Chemical composition and antibacterial properties of curcuma longa volatile oil and solvents extracts against selected clinical bacteria

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Research Article

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Posted Date: February 24th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8941794/v1

Additional Declarations: The authors declare no competing interests.

Chemicals Composition and Antibacterial Properties of *Curcuma Longa* Volatile Oil and solvents extracts against selected Clinical Bacteria

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Abstract

Turmeric (*Curcuma Longa*) rhizome is a natural product of plant that is usually consumed. Its bioactive compounds can be explored to control bacterial growth. This study evaluated the chemical composition of turmeric volatile oil and extracts against clinical bacteria.

Bioactive compounds of turmeric rhizome were subjected to hydrodistillation using Clevenger apparatus. The non volatile extracts were carried out using Hexane and Methanol. The oil and the extracts were subjected to gas chromatography-mass spectrometry (GC-MS) and were evaluated for their antibacterial activity by agar well diffusion assay. Minimum inhibitory concentration (MIC) was determined using the standard method.

The results showed that eighty-four (84) compounds were identified in turmeric volatile oil with ar-turmerone (19.01%), cedr-8-ene (10.13%), and β-terpinene (10.01%) being predominant. The main constituents of turmeric n-hexane were turmerone (13.39 %) and14-beta-H-pregna (9.05%). Methanol extracts contained turmerone (12.46%) and 14-beta-H-pregna (8.72%) respectively. Findings revealed that volatile oil and the extracts have antibacterial properties against *S. aureus, K. ornithinolytica,* and *C. gillenii*, turmeric n-hexane extract had the highest zone of inhibition (28±1.03 mm) against *C. gillenii* followed by *K. ornithinolytica* (26±1.63 mm), and *S. aureus* (25±0.33 mm). The MIC results showed that turmeric volatile oil showed considerable activity against *K. ornithinolytica* at concentration of 6.25 mg/ml than for all other bacteria.

In conclusion, the volatile oils of turmeric oil and extracts have potentials for use as a natural agent against some clinical bacterial species.

Keywords: Turmeric, Chemical composition, Antibacterial agents, Clinical bacterial isolates

Introduction

Bacteria are the most primary cause of human infections, the diseases caused by bacterial have a negative influence on human and animal (Roushan *et al,* 1876). Antibiotics are synthetic compounds specially designed to inhibit and treat bacterial infections (Petal et al, 2023). Recently, there is a wide range of verifiable studies that that showed that some bacteria are resistance against commonly used antibiotics drug (Koulenti *et al*, 2019) There is a need for an alternative antimicrobial that can inhibit or prevent the growth of bacteria. This assertion has led to the conception of this investigation to explore the chemical compounds inherent in plants to solve the problem of antibacterial drug resistance. It has been reported that volatile oils and extracts obtained from plants has antimicrobial properties which has a wide range of complex and diverse chemical compounds as shown in Figure 1 (Gupta *et al*, 2015).

Turmeric (*Curcuma longa* Linn) is a tropical perennial rhizome plants that belong to *Zingiberaceae* family (Gupta *et al*, 2015). It is originally from India (Amalraq *et al,* 2017) and commonly found in Southern Asia (Jayaprakasha *et al,* 2018). It is one of the most important medicinal rhizome which exhibit yellow-orange pigments with different biological activities (Sharmeen *et al*, 2021; Abdulkhaleq *et al*, 2018; Chiang *et al*, 2019; Barchitta *et al*, 2019) such as anti-inflammatory, immune-modulator, antioxidant, hypolipidaemic, antimicrobial, anticarcinogenic, antitumor, radioprotective, neuroprotective, hepato-protective, netroprotective, and vasoprotective activities (Kamal *et al*., 2023; Tundis *et al*., 2023; Kunnumakkara *et al*, 2019; dosoky *et al*, 2018). The yellow color was due to the presence of three major curcuminoids present in turmeric rhizome (Kebede *et al*., 2021) which include curcumin, demethoxycurcumin and bis-demethoxycurcumin (Ravindran 2007), which exhibit antibacterial action against bacteria such as Bacillus subtilis, *Staphylococcus aureus* (Meng-meng *et al*, 2020; Kebede *et al*, 2021). The aromatic taste of *Curcuma longa* is attributed to the presence of ar-, α- and β-turmerone (Dosoky *et al*., 2019). These compounds are responsible for the aromatic qualities of the plants and also exhibit various biological activities including antimicrobial, antifungal, and insecticidal properties (Kamle *et al*., 2019; Sathiyamoorthy *et al*, 2022). It plays a specific role in traditional medicine, as it contains phytochemical compounds such as fatty acid, terpenoids, flavonoids, phenolics, and carotenoids (Kumar *et al*, 2018)

The major chemical components of turmeric oil are α-turmerone, β-turmerone, and ar-turmerone as well as minor components are cineole, α-phellandrene, β-caryophyllene, and α-zingiberene (Ravindran *et al*, 2018). It has an important property that makes these compounds penetrate into the cell wall of bacteria to cause cell permeabilization resulting into the leakage of inorganic cations which inhibit the growth of pathogenic bacteria such as *Salmonella typhi,* *Escherichia coli*, and *Staphylococcus aureus*. Turmeric volatile oil and extract have a pharmacological chemical compounds such as ar-turmerone, α- and β-turmerone which contribute to the antimicrobial properties that can be used instead of synthetic antibiotics against microorganisms. Turmeric has been studied as natural antimicrobial agent for preventing skin infections in wound coverings. It inhibits the growth of some microorganisms like *Pseudomonas aeruginosa, Acinetobacter baumannii, and Klebsiella pneumoniae* (Figure 2). It is very effective against several pathogenic Gram positive bacteria such as *Staphylococcus aureus*, *Staphylococcus epidermidis,* and *Enterococcus* species that cause many infections such as skin problems, pneumonia, meningitis, and urinary tract infection (Meng-meng *et al*, 2020).

Commonly used antibiotics are rapidly increasing in resistance and other alternatives need to be explored, such as natural products that may inhibit microorganisms especially those of bacteria origin and may act as effective antimicrobial agents (Arsene *at al*, 2021) Hence, this study evaluated bioactive compounds of turmeric rhizome and determined its antibacterial property in order to provide protection for healthy living.

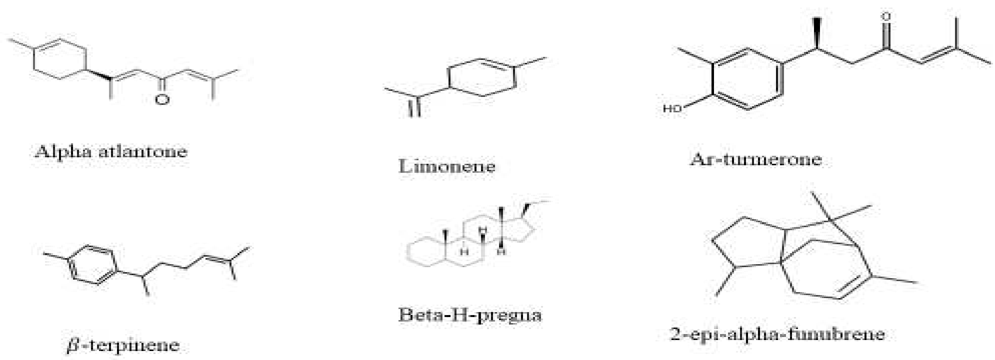


Figure 1: Chemical structure of some turmeric volatile oil, n-hexane and methanol extracts

Materials and Methods

Sample collection and identification

Turmeric rhizome were freshly harvested around Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria in the month of October, 2025 and authenticated at the Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria.

