in low concentrations.

Table 4: Major Bioactive Compounds Identified in F1 Ethanol Extract of *G Senegalensis*

No	Identified Compound	RT (Min)	Molecular Formula	Molecular Weight (g/mol)	Peak Area (%)
1	Butyl isobutyrate	3.540	$C_8H_{16}O_2$	144	4.55
2	Diethylene glycol monomethyl ether	3.643	$C_5H_{12}O_3$	120	5.66
3	1,1-Dibutoxybutane	4.134	$C_{12}H_{26}O_2$	202	2.90
4	Ethoxytriglycol	5.462	$C_8H_{18}O_4$	178	1.01
5	Methyl 14-methylpentadecanoate	6.866	$C_{17}H_{34}O_2$	270	0.57
6	Hexadecanoic acid	8.258	$C_{16}H_{32}O_2$	256	0.43
7	Methyl linolelaidate	16.855	$C_{19}H_{34}O_2$	294	24.88
8	Methyl 11-octadecenoate	19.879	$C_{19}H_{36}O_2$	296	9.59
9	Methyl n-octadecanoate	19.963	$C_{19}H_{38}O_2$	298	39.90
10	8-(2-Octylcyclopropyl) -octanal	20.876	$C_{19}H_{36}O$	280	1.15
11	Linoleic acid	22.463	$C_{18}H_{32}O_2$	280	0.60
12	Oleic Acid	22.778	$C_{18}H_{34}O_2$	282	0.87
13	Pentafluoropropionic acid	24.179	$C_{16}H_{27}F_5O_2$	346	2.19
14	Z-9-Tetradecenol	24.451	$C_{14}H_{26}O$	210	2.65
15	Glycerol 2-monooleate	26.331	$C_{21}H_{40}O_4$	356	3.04

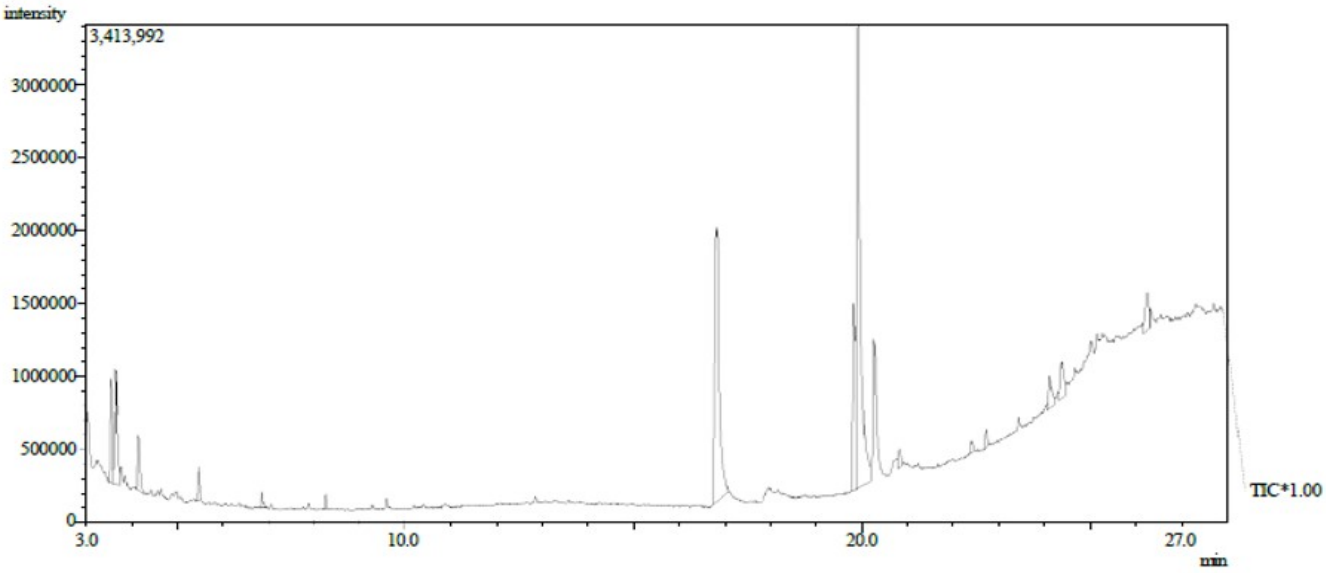

Figure 2: Chromatogram of F1 Aqueous Fraction of Extract of *G. senegalensis*

Table 5. Major Bioactive Compounds Identified in F2 Ethanol Fraction of *G. senegalensis*

