GC-MS analysis of bioactive compounds and antimicrobial potential of the essential oil of *Cymbopogon citratus* (DC.) Stapf

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Abstract
Cymbopogon citratus (DC) Stapf. commonly known as lemongrass belongs to the family Poaceae which counts more than 635 genera and 9000 species. This herb plant is widely distributed around the world. Lemongrass is used as food flavouring and can be dried and powdered or used fresh. It is commonly used in teas, soups and curries, it may also be served with poultry, fish beef and seafood. This plant has been highly valued in the pharmaceutical, aromatic, fragrance and food industries due to the high content of essential oil in its leaves. In this present study, essential oil of the leaves of C. citratus by GC-MS analysis clearly showed the presence of 33 compounds.

In addition, the antimicrobial activities of the essential oil were evaluated by disk diffusion method against selected human pathogenic organisms. The results showed a strong antimicrobial activity against all the tested microorganisms.

Keywords: GC-MS analysis, Essential oil, Antimicrobial, Disk diffusion, Ampicillin.

Introduction

Medicinal plants which form the backbone of traditional medicine, have been the subject of very intense pharmacological studies in the last few decades. This has been brought about by the acknowledgement of the value of medicinal plant as potential source of new compounds of therapeutic value and as source of new compounds in drug development. In many parts of the world, medicinal plants are used for antibacterial, antifungal and antiviral activities. Plant derived drugs serve as a prototype to develop more affective and loss toxic medicines[1].

Essential oils are important secondary metabolites of various medicinal and aromatic plants grown in tropical and subtropical countries. They can be obtained from various parts of the plants like leaves, stem, bark and flowers by hydrodistillation, solvent extraction, cold pressing and supercritical fluid extraction[2]. Essential oils are important natural products used for their flavour and fragrances in food, pharmaceutical and perfumery industries. They are also sources of aroma chemicals, particularly of enantiomers that are useful as chiral building blocks in syntheses. Biological and pharmacological activities of essential oils and their constituents have been gathering momentum in recent years. Essential oils therefore will continue to be indispensable natural ingredients[3].

Cymbopogon citratus (DC) Stapf. commonly known as lemongrass belongs to the family Poaceae which counts more than 635 genera and 9000 species. This herb plant is widely distributed around the world[4]. Lemongrass is used as food flavouring and can be dried and powdered or used fresh. It is commonly used in teas, soups and curries, it may also be served with poultry, fish beef and seafood[5,6]. This plant has been highly valued in the pharmaceutical, aromatic, fragrance and food industries due to the high content of essential oil in its leaves. The major components of essential oil obtained from lemon grass are the neral, citral and geranial along with other components that are found in lower amounts. These major components show sedative, diuretic, analgesic, vermicide, insecticide, larvicide and anti-microbial effects[7,8].

Natural essential oils are more environmentally friendly than synthetic products due to biodegradation and environmental safety issues[9,10]. *C. citratus* is being used for treatment of nervous and gastrointestinal disturbances and as an antispasmodic, analgesic, anti-inflammatory, antipyretic, diuretic and sedative[11]. In this connection, the present study aimed to report the detailed GC-MS analysis of Bioactive Compounds and Antimicrobial Potential of the Essential Oil of *Cymbopogon citratus* (DC.) Stapf.

Material and Methods

Collection of plant materials: The fresh leaves of *Cymbopogon citratus* were collected from Grizzled squirrel wildlife sanctuary, Senbaghathoopu, Srivillipudhur, Tamil Nadu, India. The collected specimens were properly identified with the standard literature and authenticated with valid voucher specimens. The voucher specimens were deposited in the herbarium of Department of Botany, SKC.

Extraction of essential oil: A total of 250g of fresh leaves of *C. citratus* and 2500ml of water were subjected into Clevenger type apparatus by using hydro-distillation for about 2-3 hrs at 60^0C[12,13]. The essential oils were extracted, then the oils were collected separately and dehydrated over anhydrous sodium sulfate and stored in airtight vials at 4°C for further study.

GC-MS analysis of Bioactive Compounds: GC-MS analysis of extracted essential oils was performed by using Shimadzu GC-MS QP2010 Ultra model and Gas Chromatograph interfaced to a mass spectrometer (GC-MS) equipped with a Rxi-5Sil MS, fused silica capillary column (30 ml × 0.25 mm ID × 1× df, composed of 100% Dimethyl polysiloxane1,4- bis(dimethylsiloxy) phenylene dimethyl polysiloxane). For GC/MS detection, an electron ionization system with an ionizing energy of 70 eV was used. Helium gas (99.999%) was used as the carrier gas at constant flow rate 1 ml/min and an injection volume of 1 µl was employed at (Split ratio of 50:1) injector temperature 250°C and ion source temperature 280°C.