Extraction of turmeric extracts using n-hexane solvent

Two hundred grams (200 g) of powder turmeric samples were weighted and loaded into Soxhlet extractor. The sample was extracted for 1 hour using n-hexane as extractor solvent. The solvent was evaporated to dryness under vacuum to give n-hexane turmeric extract and the oil.

Extraction of turmeric extracts using methanol solvent

One hundred grams (100 g) of residue from n-hexane turmeric samples was measured on an electronic balance. The weighed residue was then dispensed into PET bottle containing 500 ml of 95% methanol. The turmeric rhizome was soaked for 72 hours, after which the solution was carefully filtered with a muslin cloth into a sterilized 250 ml conical flask.

Extraction of turmeric volatile oil by Hydrodistillation

Fresh turmeric rhizome was subjected to hydrodistillation in Clevenger's apparatus for 5 hours. The light yellow coloured oil obtained was dried over minimum amount of anhydrous sodium sulphate to remove any traces of water. It was stored in the refrigerator for chemical composition analysis and antimicrobial activities.

Identification of chemical components using GC/MS analysis

The active chemical components of turmeric volatile oil and extracts were analyzed using Gas Chromatography-Mass spectrometry (GC-MS) analysis to identify the chemical constituents. The experiments were performed on Agilent Technologies 7890B gas chromatograph, equipped with weakly polar, silica capillary column, HP-5MS (5% diphenyl- and 95% dimethyl-polysiloxane, 30 m x 0.25 mm, 0.25 μm film thickness; Agilent Technologies, USA) and coupled with inert, selective 5977A mass detector of the same company. One μl of the sample dissolved in diethyl ether in the concentration of 500 ppm was injected in 20:1 split mode. Helium was used as the carrier gas, at a constant flow rate of 1 cm3/min. The oven temperature was programmed from 50 °C for 2.25 minutes and then increased to 290 °C at the rate of 4 °C/min. Temperatures of the MSD transfer line, ion source and quadruple mass analyzer were set at 300 °C, 230 °C, and 150 °C, respectively. The ionization voltage was 70 eV and mass range m/z 35-650.

Antibacterial assay of turmeric volatile oil and extracts

Test organisms

All bacterial isolates used for the research study were collected from Adekunle Ajasin University Health Centre, Akungba-Akoko, Ondo State, Nigeria. The selected bacteria included *Staphylococcus aureus*, *Streptococcus* sp, *Enterobacter agglomerans, Citrobactor gillenii, Klebsiella ornithinolytica,* and *Escherichia coli*. The six organisms were cultured in nutrient broth for 24 hours at 37°C. The six organisms were cultured in nutrient broth for 24 hours at 37°C. The concentration of each bacterium was adjusted to match the 0.5 McFarland standard.

Media preparation

Nutrient agar (NA) and Mueller Hinton Agar (MHA) were prepared according to the manufacturers' instructions where 28 g, 38 g, respectively of each medium was dissolved into 1000 ml of distilled water and sterilized at 121 ºC for 15 minutes. Molten agar preparations were allowed to cool to 45ºC; each cooled agar was then poured into Petri dishes and also allowed to solidify.

Antibacterial Sensitivity Test (AST)

The antibacterial screening of the compound against some clinical isolates was conducted on Mueller-Hinton (MH) agar by the modified agar well diffusion method according to the method described by Balouiri.[16] Mueller-Hinton agar was prepared according to the manufacturer's instructions and allowed to set. Using a 9 mm diameter sterile cork borer, three wells were made on each agar plate and spaced 20 mm apart. The prepared antibacterial solutions of turmeric oil and extracts, as well as the controls (positive Chloramphenicol control), were dispensed into their respective labeled wells. The MH agar plates were subsequently incubated at 37°C for 18 hours, after which the diameter of the zones of inhibition (ZI) was measured.

Determination of Minimum Inhibitory Concentration (MIC)

A cell viability assay described by Adeoyo *et al.* was adopted (Adeoyo *et al,* 2019). Each compound was adjusted to a final concentration of 200 mg/ml. A stock solution of 200 mg/ml of turmeric volatile oil and extracts were prepared and subjected to serial dilutions of the stock solution to obtain additional concentrations with distilled water of 100 mg/ml, 50 mg/ml, 25 mg/ml, 12.5 mg/ml, and 6.25 mg/ml. The test organisms were grown for 18 hours at 37 °C and 2 ml of each bacterial liquid culture (optical density adjusted to match 0.5 McFarland standard) was distributed into five test tubes. The test tubes were incubated at 37°C for 18 hours. A 0.4 ml (0.2 mg/ml) thiazolyl blue tetrazolium bromide was added and was incubated at 37°C for 30 min to detect the MIC. The presence of viable bacterial cells reduced the yellow dye to a purple colour. MIC is the lowest concentration that prevented change and inhibited bacterial growth.

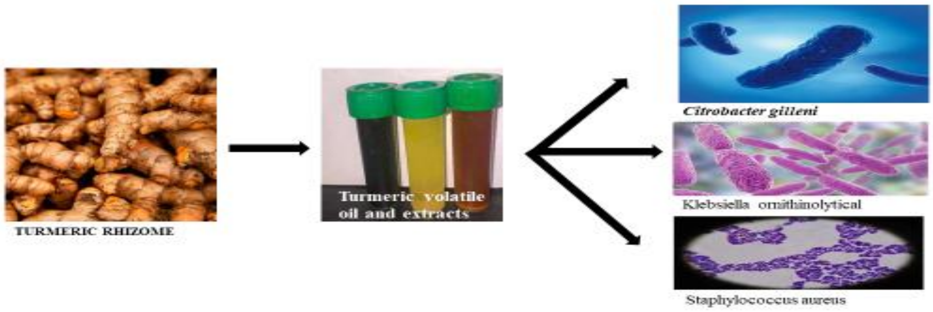


Figure 2: Antimicrobial properties of turmeric oil volatile against bacterial species