Table 5 presents the major bioactive compounds identified in the ethanol fraction (F2) of *G. senegalensis* using GC–MS analysis. A total of nine compounds were detected, with significant variation in concentration based on peak area percentages. The most abundant compounds were 8-(2-Octylcyclopropyl)-octanal (40.36%) and Pentafluoropropionic acid (40.19%), indicating their potential as key bioactive constituents in the extract. These high levels suggest they may contribute significantly to the plant's biological activity. Linoleic acid (18.23%) was also present in a notable amount, supporting the medicinal potential of the plant due to its known anti-inflammatory and antioxidant properties. Butyl isobutyrate (12.39%) appeared as a prominent volatile ester, possibly contributing to antimicrobial or aromatic characteristics. Other minor compounds such as Methyl 11-octadecenoate (3.60%), Z-9-Tetradecenol (4.33%), and Glycerol 2-monooleate (2.15%) add to the extract's chemical diversity, each with possible functional or therapeutic roles. Overall, the F2 ethanol fraction of *G. senegalensis* contains a complex mixture of fatty acids, esters, aldehydes, and alcohols, with several dominant compounds that may underlie its pharmacological effects.

Table 5: Major Bioactive Compounds Identified in F2 Ethanol Extract of *G. Senegalensis*

No	Phytochemical Compound	RT (Min)	Molecular Formula	Molecular Weight (g/mol)	Peak Area (%)
1	Butyl isobutyrate	3.676	$C_8H_{16}O_2$	144	12.39
2	Diethylene glycol monomethyl ether	7.157	$C_5H_{12}O_3$	120	1.48
3	Methyl linolelaidate	19.882	$C_{19}H_{34}O_2$	294	0.94
4	Methyl 11-octadecenoate	19.992	$C_{19}H_{36}O_2$	296	3.60
5	8-(2-Octylcyclopropyl) -octanal	21.001	$C_{19}H_{36}O$	280	40.36
6	Linoleic acid	22.068	$C_{18}H_{32}O_2$	280	18.23
7	Pentafluoropropionic acid	22.686	$C_{16}H_{27}F_5O_2$	346	40.19
8	Z-9-Tetradecenol	23.155	$C_{14}H_{26}O$	210	4.33
9	Glycerol 2-monooleate	27.959	$C_{21}H_{40}O_4$	356	2.15

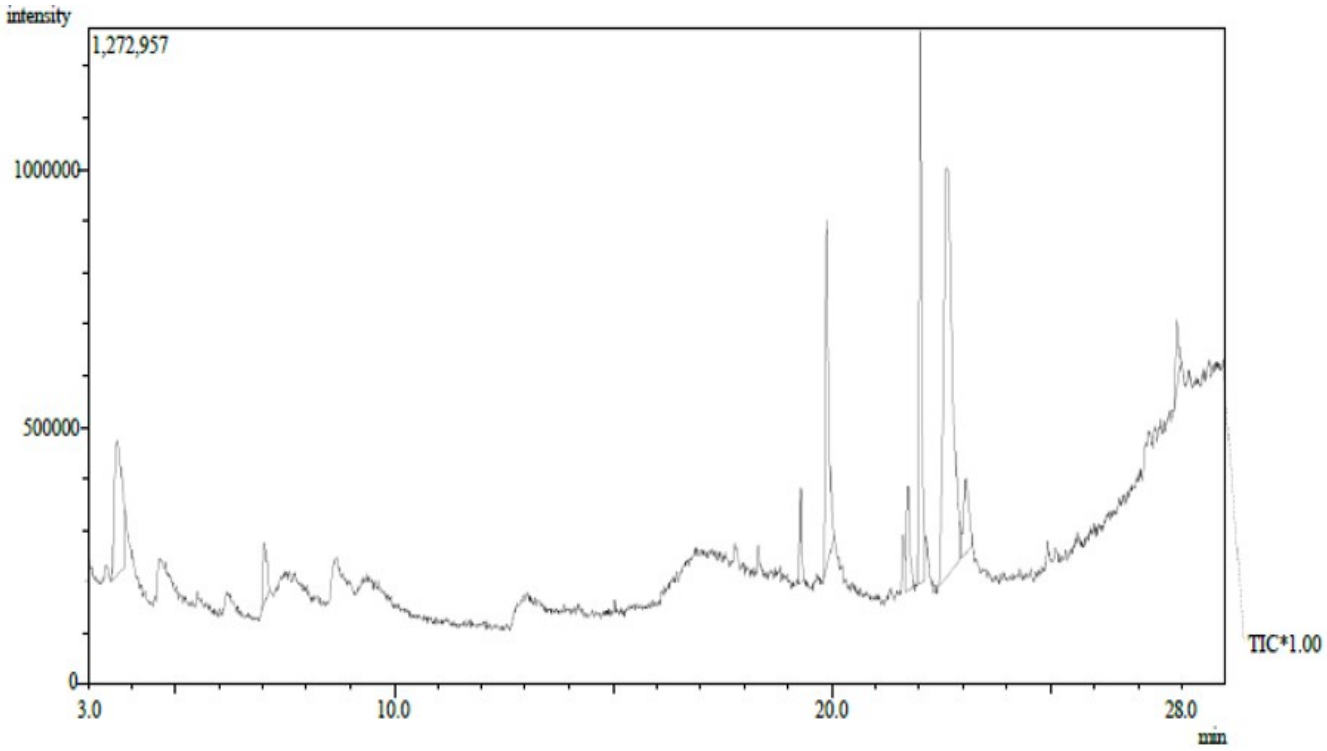

Figure 3: Chromatogram of F2 Ethanol Fraction of Extract of *G. senegalensis*

Table 6: Major Bioactive Compounds Identified in F2 Aqueous Fraction of *G. Senegalensis*