The oven temperature was programmed from 100°C (isothermal for 2 min) with an increase of 5°C/min to 200°C, then 10°C/min to 280°C, ending with a 2 min isothermal at 280°C. Mass spectra were taken at 70eV; a scan interval of 0.3 seconds and fragments from 40 to 800 Da, total GC running time was 32 minutes and the software adopted to handle mass spectra and chromatograms was Lab Solutions.

Identification of Bioactive components: The identity of the components in the extracts was assigned by the comparison of their retention indices and mass spectra fragmentation patterns with those stored on the computer library and also with published literatures. NIST08s.LIB, WILEY8. LIB library sources were used for matching the identified components from the essential oil.

Determination of antimicrobial activities

Disk diffusion method: The antimicrobial activity test was carried out on essential oils of *C. citratus* using the disk diffusion method against selected human pathogenic organisms. Nutrient agar (NA) plates were spread with the help of L-rod inside the laminar air flow chamber with 8 hours old broth culture of respective bacteria and fungi.

The 6 mm diameter discs were prepared with Whatmann no. 1 paper among these different concentration (50µg/ml, 100µg/ml and 150µg/ml) of the essential oil of *C.citratus*. Standard antibiotic ampicillin (10 mcg) was selected to serve as positive control and the plates were incubated at 37°C for 18-24 h for bacterial pathogens and 28°C for 48 hours for fungal pathogens. The diameter of the inhibition zone (mm) was measured by zone scale and the activity index was also calculated for triplicate of each experiment.

Results and Discussion

GC-MS analysis of Bioactive Compounds: Medicinal plant possess many bioactive compounds including phenolic and polyphenolic compounds which play key function in detoxification of stress induced by free radicals and exhibit antimicrobial activities[14]. Many studies have been undertaken with the aim of determining the antimicrobial and phytochemical constituents of medicinal plants and using them for the treatment of both topical and systemic microbial infections as possible alternatives to chemical synthetic drugs to which many infectious microorganisms have become resistant[15].

This present study focused on the detailed GC-MS analysis of Bioactive Compounds and Antimicrobial Potential of the essential oil of *Cymbopogon citratus* (DC.) Stapf. The GC-MS identification of the bioactive compounds was based on comparison of their mass spectra with NIST and WILEY libraries. The identification of the chemical compounds was confirmed based on the peak area, retention time, molecular formula, molecular weight of the compounds and structure. Essential oil of the leaves of *C.citratus* by GC-MS analysis clearly showed the presence of 33 compounds. In GC-MS analysis, *C.citratus* showed 03 major and 20 minor compounds.

In a previous study, Joachin et al[16] reported that 16 chemical constituents were identified in *C. citratus* among which geranial (27.04 %), neral (19.93 %) and myrcene (27.04 %) were the major constituents. Compared to the previous report, the present study clearly showed 33 compounds in essential oil of the leaves of *C.citratus*. The active principles with their retention time (RT), molecular formula, molecular weight of the compounds, structure and peak area as in percentage are presented in figure 1 and table 1.