Results

The results of the GC-MS of turmeric n-hexane extract, methanol extract and volatile oil are presented in Tables 1, 2, and 3, respectively. The results indicated that *Curcuma longa* n-hexane extract contained a wide range of compounds from cyclohexane α-terpinene, α-lonone, turmerol ar-turmerone to sinococuline (Table 1), *Curcuma longa* methanol extract contained isobutanol, β-lonone, β-pinene, turmerone, curcumen, β-turmerone, curcumene, α-curcumen to selenophene chemical compounds (Table 2) while *Curcuma longa* volatile oil contained chemical compounds such as methylcyclohexane, turmerone, curcumen, turmerone, curcumene, carvacrol, α-selinene, altantone and azadirachtin (Table 3). Table 4 shows the predominant value of the chemical composition of the oil and its extracts. Curcumene, 2-methylhept-2-en-4-one, altantone, linoleic acid, curcumen, alpha-cadinol, allopregnanolone, palmitic acid, methylbenzene, and β-terpinene are among the prominent identified chemical compounds. Also, in table 4, it was observed that out of 72, 109 and 84 chemical constituents accounting for 98.05%, 99.51% and 99.76% of the oil composition identified in n-hexane extract, methanol extract, and volatile oils respectively, 10 chemical components were common in all the oils. The following compounds are common turmerone (13.39%, 12.46%, and 7.29), ar-turmerone (2.24%, 1.46%, and 19.01), +-alpha atlantone (2.34%, 5.59%, and 0.30), 9,12octadecadienoic acid (2.47%, 1.67%, and 0.35%), curlone (1.38%, 1.84%, and 1.63%) while other are present in two samples such as turmeric n-hexane and volatile oil contained 2-epi-alpha-funebrene (4.04% and 2.30), toluene (1.48%, 0.69%), benzene 1(I,5 dimethyl-4-hexenyl)-4-methyl (2.49% and 10.010%), respectively. N-hexane and methanol extracts contained 14-beta-H-pregna (9.05% and 8.72%) and n-hexadecanoic acid (0.81% and 1.20%).

Table 1: Chemical composition of *Curcuma longa* n-hexane extract by GC-MS analysis

S/N	RETENTION TIME	CHEMICAL COMPONENTS	OTHER NAME	AREA %
1	2.756	Cyclohexane, methyl-	Cyclohexane	0.14
2	2.839	Methylenecyclohexane-4,4-D2	4,4-Methylene Cyclohexane-2	0.30
3	3.516	Toluene	Methylbenzene	1.48
4	3.925	Cyclohexane, 1,2-dimethyl-, trans-	Trans-1,2-dimethylcyclohexane	1.86
5	4.395	2- Chloropropionic acid, pentadecyl ester	Valeric Acid	0.75
6	4.571	n-Nonadecanol-1	Nonadecyl Alcohol	0.15
7	4.961	Benzene, 1,3-dimethyl-	Meta-Xylene	1.28
8	5.175	o-Xylene	1,2-dimethylbenzene	1.44
9	5.365	p-Xylene	1,4-dimethylbenzene	1.48
10	5.678	Nonane	Nonyl hydride	0.63
11	5.888	1H-Indene, octahydro-, cis-	Cis-Hydridane	1.06
12	6.370	1,3,5-Trimethylbenzene	Mesitylene	1.15
13	6.647	Benzene, 1,2,4-trimethyl-	Pseudocumene	1.02
14	6.841	Benzene, 1-ethyl-3-methyl-	m-Ethyltoluene	1.24
15	7.226	Decane	Decyl hydride	1.36
16	7.385	Bicyclo[3.1.0]hex-2-ene, 2-methyl- 5-(1-methylethyl)-	Methylene cyclopentane	0.63
17	7.625	Eucalyptol	eucalyptol	0.87
18	7.721	Phenol, 2,6-dimethoxy-	syringol	0.54
19	7.808	Benzene, 1,2-diethyl-	1,2-Dimethylbenzene	1.00
20	7.919	p-Mentha-8-dehydeo-1,3-diene	∝-Terpinene	1.31
21	8.333	4-Isopropylidene-1-cyclohexene	∝ −Lonone	1.25
22	8.595	Undecane	Hendecane	0.72
23	8.703	trans-Decalin, 2-methyl-	2-Methyltrans-Decalin	0.80
24	8.915	Cyclodecene, 1-methyl-	1-methycyclodecene	0.87
25	9.215	Benzene, 2-ethyl-1,4-dimethyl-	2-Ethyl-p-Xylene	0.31
26	9.322	Benzene, 1,2,3,4-tetramethyl-	prehnitol	0.21
27	9.434	Benzene, 1-ethyl-2,3-dimethyl-	1-Ethyl-2,3-Dimethyl-Benzene	0.36
28	9.586	2-(4'-methylphenyl)-propanal	4-Methyl hydratropaldehyde	0.10
29	9.696	Naphthalene	Naphthalin	0.23
30	9.849	Dodecane	Duodecane	1.95
31	10.701	Bicyclo[2.2.1]heptan-2-ol, 3,3-dimethyl-	N-[4-Bromo-N-Butyl-2-	0.06
32	10.830	2-Piperidinone, N-[4-bromo-n-butyl]-	Piperidinone,	0.19
33	11.232	Tridecane	Tridecyl Hydride	0.28
34	11.552	Naphthalene, 1-methyl-	1-Methyl Naphthalene	0.16
35	11.807	(1R*,5R*)-1,5-Dimethylbicyclo[3.3.0]oct-3-en-2-one	Fenchone	0.10
36	12.037	1H-Inden-1-one, 2,4,5,6,7,7a-hexahydro-4,4,7a-trimethyl-	Patchouleone	0.20
37	12.976	Caryophyllene	Caryophillin	1.75
38	13.810	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	Citronella	2.49
39	14.165	trans-.alpha.-Bergamotene	∝ −santalene	1.19
40	15.180	2-epi-.alpha.-Funebrene	α-Funebrene	4.40
41	15.437	Di-epi-.alpha.-cedrene-	α-Cadinol	3.67
42	17.300	Tumerone	Turmerol	13.39
43	17.769	aR-Turmerone	Ar-turmerone Dehydrocurdione	2.24

44	17.993	Curlone	Recifcolide	1.38
45	18.260	(6R,7R)-Bisabolone	Altantone	1.18
46	18.377	(+)-.alpha.-Atlantone	Phenylsilatrane	3.14
47	18.544	Bornyl tiglate	Fenpropathrin	0.44
48	18.683	4-[dimethyl(phenyl)silyl]-2-oxanon	Chrysanthemumic Acid	1.57
49	18.755	Spirohexane-5-carboxylic acid, 1,1,2,2-tetramethyl-, methyl ester	Geranio	1.29
50	18.896	Cyclohexane-1-methanol, 3,3-dimethyl-2-(3-methyl-1,3-butadienyl)-	Tolyporphin	1.67
51	19.092	6-(2-Hydroxy-4-methylphenyl)-2-methylhept-2-en-4-one	Plicatin B	2.65
52	19.569	6-(3-Hydroxy-4-methylphenyl)-2-methylhept-2-en-4-one	Palmitic Acid	3.02
53	19.974	n-Hexadecanoic acid	B-Phellandrene	0.81
54	20.112	2-Pentene, 4,4-dimethyl-, (E)-	Zingiberene	1.03
55	20.202	.beta-tumerone	Palmitoleic Acid	1.56
56	20.438	cis-10-Heptadecenoicacid	Adamantone	0.35
57	20.508	4-Fluoropentacyclo [4.3.0.0(2,5).0(3,8).0(4,7)] nonane	Phenylsilatrane	0.59
58	20.662	3-(Dimethylphenylsilyl)-3-methylcyclopentanone	Dicyclohexylmethanone	1.13
59	20.864	Methanone, dicyclohexyl-	Linoleic Acid	0.29
60	21.147	9,12-Octadecadienoic acid (Z,Z)-	Methyl Linoleate	2.47
61	21.469	Linoleyl methyl ketone	Allopregnanolone	1.58
62	21.704	14-.beta.-H-pregna	Behenicane	9.05
63	21.953	1-Docosene	Musculure	0.21
64	22.163	9-Tricosene, (Z)-M	Maleic Hydrazide	0.54
65	22.250	4-[(1Z)-(N-Hydroxyethanimidoyl)-2-methylpyridazin-3(2H)-one	Eicosen-1-ene	0.28
66	22.372	1-Eicosene	Ceromelissene	0.30
67	23.035	1-Hexacosene	Cerylane	1.43
68	23.163	Hexacosane	Triphenylmethane	0.64
69	23.460	Cyclohexane, 1,3,5-triphenyl-	Methyltrimethoxytin	0.76
70	24.205	Methoxymethyl(triethyl)stannane	Melatonin Precursor	1.03
71	24.335	1H-Indole, 5-methyl-2-phenyl-	Sinococuline	0.84
72	26.329	B-Homomorphinan-7-one, 5-chloro-5, 6,8,14-tetradehydro-3-hydroxy-2,4,6-trimethoxy-17-methyl-,		0.41