The results in Table 6present the major bioactive compounds identified in the F2 aqueous fraction of *G. senegalensis* by GC-MS analysis. Four key compounds were detected with varying peak area percentages. Squalene was the most abundant compound, constituting 54.35% of the total peak area, indicating it is the predominant bioactive constituent. The fatty acid derivative, 2-hydroxy-1-(hydroxymethyl)ethyl pentadecanoate, accounted for 21.38% of the peak area, while 1,2,3-trimethyl benzene and cyclohexylcyclopentane were present in smaller amounts, with peak areas of 12.81% and 11.46%, respectively. The dominance of squalene and the presence of other bioactive compounds suggest a complex phytochemical composition that may underlie the medicinal properties of the extract.

Table 6: Major Bioactive Compounds Identified in F2 Ethanol Extract of *G. Senegalensis*

No	Phytochemical Compound	RT (Min)	Molecular Formula	Molecular Weight (g/mol)	Peak Area (%)
1	Cyclohexylcyclopentane	3.593	$C_{11}H_{20}$	152	11.46
2	1,2,3-Trimethyl benzene	3.696	C_9H_{12}	120	12.81
3	2-Hydroxy-1-(hydroxymethyl)ethyl pentadecanoate	22.696	$C_{18}H_{36}O_4$	316	21.38
4	Squalene	27.676	$C_{30}H_{50}$	410	54.35

Table 7: Major Bioactive Compounds Identified in F3 ethanol Fraction of *G. senegalensis*

Table 7 presents the major bioactive compounds identified in the F3 ethanol fraction of *G. senegalensis* using GC–MS analysis. A total of thirteen compounds were detected, with significant variations in concentration as indicated by peak area percentages. The most abundant compound was 2-Methyl-Z,Z-3,13-octadecadienol, accounting for 34.44% of the total peak area, suggesting it is the predominant bioactive