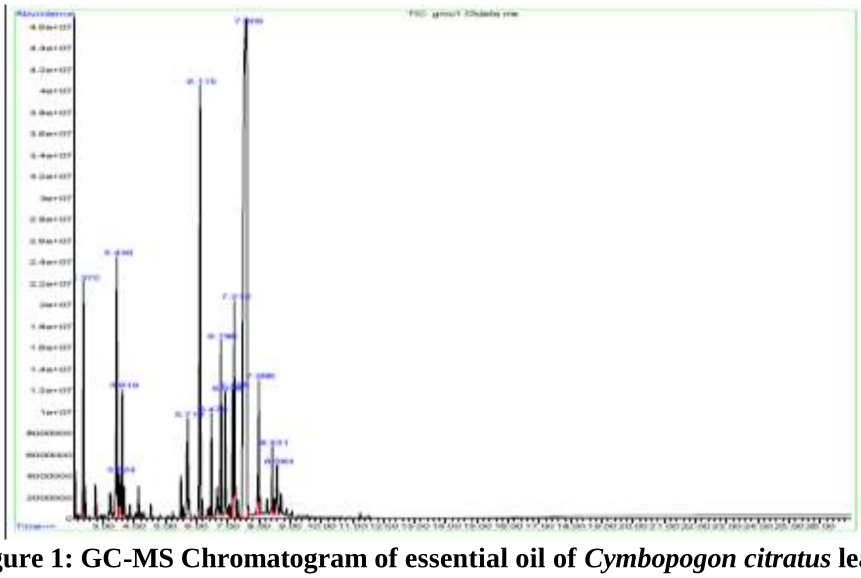
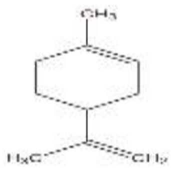
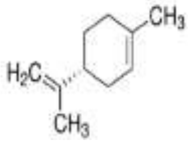
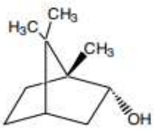
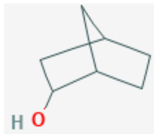
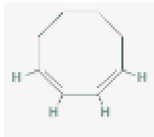
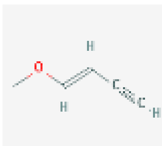
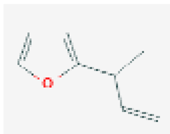
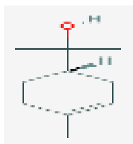
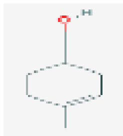
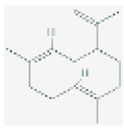
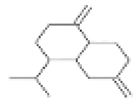
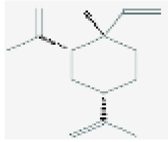
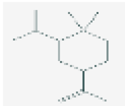
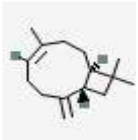
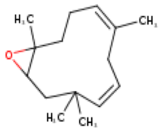
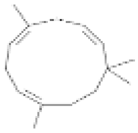
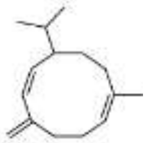
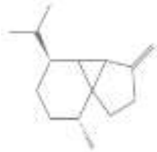
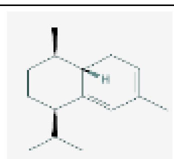
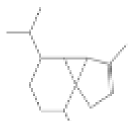
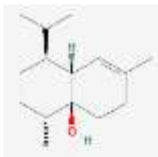
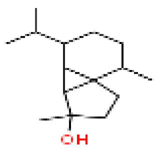
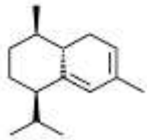
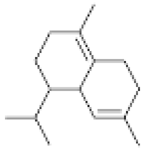
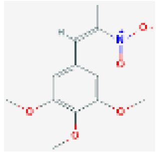
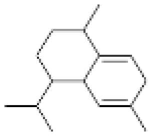
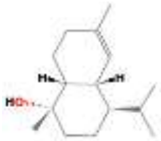
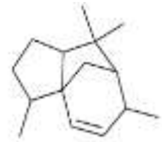
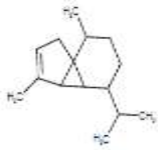
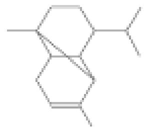
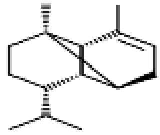


Figure 1: GC-MS Chromatogram of essential oil of *Cymbopogon citratus* leaves

Table 1
Bioactive compounds identified from essential oil of *Cymbopogon citratus* leaves

S.N.	RT	Name of the Compound	MW g/mol	MF	Structure	Area %
1	2.370	D-Limonene	136.23	C_{10} H_{16}		4.73
2	2.370	Limonene	136.23	$C_{10}H_{16}$		4.73
3	3.439	1,7,7Trimethylbicyclo[2.2.1]heptan-2-ol	154.25	$C_{10}H_{18}O$		6.75
4	3.439	Endo-borneol	154.25	$C_{10}H_{18}O$		6.75
5	3.439	Bicyclo[2.2.1]heptan-2-ol.1.7-trimethyl-(1S-endo)	154.24	$C_{10}H_{18}O$		6.75
6	3.524	1,3-Cyclooctadiene,(z,z)	108.18	C_8H_{12}		1.49
7	3.524	1-octen-3-yne	52.07	C_4H_4		1.49
8	3.524	Furan,2-(2-propenyl)	122.16	$C_8H_{10}O$		1.49
9	3.619	L-alpha.-Terpineol	154.25	$C_{10}H_{18}O$		2.06
10	3.619	.alpha.-Terpineol	154.25	$C_{10}H_{18}O$		2.06
11	5.718	8-Isopropenyl-1,5-dimethyl-cyclodeca-1,5-diene	204.35	$C_{15}H_{24}$		3.90