Table 2: Chemical composition of *Curcuma longa* methanol extract by GC-MS analysis

S/N	RETENTION TIME	CHEMICAL COMPONENTS	OTHER NAME	AREA %
1	3.224	1-propanol,2-methyl	Isobutanol	0.80
2	3.455	Acetic acid	Vinegar acid	2.24
3	3.716	1-Butanol, 3-methyl-	Isoamyl alcohol	6.34
4	3.874	Ethyl Acetate	Acetic Ether	0.07
5	4.173	(R,R)-Butane-2,3-diol	Buteiol	0.63
6	4.638	Dimethyl Sulfoxide	Methyl sulfoxide	0.34
7	4.758	Methane, sulfinylbis-	Dimethyl Sulfoxide	0.20
8	4.820	1-Butanol, 3-methyl,acetate	Methylsulfinylbis(Methane)	0.20
9	5.077	Butane, 1-(1methylethoxy)-	Isoamyl acetate	0.14
10	5.254	3,4-O-Isopropylidene-d-galactose	Isopropylidene-D-galactose	0.08
11	5.437	1,3-Dihydroxyacetone dimer	Dihydroxyacetone dimer	0.38

12	5.655	methanesulfinic acid methyl ester	Methylmethanesulfinylcarbamate	0.07
13	5.736	2-Hydroxy-2-cyclopenten-1-one	Cyclopentenedione	0.15
14	6.003	Pentane, 1-(1-ethoxyethoxy)-	Diethylene glycol diethyl ether	0.10
15	6.200	1,2-bis(2,4-dimethylphenyl)diazane	Butter Yellow	0.10
16	6.327	Acetaldehyde ethyl isoamyl acetal	Isoamyl Ethyl Acetal	0.11
17	6.484	1-Oxa-2-silacyclopentane, 2,2-dimethyl-	Dioxolane, 2,2-Dimethyl-2-Sila-	0.10
18	6.604	Phenol	Carbolic acid	0.63
19	6.817	1,3-Cyclohexadiene, 2-methyl-5-(1-methylethyl)-	5-isopropyl-2-methylcyclohexa-1,3-diene	0.48
20	6.966	Butyric acid-2-D1	Deuterated butyric acid	0.08
21	7.083	Glycerin	Glycerol	0.22
22	7.167	3-Cyclohexen-1-d-1-ol	Deuterated cyclohexanol	0.23
23	7.578	Diglycerol	Dihydroxyldiether	0.30
24	7.686	1,2,3-Propanetriol	Glycerol	0.26
25	7.844	Erythritol	Mesobutyrol	0.32
26	7.961	Disulfide, methyl 1-(propylthio)ethyl	Dially disulfide	0.18
27	8.209	Phenol, 2-methoxy-	Guaiacol	0.95
28	8.365	2,5-Disila-7-octene	Disilylethene	0.16
29	8.537	2-Butenoic acid, 2-methyl-, 2-methylpropyl ester, (E)-	Angelic acid	0.14
30	9.072	4H-Pyran-4-one, 2,3-dihydro-3,5-di hydroxy-6-methyl-	γ-pyron	0.08
31	9.384	[Ethyl 5-methylhexanoate	Ethyl-s-methylcaproate	0.06
32	9.525	2-Phenyl-2-tert-butoxycyclopropane carboxylic acid,ethyl ester	Permethrin	0.28
33	9.627	Benzo[b]thiophene, 2,3-dihydro-3-methyl	2-methyl-2,3-dihydro-3-methyl-	0.08
34	9.723	Octanoic acid, ethyl ester	Ethyl Octanoate	0.27
35	9.893	3-isopropyl-6-methyl-7-oxabicyclo[4.1.0]hept-4-ene	β-Pinene	0.05
36	10.150	4-Vinylphenol	p- vinylphenol	1.34
37	10.373	Bicyclo[4.1.0]hepta-1,3,5-triene,7,7-difluoro-	7,7-Difluoronorbornadiene	0.06
38	10.813	4-(Methoxymethyl)m benzaldehyde	Para-methoxymethyl benzaldehyde	0.20
39	10.894	(5E)-2,6-dimethyl-4-octa-2,5,7-trienone	β - lonone	0.11
40	11.186	Bicyclo[2.2.1]hept-2-ene, 2,3-dimethyl-	β-Pinene	0.33
41	11.290	Ethanone, 1-(2-hydroxy-5-methylphenyl)-	-2-hydro-methylacetophenone	0.05
42	11.336	2-Cyclohexen-1-one, 5,5-dimethyl-3 -(2-methyl-1-propenyl)-	α-lonone	0.06
43	11.489	2-methoxy-4-vinyl-phenol	vinyguaiocol	2.05
44	11.964	Vanillin	vanilline	0.14
45	12.037	Eugenol	caryophyllin	0.08
46	12.132	Ethyl 5-methylhexanoate	ethyl-5-methycaproate	0.13
47	12.237	Butanoic acid, ethyl ester	ethyl linolenate	0.07
48	12.342	Benzaldehyde, 4-hydroxy-	P-hydroxybenzaldehyde	0.42
49	12.460	Decanoic acid, ethyl ester	Ethyl Decanoate	0.53
50	12.636	Benzaldehyde, 3-hydroxy-4-methoxy-	Vanillin	0.97
51	12.910	Caryophyllene	∝-Caryophyllene	0.15
52	13.114	Lauric acid, 2-methylbutyl ester	2-Methylbutyllaurate	0.05
53	13.207	3-Methylplumbagin	Plymagin	0.20
54	13.296	Dimethyl phthalate	Methyl phthalate	0.05
55	13.398	(1R,4R,5S)-1,8-Dimethyl-4-(prop-1- en-2 yl)spiro[4.5]dec-7-ene	B-Pinene	0.40
56	13.642	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	∝-cedrene	0.93
57	13.790	1,3-Cyclohexadiene, 5-(1,5-dimethy l-4-hexenyl)-2-methyl-, [S-(R*,S*)]-	γ-terpinene	0.65
58	14.155	.beta.-Sesquiphellandrene	β-bisabolene	0.74
59	14.637	1,3-Difluoroazulene	guanacastepene Nerolidol	0.46
60	14.853	2-Methyl-6-(p-tolyl)hept-2-en-4-ol	Germacrene-b	1.05
61	14.968	Germacrene-b	Cedrene	0.28