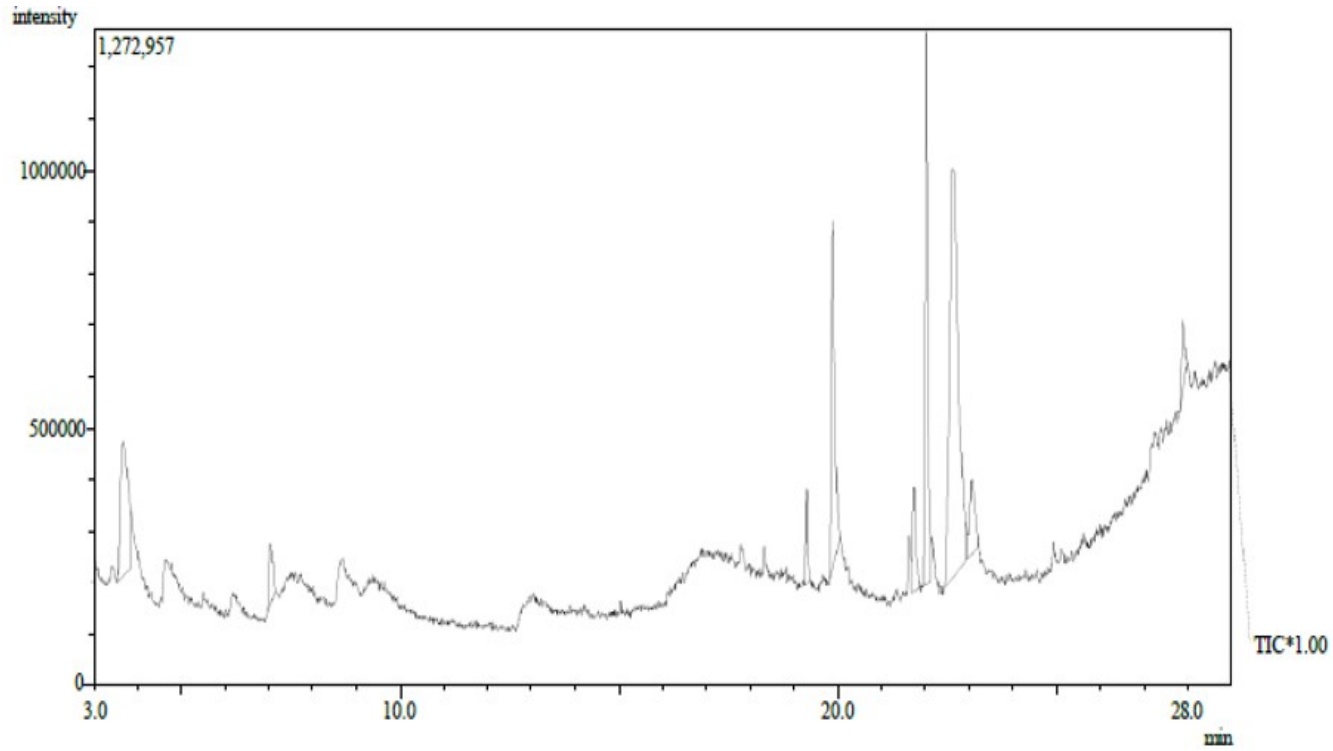

Figure 4: Chromatogram of F2 Aqueous Fraction of Extract of *G. senegalensis*

component in the ethanol extract. This was followed by Methyl stearolate (17.96%), Methyl 11-octadecenoate (7.87%), and Hexadecanoic acid (7.60%). These compounds are primarily fatty acid esters and long-chain hydrocarbons, which are often associated with antioxidant, anti-inflammatory, and antimicrobial properties. Other notable compounds include Methyl 2-oxooctadecanoate (5.31%), Methyl tridecanoate (5.36%), and Methyl (13E,16E)-13, 16-octadecadienoate (5.15%), all of which contribute to the bioactivity of the extract through their lipid-based structures. Minor constituents such as Squalene (1.12%), Erucic acid (1.15%), and Brassidic acid (2.97%) were also present.

Table 7: Herbal polymers source, properties and application

NO.	Phytochemical Compound	RT (Min)	Molecular Formula	Molecular Weight (g/mol)	Peak Area (%)
1	(Z)-9-(E)-12-Tetradecadien-1-ol acetate	12.721	$C_{16}H_{28}O_2$	252	3.23
2	Methyl 11-octadecenoate	13.484	$C_{19}H_{36}O_2$	296	7.87
3	Methyl 2-oxooctadecanoate	16.245	$C_{19}H_{36}O_3$	312	5.31
4	Methyl tridecanoate	16.751	$C_{14}H_{28}O_2$	228	5.36
5	Hexadecanoic acid	17.765	$C_{16}H_{32}O_2$	256	7.60
6	Methyl (13E,16E)-13,16-octadecadienoate	18.325	$C_{19}H_{34}O_2$	294	5.15
7	14-Methyl-14-(3-oxobutyryloxy)-hexadec-15-enoic acid	19.047	$C_{22}H_{38}O_5$	382	4.95
8	Methyl petroselinate	19.885	$C_{19}H_{36}O_2$	296	2.29
9	2-Methyl-Z,Z-3,13-octadecadienol	20.646	$C_{19}H_{36}O$	280	34.44
10	Methyl stearolate	21.180	$C_{19}H_{34}O_2$	294	17.96
11	Brassidic acid	23.744	$C_{22}H_{42}O_2$	338	2.97
12	Erucic acid	26.010	$C_{22}H_{42}O_2$	338	1.15
13	Squalene	26.954	$C_{30}H_{50}$	410	1.12