12	5.718	Naphthalene,decahydro-1,6-bis(methylene)-4-(1-methylethyl),(4,alpha.,4a.alpha.,8a.alpha.)-	204.35	$C_{15}H_{24}$		3.90
13	5.718	Cyclohexane,1-ethenyl-1-methyl-2,4-bis(1 methylethenyl)-,[1S-(1.alpha.,2.beta.,4.beta.)]-	204.35	$C_{15}H_{24}$		3.90
14	6.115	Caryophyllene	204.35	$C_{15}H_{24}$		11.24
15	6.115	Bicyclo[7.2.0]undec-4 ene,4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]-	204.35	$C_{15}H_{24}$		11.24
16	6.474	Humulene	204.35	$C_{15}H_{24}$		1.79
17	6.474	1,4,7,cycloundecatriene,1,5,9,-tetramrthyl-Z,Z,Z-	204.35	$C_{15}H_{24}$		1.79
18	6.789	1,6-Cyclodecadiene,1-methyl-5-methylene-8-(1-methylethyl)-,[S-(E,E)]-	204.35	$C_{15}H_{24}$		3.60
19	6.789	1HCyclopenta[1,3]cyclopropa[1,2]benzene,octahydro-7-methyl-3-methylene-4-(1-methylethyl)-,[3aS-(3a.al)]	204.35	$C_{15}H_{24}$		3.60
20	6.918	Cis-muurola-3,5-diene	204.35	$C_{15}H_{24}$		2.71
21	6.918	.alpha,-Cubebene	204.35	$C_{15}H_{24}$		2.71
22	7.155	4-epi-cubedol	222.37	$C_{15}H_{26}O$		2.76
23	7.155	Cubedol	222.37	$C_{15}H_{26}$		2.76

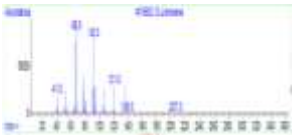
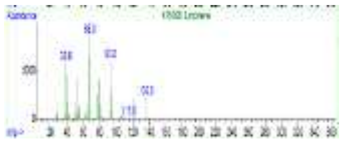
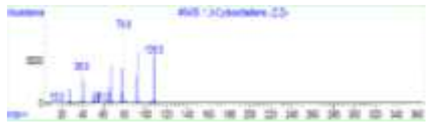
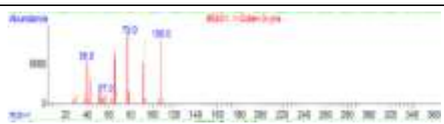
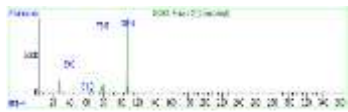
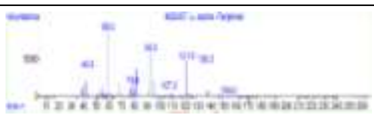
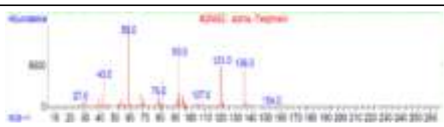
24	7.155	Cis-muurola-3,5-diene	204.35	$C_{15}H_{24}$		2.76
25	7.212	Naphthalene,1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl),(1S-cis)-	204.35	$C_{15}H_{24}$		4.65
26	7.609	Benzene,1,2,3-trimethoxy-5-(2-propenyl)-	253.25	$C_{12}H_{15}NO_5$		48.00
27	7.996	Caryophyllene oxide	220.35	$C_{15}H_{24}O$		3.23
28	8.431	Naphthalene,1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)-	204.35	$C_{15}H_{24}$		1.49
29	8.431	1Naphthalenol,1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-,[1S-(1.alpha.,4.alpha.,4a.beta.,)]	222.36	$C_{15}H_{26}O$		1.49
30	8.431	Di-epi-.alpha.-cedrene-(I)	204.35	$C_{15}H_{24}$		1.49
31	8.583	.alpha.-cubebene	204.35	$C_{15}H_{24}$		1.62
32	8.583	.alpha.-copaene	204.35	$C_{15}\ H_{24}$		1.62
33	8.583	Copaene	204.35	$C_{15}H_{24}$		1.62