62	15.151	Benzene, 1-(3 cyclopentylpropyl)-,4 dimethyl-	Turmerone	2.67
63	15.321	.beta. tumerone	Curcumen	0.68
64	15.437	aR-Turmerone	β-turmerone	1.46
65	15.531	Curlone	Curcumene	1.84
66	15.975	Tumerone	α-curcumen	12.46
67	16.168	.alpha.-tumerone	bornan-2-one	5.59
68	16.552	Bicyclo[3.1.1]heptan-2-one, 6,6-dimethyl(1R)-	4-hydroxybenzalacetone	0.18
69	16.692	1-(4 Hydroxybenzylidene) acetone	Torreyol	1.23
70	16.768	3-Methyl-6-(6-methylhept-5-en-2-yl)cyclohex-2-enone	Altantone	0.99
71	17.063	(E)-Atlantone 2-	Exo bornyl acrylate	2.25
72	17.306	Propenoic acid, 1,7,7-trimethyl bicycle [2.2.1] hept-2-yl ester,	Feruloylacetone	0.89
73	17.538	3-Buten-2-one, 4-(4-hydroxy-3-methoxyphenyl)-	Ferulic acid methyl ester	2.44
74	17.736	2-Propenoic acid, 3-(4-hydroxy-3-methoxyphenyl)-, methyl ester	fuberidazole	0.77
75	17.810	1,2,5-Oxadiazol-3-amine, 4-[5-(1, methyl-5-pyrazolyl)-1,2,4-oxadiazol-3-yl]-	Acetoxydimethylphenysilane	0.30
76	18.063	8-Acetoxy-3 (dimethylphenylsilanyl)-3-methyl-1,2,3,4-tetrahydrobenzo [a]anthracene-7,12-dione	Benzoyl-p-toluidine	0.39
77	18.200	N-[(Benzoyl)(p-toluidino)-methyl] acetamide	Camphor	0.68
78	18.288	2-Norpinanone, 6,6-dimethyl-	Abietic	0.12
79	18.412	(S)-3-Methyl-6-((S)-6-methyl-4-oxohept-5-en-2-yl)-cyclohex-2-enone	Methylturbeculostearate	0.56
80	18.502	Pentadecanoic acid, 14-methyl-, methyl ester	Orcinol	1.17
81	18.651	6-(3-Hydroxy-4-methylphenyl)-2-methylhept-2-en-4-one	Emodin methyl ester	0.37
82	18.723	11H-Dibenzo[b,e][1,4]dioxepin-7-carboxylic acid, 2-chloro-3,8-dihydroxy-1,4,6,9 tetramethyl-11-oxo-, methyl ester	Palmitic acid	0.33
83	18.915	n-Hexadecanoic acid	α-atlantone	1.22
84	19.041	(+)-alpha.-Atlantone	Ethyl palmitate	0.12
85	19.158	Hexadecanoic acid, ethyl ester	Diacetyl methane	0.40
86	19.296	3-Nonen-5-one	Cyclododecane	1.11
87	19.546	1H-Cyclopentacyclododecene-1,7(4H) -dione, dodecahydro-	Allopurinol	0.30
88	19.705	[1,2,4]Triazolo[1,5-a]pyrimidin-5-ol, 7-methyl-6-nitro-	Henicosanol	0.25
89	19.846	1-Heneicosanol	Grandisol	0.47
90	19.980	Cyclopropanol, 1-(3,7-dimethyl-1-octenyl)-	Methyl oleate	0.19
91	20.183	9-Octadecenoic acid, methyl ester	Nifuroxazide	1.25
92	20.280	Benzoic acid, 4-nitro-, 2-(5,5-dimethyl-3-oxo-		0.17
93	20.398	1-cyclohexen-1-yl)-1-phenylhydrazide Methyl stearate	Methyl octadecanoate Linoleic acid	0.23
94	20.555	9,12-Octadecadienoic acid (Z, Z)-	Ethyl linoleate	1.62
95	20.742	Ethyl (9Z,12Z)-9,12-octadecadienoate	Allopregnane	0.57
96	20.941	14-beta.-H-pregna	Ethyl stearate	8.92
97	20.998	Octadecanoic acid, ethyl ester	Nonacosene	0.15
98	21.958	Z-14-Nonacosene	Methylpyridoxine amidoxime	0.17
99	22.353	4-[(1Z)-(N-Hydroxyethanimidoyl)-2-methylpyridazin-3(2H)-one	Cycloparaffin	0.19
100	23.134	Cyclotriacontane	Cerylene	3.81
101	23.487	1-Hexacosene	Baccharin	0.95
102	24.085	Baccharane	Nonacosene	1.99
103	24.280	Z-14-Nonacosene	Tiamulin	0.54
104	25.184	cis-6-Ethyl-cis-4a,trans-8a-perhydro-trans-1-(2-methoxycarbonylethyl)-trans-2,trans-6,8a-trimethylnaph thalene-2-carboxylic acid	Ergosterol	1.14

105	25.949	Ergost-5-en-3.beta.-ol	Pluchealdehyde B	2.31
106	26.280	Plucheasesquiterpenyl ester [4,8-Dimethyl dodeca-7Z-enyl-9'.alpha.,10'-,alpha.-dihydroxyundecan-1'-oat	Stigmasteryl alcohol	1.25
107	26.617	Stigmasterol	Selenophene	2.28
108	27.535	3-Methylseleno-2-(1,3-dioxolan-2 yl) benzo[b]thiophene	Beta-sitosterol	0.44
109	27.862	(3S,8S,9S,10R,13R,14S,17R)-17-[(1R,3S)-3-ethyl-1,5-dimethyl-hexyl]-0,13dimethyl2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol		2.50