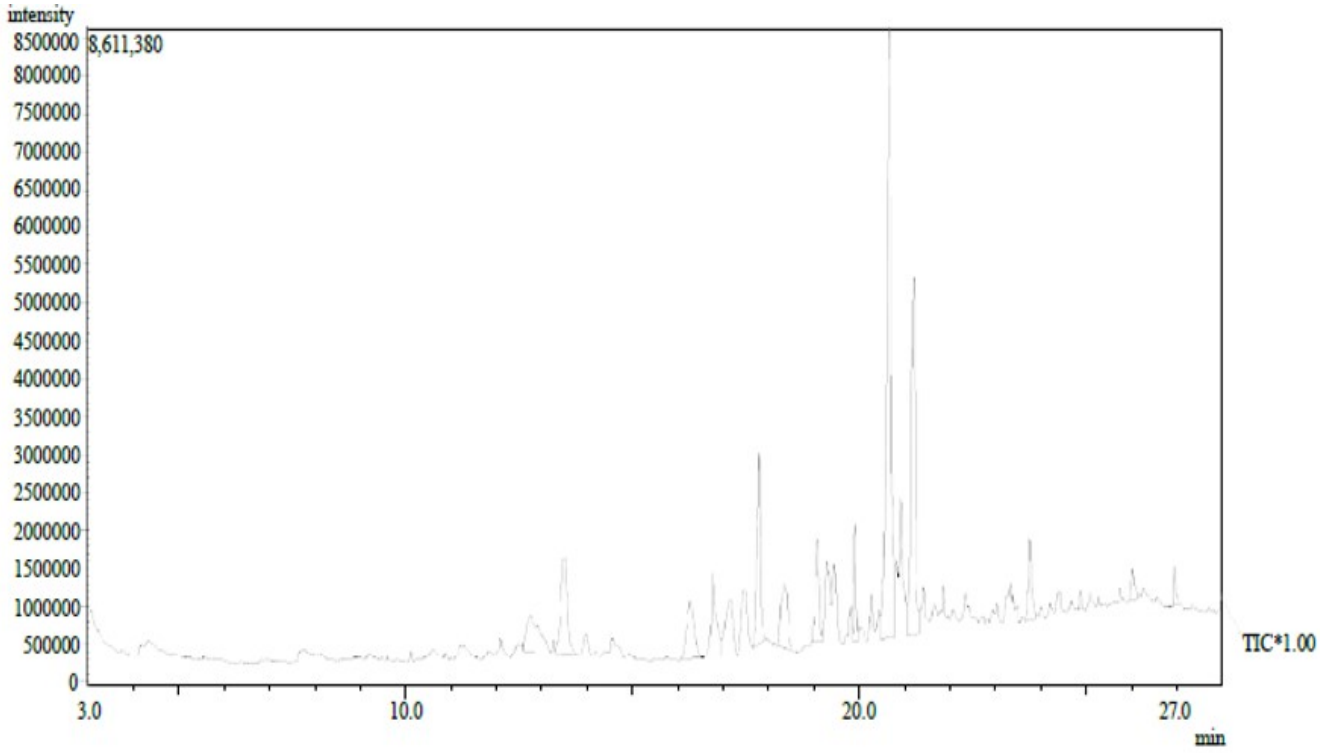

Figure 5: Chromatogram of F3 Ethanol Fraction of Extract of *G. senegalensis*

Table 8 Qualitative Phytochemical Analyses of Aqueous and Ethanol Extract of *G. senegalensis*

Table 8 presents the qualitative phytochemical composition of the aqueous and ethanol extracts of *Guiera senegalensis*. The analysis shows that both extracts contain a wide variety of secondary metabolites. Specifically, flavonoids, alkaloids, phenols, saponins, tannins, terpenoids, phlobatannins, flavonols/flavones, quinones, and resins were present in both extracts, indicating that these compounds are soluble in both water and ethanol. However, differences in solubility were observed for some phytochemicals. Anthraquinones and coumarins were detected only in the ethanol extract, suggesting that these compounds are more soluble in ethanol. Conversely, triterpenoids were found only in the aqueous extract, indicating a greater affinity for water. Several phytochemicals, including phytosteroids, vitamin A, cardiac glycosides, anthocyanins, amino acids, and chalcones, were absent in both extracts. This absence suggests that either these compounds are not present in *Guiera senegalensis* or are present in concentrations too low to be detected by the qualitative methods used.

Table 8: Qualitative Phytochemical Analysis of Aqueous and Ethanol Extract of *G. senegalensis*

S/N	Phytochemical	Aqueous (mg/g dry wt)	Ethanol (mg/g dry wt)
1	Flavonoids	+	+
2	Alkaloids	+	+
3	Phenols	+	+
4	Saponins	+	+
5	Tannins	+	+
6	Terpenoids	+	+
7	Phytosteroids	-	-
8	Phytosteroids	-	-
9	Vitamin A	-	-
10	Cardiac glycoside	-	-
11	Anthraquinones	-	+
12	Anthocyanins	-	-
13	Phlobatannins	+	+
14	Flavonols/flavones	+	+
15	Coumarins	-	+
16	Quinones	+	+
17	Triterpenoids	+	-
18	Amino acids	-	-
19	Chalcones	-	-
20	Resins	+	+

Key: - represents absent while + means present

Table 9 Quantitative Phytochemical Analyses of Aqueous and Ethanol Extracts of *G. senegalensis*

Table 9 presents the concentrations of selected phytochemicals extracted using aqueous and ethanol solvents, measured in mg/g of dry weight. The results indicate variation in phytochemical yield based on the solvent used.

Flavonoid content was relatively similar between the aqueous (5.17 ± 1.12 mg/g) and ethanol (5.27 ± 0.52 mg/g) extracts, with ethanol yielding slightly higher and more consistent results. Alkaloids were significantly more concentrated in the ethanol extract (3.78 ± 1.76 mg/g) compared to the aqueous extract (2.04 ± 0.98 mg/g), suggesting that ethanol is a more effective solvent for alkaloid extraction. Phenolic compounds showed the highest differential, with the ethanol extract (11.62 ± 1.20 mg/g) nearly doubling the phenol concentration found in the aqueous extract (6.18 ± 0.25 mg/g). This trend was also observed for saponins and tannins, both of which had higher concentrations in the ethanol extract (4.75 ± 0.13 mg/g and 4.87 ± 0.32 mg/g, respectively) than in the aqueous extract (3.93 ± 1.20 mg/g and 3.56 ± 1.14 mg/g, respectively). Terpenoid concentrations were relatively low in both extracts, with slightly higher values in the ethanol extract (1.75 ± 1.25 mg/g) than in the aqueous extract (1.52 ± 0.46 mg/g), although the variability was notably greater in the ethanol sample.

Table 9: Quantitative Phytochemical Analyses of Aqueous and Ethanol Extract of *G. senegalensis*

S/N	Phytochemical	Aqueous (mg/g dry wt)	Ethanol (mg/g dry wt)
1	Flavonoids	5.17 ± 1.12	5.27 ± 0.52
2	Alkaloids	2.04 ± 0.98	3.78 ± 1.76
3	Phenols	6.18 ± 0.25	11.62 ± 1.20
4	Saponins	3.93 ± 1.20	4.75 ± 0.13
5	Tannins	3.56 ± 1.14	4.87 ± 0.32
6	Terpenoids	1.52 ± 0.46	1.75 ± 1.25

4. Discussion

The global rise of antibiotic-resistant bacterial infections poses a significant threat to public health, particularly due to resistant strains of *Escherichia coli* and *Staphylococcus aureus*. *Guiera senegalensis* has emerged as a promising source of antibacterial agents.

Data from Table 1 clearly show that the aqueous extract of *G. senegalensis* exhibits a dose-dependent antibacterial effect on both *E. coli* and *S. aureus*. Inhibition zones for *E. coli* expanded from 7.85 ± 0.45 mm to 16.22 ± 0.11 mm, and from 9.17 ± 0.17 mm to 17.22 ± 0.12 mm for *S. aureus*, with increasing extract concentration. These results are consistent with earlier findings suggesting that higher concentrations of plant extracts improve antimicrobial efficacy due to greater availability of active compounds [10, 11]. Additionally, the extract was consistently more effective against *S. aureus* than *E. coli*, aligning with the widely reported trend that Gram-positive bacteria are generally more susceptible to plant-based antimicrobials than Gram-negative species. This may be due to the outer membrane of Gram-negative bacteria, which acts as a barrier to phytochemicals [12].

Despite showing promising activity, the extract's inhibition zones were significantly smaller than those produced by a standard antibiotic (20.66 ± 0.35 mm for *E. coli* and 21.34 ± 0.23 mm for *S. aureus*), indicating moderate potency. Similar findings have been reported in earlier studies on plant extracts [13, 14], supporting the extract's potential as an adjunct antimicrobial treatment and the need for further purification to isolate the active compounds.

The ethanol extract also demonstrated stronger antibacterial activity against *S. aureus* than *E. coli*, reinforcing prior conclusions that Gram-positive bacteria are more vulnerable to phytochemicals. This susceptibility difference is primarily attributed to the complex outer membrane structure in Gram-negative bacteria, which limits the entry of many antimicrobial agents [15]. A significant increase in inhibition was observed at the highest extract concentration (1000 μ g/ml), further supporting its dose-dependent activity. However, even at this concentration, the inhibition zones were still smaller than those of the reference antibiotic (22.30 mm for *E. coli* and 22.71 mm for *S. aureus*), echoing previous studies that plant extracts typically show moderate antibacterial effects compared to conventional antibiotics [16]. Similar trends were noted by [17, 18], who also reported increased antibacterial effects at higher ethanol extract concentrations and greater sensitivity of Gram-positive bacteria.

Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) results Table 2 revealed a dose-dependent pattern, with values decreasing as extract concentration increased. Ethanol extracts tended to have slightly higher MIC values than aqueous extracts, particularly against *S. aureus*, possibly [19] due to differences in solvent polarity affecting phytochemical solubility and bioavailability [19]. These observations align with findings from [19], who also reported stronger effects of aqueous extracts on *E. coli* and discussed the influence of bacterial cell wall structures. Gram-negative bacteria's outer membranes can allow certain hydrophilic compounds to enter, whereas Gram-positive bacteria's thicker peptidoglycan layer may restrict extract permeability.

Higher MBC values for *S. aureus* further support the notion that Gram-positive bacteria can be more resistant to plant extracts . The pattern of MBC values being higher than MIC values agrees with previous studies [20], which suggest that bacterial killing often requires higher concentrations than growth inhibition. The slightly lower MBCs for ethanol extracts against *E. coli* at some doses may be attributed to ethanol's capacity to extract a broader array of bioactive, less polar compounds [21] These results further affirm the antimicrobial potential of *G. senegalensis*, particularly its aqueous extracts, as reported in studies by [19, 22].