Table 3: Chemical composition of *Curcuma longa* volatile oil by GC-MS analysis

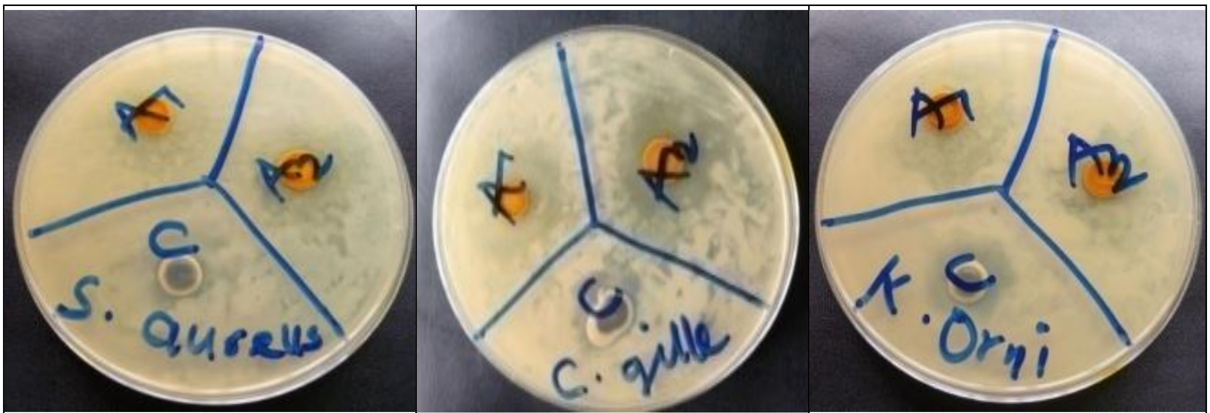
S/N	RETENTION TIME	CHEMICAL COMPONENTS	OTHER NAME	AREA %
1	2.677	Cyclohexane, methyl-	Methylcyclohexane	0.03
2	3.212	Toluene	Methylbenzene	0.69
3	3.603	1,3,5-Cycloheptatriene	Tropylium	0.13
4	4.532	1-Docosene	Docosen-1-en	0.01
5	4.645	Benzene,1,3-dimethyl-	M-Xylene	0.02
6	5.087	Nonane	Nonane	0.02
7	5.550	Bicyclo[3.1.0]hex-2-ene,2-methyl-5-(1 methylethyl)-	Cyclohexene	0.03
8	5.675	(1R)-2,6,6-Trimethylbicyclo [3.1.1] hept-2-ene	Borneol	1.37
9	6.634	beta.-Myrcene	Acyclic Alcohol	0.22
10	6.852	alpha.-phellandrene	Phellandrene	2.65
11	7.586	Bicyclo[3.1.0]hex-2-ene,2-methyl- 5-(1-methylethyl)-	Methylenecyclopentane	3.51
12	7.800	o-Cymene	Isocymene	1.37
13	7.973	.gamma.-Terpinene	M-Mentha-1,4-Diene	2.56
14	8.288	Cyclohexene,1-methyl-4-(1methylethylidene)-	∝-Terpinene	1.11
15	8.459	(+)-4-Carene	3-Carene	4.78
16	9.583	2-Cyclohexen-1-ol,1-methyl-4-(1-methylethyl)-, cis-	Menthol	0.38
17	9.688	Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)-	Menthone	0.67
18	10.007	(3E)-2,7-dimethyl-2-octa-3,6-dieno	Ocimene	3.24
19	11.205	1-Oxaspiro[2.5]oct-5-ene, 8,8-dimethyl-4-methylene-	Limonene Oxide	0.44
20	11.366	Cyclohexene, 4-methyl-1-(1-methylethenyl)-	α -Terpinene	0.25
21	11.468	1H-Inden-1-one, 3a,4,5,6,7,7a-hexahydro-3a-methyl-, cis-	Caryophyllene	0.93
22	11.950	Carvacrol	Cymophenol	0.35
23	12.069	Tricyclo[3.3.1.13,7]decane, 2-methyl	Camphane	0.33
24	12.372	p-Cymen-7-ol	Carvacrol	0.44
25	12.440	Benzenemethanol, 4-(1-methylethyl)	P-Menthanol	0.19
26	13.810	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	Para-Caryphyllene	10.01
27	14.470	1H-3a,7-Methanoazulene, 2,3,4,7,8,8a-hexahydro-3,6,8,8-Tetramethyl, 3R(3.alpha.,3a.beta.,7.beta.,8a.alpha.)]-	Longifolene Alpha-Cadinol	9.41
28	15.685	2-epi-.alpha.-Funebrene	Isocyclogeraniol	2.30
29	15.795	3-Cyclohexene-1-ethanol, .alpha.-ethenyl-.alpha.,3-dimethyl-6-(methylethylidene)-	α -Pinene	0.54
30	15.862	(1S,5S)-2-Methyl-5-((R)-6-methylhept-5-en-2-yl)bicyclo[3.1.0]hex-2-ene	Turmerone	0.45
31	16.864	aR-Turmerone	Curcumene	19.73
32	17.622	Turmerone	Carvacrol	7.29
33	18.397	Curlone	A-Selinene	1.63
34	18.586			1.84

		(R)-1-Methyl-4-(6-methylhept-5-en-2-yl)cyclohexa-	Altantone	
35	18.784	1,4-diene	Decahydroadamantane	2.54
36	18.936	(Z)-.alpha.-Atlantone	Naphthol	0.77
37	19.039	Adamantane	Cedrol	0.87
38	19.112	(8-amino-1-naphthyl)-phenyl-amine		1.33
		(3aR,8aR,9aR)-8a-methyl-3,5dimethylene		
		3a,4,4a,6,7,8,9,9aoctahydrobenzo[f]benzofuran-2-	Nopyl Acetate	
39	19.246	one	Diethyl Ketone	0.82
40	19.357	Tricyclo[5.2.1.0(2,6)]decan-3-one	Guaiol	0.81
41	19.417	3- Nonen-5-one		0.53
		(S)-3-Methyl-6-((S)-6-methyl-4-oxohept-5-en-2-	P-Hydroxybenzyl	
42	19.477	yl)cyclohex-2-enone	AcetoneSulfolane	0.48
43	19.568	2-Butanone,4-(4-hydroxyphenyl)-	Pralmorelin	1.90
44	19.794	Dicyclohexyl sulfone	Undecyl Chloro Acetate	0.71
45	20.014	3-Pentyl-4,5,6,7-tetrahydro-1H-indazole	Cyclohexyl Bromo Acetate	2.07
46	20.210	Chloroacetic acid, undecyl ester	Senecioic Acid	0.36
47	20.308	2-Bromopropionic acid, cyclohexyl ester		0.44
		3-Methyl-2-butenoic acid, 2-methyloct-5-yn-4-yl	4,4Diflouro-	
48	20.390	ester	Diphenylmethanol	0.26
49	20.481	4,4'-Difluorobenzhydrol	Ethylmethylheptynol	0.33
50	20.555	3-Ethyl-5-methyl-1-heptyn-3-	Dieldrin	0.48
51	20.680	2Nonadecanone	Linoleic Acid	0.35
52	20.807	Aldrin-transdiol	Dieldrin	0.23
53	20.912	9,12-Octadecadienoic acid (Z,Z)-	Heliitropin	0.21
54	21.060	Coronarin A		0.30
		3-Penten-2-one,1-[5-(3-furanyl)tetrahydro-2-methyl-	α -Altantone	
55	21.165	2-furanyl]-4-methyl-	β-Altantone	0.03
56	21.235	(+)-.alpha.-Atlantone	γ-Altantone	1.I6
57	21.378	(E)-.gamma.-Atlantone	Cis- α -Altantone	0.04
58	21.553	(Z)-.gamma.-Atlantone	Cyclohexytrichlorosilane	2.54
59	21.622	(Z)-.alpha.-Atlantone	Dicyclohexyl Phthalate	0.05
60	21.727	Trichloro(cyclohexylmethyl)silane	Dodecylmethylether	0.07
61	21.905	Borinic acid, diethyl-, 1-cyclododecen-1-yl ester	Pulegol	0.18
62	22.057	1-Docosanol, methyl ether	azadirachin	0.04
63	22.118	Pulicanol		0.05
		2-Butenoic acid, 2-methyl-,		
		2(acetyloxy)1,1a,2,3,4,6,7,10,11,11a-decahydr$_o$-		
		7,10-dihydroxy-1,1,3,6,9-pentamethyl-4a,7a-epoxy-		
		5Hcyclopenta[a]cyclopropa[f]cycloundecen-11-yl		
		ester, [1aR[1aR*,2R*,3S*,4aR*,6S*,7S*,7aS*	β-Terpinol	
64	22.201	,8E,10R*,11R*(E),11aS*]]		0.03
		Cyclohexanol, 2-methyl-3-(1-methylethenyl)	Dibutyl,Cyclohexaneactanoa	
65	22.448	(1.alpha.,2.alpha.,3.alpha.)-	te	0.11
		Cyclohexaneoctanoic acid, 2-butyl-, methyl ester	Oleamide	
66	22.531		Metroindazole Benzoate	0.12
67	22.880	9-Octadecenamide,(Z)-		0.08
		(3-Methylbenzoyl)carbamic acid, (5-methyl- 2-	Indomethacin	
68	23.029	nitroimidazol-1-yl) ethyl ester		0.10
		2H-Isoindole-2-carboxylic acid, 1.3-dihydro-1,3-	Propineb	
69	23.174	dioxo-, ethyl ester		0.10
		(E)-Ethyl-3-{4-methyl-2-	A-Longipinene	
70	23.423	(methylcarbamoyl)phenyl}acrylate	Allethrin	0.12
71	23.549	.alpha.-Longipinene		0.15
		1-Butyl-3-(1-methylethenyl)-1-methoxy-2	α-Pinene	
72	23.666	methylcyclopropane		0.17
		3-Oxabicyclo[5.1.0]octane, 5,5-dimethyl-4-(3-		
		methyl-3-	Bromalol	
73	23.795	butenylidene)-2-methylene-, cis-(.+-.)-	Cyclohexyltrichlorosilane	0.29
74	23.990	3-Bromo-5,5-dimethyl-cyclohex-2-enol	Tolan	0.35
75	24.241	Silane, trichlorocyclohexyl-	Acridine Orange	0.30