Gas chromatography–mass spectrometry (GC-MS) analysis of the ethanol fraction (F1) of Garcinia senegalensis revealed a complex array of phytochemicals, mainly aliphatic hydrocarbons, fatty acids, and aromatic compounds Table 3. Key constituents included propylcyclohexane (16.56%), 2,7-dimethyloctane (10.61%), 4-methyldecane (9.21%), and tridecane (9.40%). These compounds are consistent with previous studies of Garcinia species and support the plant's traditional medicinal applications. Long-chain saturated hydrocarbons and methylated alkanes have been linked to antimicrobial activity through membrane disruption [23, 24]. Cyclic hydrocarbons like cyclohexene are associated with antioxidant properties [25].

Lipid-derived compounds such as palmitic acid (1.34%) and linolenic acid (1.70%) were also identified and are known for their antimicrobial, anti-inflammatory, and antioxidant effects [26]. Palmitic acid, for example, can disrupt bacterial membrane fluidity, while linolenic acid has been associated with anti-cancer and cardioprotective actions [27]. Phytol (1.10%), a diterpene alcohol, has documented antioxidant and anti-inflammatory properties and may contribute to the plant's therapeutic effects [28]. Aromatic compounds, including (2-Phenylcyclobutyl) benzene and sulfur-containing analogs, were also present. These structures often possess antimicrobial or anticancer

activity due to their interactions with DNA or microbial enzymes [29, 30]. The combination of these unique compounds may distinguish *G. senegalensis* from other Garcinia species and suggests untapped pharmacological potential.

GC-MS of the F1 aqueous fraction of *Guiera senegalensis* identified 15 bioactive constituents, mainly fatty acid esters, long-chain alcohols, glycol ethers, and carboxylic acids Table 4. Major components included methyl n-octadecanoate (39.90%), methyl linolelaidate (24.88%), and methyl 11-octadecenoate (9.59%), indicating a lipid-rich extract.

Methyl n-octadecanoate (methyl stearate) is a well-known antimicrobial and anti-inflammatory agent, frequently reported in traditional medicine [31]. The unsaturated fatty acid esters also support anti-inflammatory and skin-healing properties [32]. Additional fatty acids such as palmitic, oleic, and linoleic acids, even in smaller amounts, are relevant due to their established roles in antioxidant and cytoprotective activity [33]. Glycerol 2-monooleate, found at 3.04%, is notable for its emulsifying and antimicrobial roles, and is used in pharmaceutical products [34].

Z-9-tetradecenol, a long-chain alcohol, may contribute insecticidal or aromatic properties, while glycol ethers like diethylene glycol monomethyl ether (5.66%) and ethoxytriglycol may reflect trace solvent residues or naturally occurring analogs with mild bioactivity. Volatile esters like butyl isobutyrate (4.55%) may enhance the extract's antimicrobial and aromatic profile.

Uncommon compounds such as 8-(2-octylcyclopropyl)-octanal and pentafluoropropionic acid derivatives suggest the presence of novel structures with potential cytotoxic or enzyme-modulating effects. Overall, the aqueous extract presents a diverse array of lipid-based and bioactive molecules, supporting its traditional use for antimicrobial, anti-inflammatory, and wound-healing purposes [35]. The findings underscore the plant's potential for pharmaceutical development and validate continued research into its unique phytochemistry.

Gas chromatography–mass spectrometry (GC–MS) analysis of the F2 ethanol fraction from *Guiera senegalensis* revealed a complex array of bioactive constituents, mainly comprising fatty acids, esters, and aldehydes Table 5. The predominant compounds were 8-(2-Octylcyclopropyl)-octanal (40.36%), pentafluoropropionic acid (40.19%), and linoleic acid (18.23%), along with trace levels of various methyl esters and glycerol derivatives.

Linoleic acid, a polyunsaturated fatty acid, is known for its anti-inflammatory, antioxidant, and cardioprotective properties. Its significant presence here supports the traditional application of *G. senegalensis* in treating infections and inflammatory ailments. Additionally, smaller quantities of fatty acid esters like methyl linolelaidate and methyl 11-octadecenoate, known for anti-inflammatory and lipid-modulating effects, further reinforce its medicinal relevance Interestingly, 8-(2-Octylcyclopropyl)-octanal was the most abundant compound, yet is scarcely reported in the literature, indicating it could be a novel or environment-specific metabolite. While little is known about this compound, structurally related aldehydes have shown antimicrobial and anti-inflammatory properties.

Pentafluoropropionic acid, a rare fluorinated compound in plant extracts, may either be a result of derivatization during analysis or a genuine phytochemical. Fluorinated fatty acids are reported to exhibit anticancer and enzyme-inhibiting activity (Xu et al., 2018), meriting further study. Other minor components like Z-9-Tetradecenol and glycerol 2-monooleate also contribute to the pharmacological profile, given their antimicrobial and emulsifying properties [35].