76	24.368	2-(Phenylethynyl)benzonitrile	Metronidazole	0.09
77	24.650	4-(9-Acridinyl)-N,N-dimethylbenzen amine		0.10
		(3-Methylbenzoyl)carbamic acid,	Bromochamigrene	
78	24.770	2-(5-methyl- 2 nitroimidazol-1-yl)ethyl ester		0.16
		(1Z, 8R*, 9R*)-8-Bromo-Chamigra-1,11(12)-dien-9-	α -Pinene Oxide	
79	24.956	ol		0.11
		Cyclopropa[1,2:1,3]dicyclopenten-3(3ah)-one,	α -Terpinol	
80	25.026	1,2,3b,6-tetrahydro-3a,6,6-trimethyl-		0.06
		Cyclohexanol,2-methyl-3-(1-methyl ethenyl).	Tosylmethionone	
81	25.187	(1.alpha.,2.alpha.,3.alpha.)-	Permethminic Acid	0.09
82	25.291	(1R,2S,5R)-(-)-Menthyl(S)-p-tolue Nesulfinate	Benzenidazole	0.08
83	25.595	Cyclopropanol,1-(3,7-dimethyl-1-octenyl)-		0.45
		(3-Methylbenzoyl)carbamic acid, 2-(5-methyl- 2-	Azadirachtin	
84	25.841	nitroimidazol-1-yl)ethyl ester		0.13
		2-Oxabicyclo[2.2.1]heptane-1-carboxylic acid, 4,7,7-trimethyl-3-oxo-,3-(5-ethoxy-3-methyl-5-oxo-1,3-pentadienyl)-2,4,4trimethyl-2-cyclohexen-1-yl,ester, [1S[1.alpha.[R*(1E,3E)],4.beta]]-		

Table 4: The predominant value of turmeric volatile oil, methanol and n-hexane extract

S/N	Name of Compounds	Other Name	N-Hexane Extract	Methanol Extract	Volatile Oil
1	Turmerone	Curcumene	13.39	12.46	7.29
2	Ar-Turmerone	2-methylhept-2-en-4-one	2.24	1.46	19.01
3	+-alpha altantone	Altantone	3.14	5.59	0.30
4	9,12-octadecadienoic acid (Z,Z)	Linoleic acid	2.47	1.67	0.35
5	Curlone	Curcumen	1.38	1.84	1.63
6	2-epi-alpha-funebrene	Alpha-cadinol	4.04	------	2.30
7	14-beta-H-pregna	Allopregnanolone	9.05	8.72	-----
8	n-hexadecanoic acid	Palmitic acid	0.81	1.20	-----
9	Toluene	Methylbenzene	1.48	------	0.69
10	Benzene 1(1,5 dimethyl-4-hexenyl)-4-methyl	β-terpinene	2.49	------	10.01



Staphylococcus aureus | *Citrobacter gillenii* | *Klebsiella ornithinolytica*

Figure 3: The sensitivity testing results of turmeric rhizome against *Staphylococcus aureus, Citrobacter gillenii,* and *Klebsiella ornithinolytica*

Antibacterial sensitivity test

The AST results of turmeric volatile oil and extracts against some selected bacterial species (Figure 3) showed that turmeric n-hexane extract had the highest zone of inhibition (28±1.03 mm) against *C. gillenii* followed by *K. ornithinolytica* (26±1.63 mm), and *S. aureus* (25±0.33 mm) while there were no noticeable inhibitory zones of clearance against *Streptococcus* sp*, E. coli,* and *Enterobacter agglomerans* (Table 5). Turmeric methanol extract had the highest zone of inhibition (22±2.01 mm) against *K. ornithinolytica* followed by *S. aureus* (20.5±0.65 mm), and least zone of inhibition with *C. gillenii* (12.5±1.66 mm) while there were no inhibitory zones of clearance against *Streptococcus sp, E. coli,* and *Enterobacter agglomerans* (Table 5). Similarly, turmeric volatile oil had the highest zone of inhibition (23±00 mm) against *C. gillenii* followed by *K. ornithinolytica* (20.5±0.11 mm), and *S. aureus* (17±0.50 mm) while there were no inhibitory zones of clearance against *Streptococcus* sp*, E. coli,* and *Enterobacter agglomerans* (Table 5).