The aqueous fraction of *G. senegalensis* yielded four major compounds: cyclohexylcyclopentane, 1,2,3-trimethyl benzene, 2-hydroxy-1-(hydroxymethyl)ethyl pentadecanoate, and squalene Table 6. Retention times ranged from 3.593 to 27.676 minutes. Squalene dominated the profile with 54.35% abundance. Cyclohexylcyclopentane, although rare in phytochemical analyses, aligns with findings from essential oils where cyclic hydrocarbons exhibit antioxidant and antimicrobial activity . Similarly, 1,2,3-trimethyl benzene has been documented in therapeutic plants and is associated with anti-inflammatory effects . The ester compound 2-hydroxy-1-(hydroxymethyl)ethyl pentadecanoate (21.38%) is known for surfactant and membrane-stabilizing roles (Kumar et al., 2019). Squalene, a triterpenoid hydrocarbon, is recognized for its antioxidant, anti-inflammatory, and anticancer functions , and its high presence supports ethnomedicinal uses of *G. senegalensis*, echoing findings in related Garcinia species. The mix of hydrocarbons and fatty acid derivatives suggests a synergistic effect, consistent with the concept of phytochemical synergy.

The ethanol extract (F3) of *G. senegalensis* Table 7 displayed numerous bioactive molecules, primarily fatty acids, esters, alcohols, and terpenoids, many with antibacterial potential. The most prominent was 2-Methyl-Z,Z-3,13-octadecadienol (34.44%), a long-chain alcohol with membrane-disrupting antibacterial action . Methyl stearolate (17.96%), derived from stearic acid, and hexadecanoic acid (7.60%) both contribute to antimicrobial efficacy by affecting bacterial membranes and enzymatic activity [36]. These compounds are commonly found in other medicinal plants like Nigella sativa and Moringa oleifera. Additional esters like methyl 11-octadecenoate, methyl tridecanoate, and methyl 2-oxooctadecanoate also showed notable antimicrobial properties. Although squalene appeared in a minor amount (1.12%), its synergistic effects with other antibacterial agents are well documented [37]. Collectively, these compounds reinforce earlier findings on the antibacterial activity of *G. senegalensis* .

Qualitative screening showed both ethanol and aqueous extracts contained a variety of secondary metabolites including flavonoids, alkaloids, phenols, saponins, tannins, terpenoids, and resins. This supports earlier studies linking these phytochemicals to antimicrobial and anti-inflammatory effects. Anthraquinones and coumarins were found only in ethanol extracts, likely due to their low polarity. Similar findings were noted by [37]. Triterpenoids were more pronounced in aqueous extracts, suggesting solvent-dependent extraction efficiency . Compounds such as phytosteroids, vitamin A, and glycosides were not detected in either extract, possibly due to low concentrations or analytical limitations.

Quantitative assays Table 8 and 9 revealed ethanol as the superior solvent, extracting greater amounts of all six phytochemical groups. Flavonoids were almost equally extracted by both solvents, consistent with their variable solubility . Ethanol-extracted alkaloids were almost double those in aqueous extracts, aligning with [37] findings on solvent efficacy. Phenols showed the most significant difference—11.62 mg/g in ethanol versus 6.18 mg/g in aqueous—supporting literature that emphasizes ethanol's superior extraction of phenolic compounds38. Saponins, tannins, and terpenoids were also more abundant in ethanol extracts, affirming its broader phytochemical extraction capability.

5. Conclusion

The increasing global prevalence of antibiotic-resistant bacterial strains, particularly *Escherichia coli* and *Staphylococcus aureus*, represents a critical threat to public health. The present study demonstrates that *Guiera senegalensis* extracts possess dose-dependent antibacterial activity against these pathogens, with significantly greater inhibition observed in *S. aureus*. This aligns with previous findings that Gram-positive bacteria are generally more susceptible to plant-based antimicrobials due to their less complex cell wall structures.

While the antibacterial effects of *G. senegalensis* extracts are moderate compared to standard antibiotics, their consistent efficacy—particularly at higher concentrations—suggests potential as adjunct or alternative antimicrobial agents. Gas chromatography–mass spectrometry (GC-MS) analysis revealed diverse bioactive constituents, including fatty acids, esters, long-chain alcohols, and hydrocarbons with known antimicrobial, antioxidant, and anti-inflammatory properties. Ethanol extracts were notably more phytochemically rich than aqueous extracts, supporting ethanol's greater extraction efficiency for secondary metabolites.

Article Information

Disclaimer (Artificial Intelligence): The 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 writing or editing of manuscripts.

Competing Interests: Authors have declared that no competing interests exist.

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