Table 5: Antibacterial sensitivity test of turmeric volatile oil and extracts against some selected bacterial species

S/N	Organism	Turmeric n-Hexane Extract (mm)	Turmeric Methanol Extract (mm)	Turmeric Volatile Oil (mm)
1	*Streptococcus* sp.	0 ± 00	0 ± 00	0 ± 00
2	*Staphylococcus aureus*	25 ± 0.33	20.5 ± 0.65	17 ± 0.50
3	*Escherichia coli*	0 ± 00	0 ± 00	0 ± 00
4	*Enterobacter agglomerans*	0 ± 00	0 ± 00	0 ± 00
5	*Klebsiella ornithinolytica*	26 ± 1.63	22 ± 2.01	20.5 ± 0.11
6	*Citrobacter gillenii*	28 ± 1.03	12.5 ± 1.66	23 ± 00

Keys: Zone diameter ≥ 20 mm = Sensitive; Zone diameter 15-19 mm = Intermediate, Zone diameter ≤ 14 mm = Resistance

Minimum inhibitory concentrations of turmeric extracts and volatile oil against bacterial species

Tables 6, 7 and 8 show the MIC of turmeric n-hexane extract, methanol extract, and volatile oil against *K. ornithinolytica*, *C. gillenii,* and *S. aureus*. Turmeric n-hexane extract, turmeric methanolic extract, and turmeric volatile oil had MIC of 25, 25, and 6.25 mg/ml, respectively against *K. ornithinolytica.* Turmeric n-hexane extract and turmeric volatile oil had MIC of 50 and 12.5 mg/ml, respectively against *C. gillenii* while both turmeric n-hexane extract and turmeric volatile oil had MIC of 25 mg/ml against *S. aureus*.

Table 6: Minimum inhibitory c**oncentration for *Klebsiella ornithinolytica***

Concentration	**100 (mg/ml)**	**50 (mg/ml)**	**25 (mg/ml)**	**12.5 (mg/ml)**	**6.25 (mg/ml)**
Turmeric n-hexane extract	+	+	+	-	-
Turmeric methanol extract	+	+	+	-	-
Turmerc volatile oil	+	+	+	+	+

Keys: + = Sensitive, - = Resistance

Table 7: Minimum inhibitory concentration for *Citrobacter gillenii*

Concentration	**100 (mg/ml)**	**50 (mg/ml)**	**25 (mg/ml)**	**12.5 (mg/ml)**	**6.25 (mg/ml)**
Turmeric n-hexane extract	+	+	-	-	-
Turmeric volatile oil	+	+	+	+	-

Keys: + = Sensitive, - = Resistance

Table 8: Minimum inhibitory concentration for *Staphylococcus aureus*

Concentration	**100 (mg/ml)**	**50 (mg/ml)**	**25 (mg/ml)**	**12.5 (mg/ml)**	**6.25 (mg/ml)**
Turmeric n-hexane extract	+	+	+	-	-
Turmeric methanol extract	+	+	+	-	-

Keys: + = Sensitive, - = Resistance

Discussion

The finding revealed the results of the GC-MS analysis of the turmeric rhizome harvested in Ekiti-State, Nigeria. The main constituent of turmeric n-hexane were turmerone (13.39 %) followed by 14-beta-H-pregna (9.05%) while methanol extracts contained turmerone (12.46%)

and 14-beta-H-pregna (8.72%). According to Singh *et al.* confirmed that ar-turmerone is the major constituent of turmeric rhizome oil from different origins (Singh *et al*, 2011). Turmeric volatile oil composed of ar-turmerone (19.01%), cedr-8-ene (10.13%) and Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl- (10.01%) as predominant compounds. Many constituents were presents in moderate quantities such as tumerone (7.29%), (+)-4-Carene (4.74) etc. The value obtained is lower than the value obtained by Chowdhury *et al* for ar-turmerone (27.78%), turmerone (17.16%) and curlone (13.82%) (Chowdhury *et al*, 2008) and the value obtained by Awasthi *et al*, (2009) for ar turmerone (31.7). Turmerone and ar-turmerone were responsible for turmeric aroma and smell (Li *et al*, 2022). Many studies have showed that turmerone helps to protect the brain from degenerative diseases such as Alzheimer's (Goozee *et al*, 2016). The chemical structure of turmeric provides a flexibility to interact and inhibit the protein synthesis of bacteria. The difference in chemical composition and concentration of turmeric may be based on the method used for extraction, plant species, age of plant and geographical location (Dosoky *et al*, 2019)

In vitro antibacterial activity of turmeric volatile oil and extracts against the six organisms was revealed in this study. Turmeric volatile oil is very effective against the growth of Gram positive and Gram negative bacteria. The results showed effectiveness of antimicrobial properties against *S. aureus, K. ornithinolytica* and *C. gilleni*. The extracts were very effective against *S. aureus* that can cause infections like meningitis, skin problems, pneumonia, bacteremia, pleuropulmonary infections and urinary tract infection (Negi *et al,* 2015) This result is consistent with those reported by Gupta and Odo (Gupta *et al,* 2015; Odo *et al,* 2023).

The MIC results showed that turmeric n-hexane and methanol extracts were able to inhibit the growth of *K. ornithinolytica* at a concentration of 25 mg/ml, but more sensitive to turmeric volatile oil at MIC of 6.25 mg/ml. This suggested that the strongest inhibitory effect of the turmeric volatile oil might be due to the higher concentrations of monoterpenoids (turmerone and ar-turmerone) present in the sample analysed. *Citrobactor gillenii* showed MIC 50 mg/ml for n-hexane and showed better activity up to 12.5 mg/ml concentration of the turmeric volatile oil. This agrees with the study of Oklo *et al* who observed MIC value of 12.5 mg/ml (Oklo *et al*, 2023)

Turmeric n-hexane and methanol extracts MIC was 25 mg/ml against *S. aureus*. This study corroborates the result of Gupta *et al.* who reported that various fractions of *C. longa* rhizome extract showed antibacterial activity against *S. aureus* (ATCC 6571) and clinical bacterium showed zone of inhibition that ranged between 9 mm and 21 mm (Gupta *et al*, 2015). In all, turmeric volatile oil had the highest MIC values of the entire tested organism and strongest antimicrobial activity was observed against *K. ornithinolytica.*

Conclusion This study revealed that the antibacterial activity of turmeric volatile oil and extracts. The composition of their bioactive compounds has been noted to depend on some factors such as geographic origin, post harvesting, and chemo-type. As it is commonly found, Gram negative bacteria were more susceptible to the volatile oil while the extracts had more effects on Gram positive bacteria. In general, these results are in accordance with those reported for this essential oil which is attributed to the presence of turmerones, bioactive compounds responsible for showing antimicrobial activity against clinical bacterial species. Based on our findings, turmeric rhizome can be effectively used as antimicrobial agents against both Gram-positive and Gram-negative bacteria (*S. aureus, K. ornithinolytica,* and *C. gillenii*). Therefore, this study recommends more studies on the exploration of turmeric rhizome as a source of bioactive compounds for the control of bacterial infection.

Abbreviation

GC-MS	Gas Chromatography-Mass Spectrometry
MIC	Minimum Inhibitory Concentrations
NA	Nutrient Agar
MHA	Mueller Hinton Agar
AST	Antibacterial Sensitivity Test

Funding

None.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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