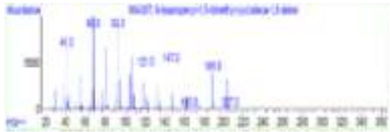
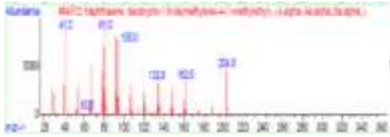
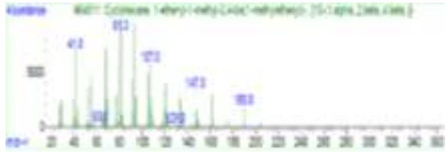
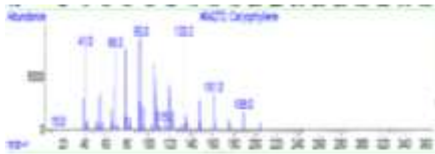
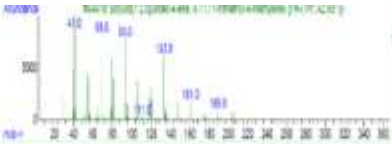
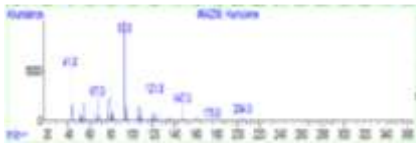
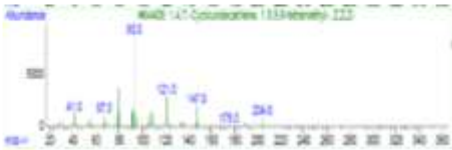
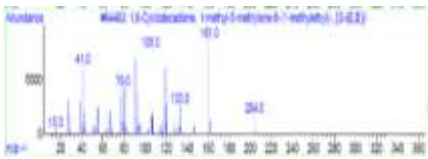
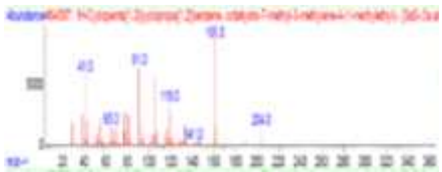
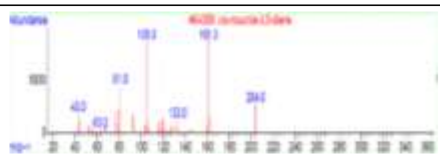
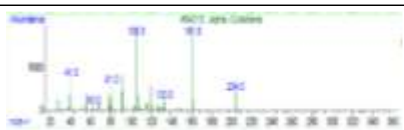
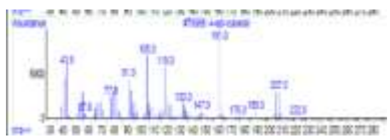
Previously Josphat et al[17] reported that the essential oil of *C. citratus* was dominated by monoterpene hydrocarbons which accounted for 94.25% of the total oil and was characterized by a high percentage of geranial (39.53%), neral (33.31%) and myrecene (11.41%). The present results revealed that benzene,1,2,3-trimethoxy-5-(2-propenyl)- (48%); caryophyllene (11.24%) and bicyclo[7.2.0]undec-4 ene,4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]- (11.24%) were reported as 3 major compounds in the essential oil of the leaves of *C.citratus*.

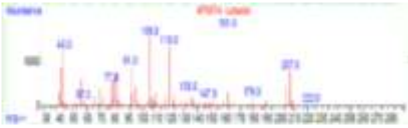
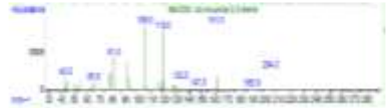
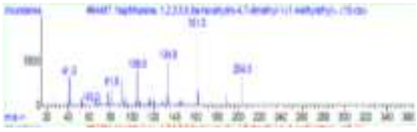
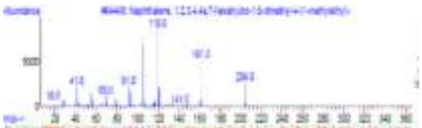
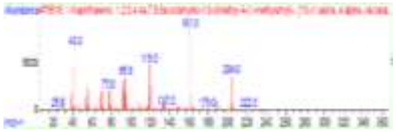
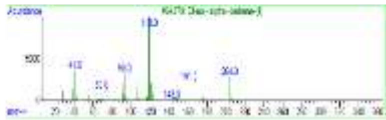
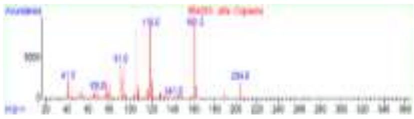
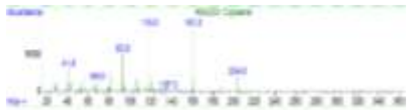
30 minor compounds such as 1,7,7 Trimethylbicyclo [2.2.1]heptan-2-ol (6.75%); Endo-borneol (6.75%); Bicyclo [2.2.1] heptan-2-ol.1.7-trimethyl -(1S-endo) (6.75%); D-

Limonene (4.73%); Limonene (4.73%); Naphthalene,1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl),(1S-cis)- (4.65%); 8-Isopropenyl-1,5-dimethyl- cyclodeca-1,5-diene (3.90%); Naphthalene, decahydro-1,6-bis (methylene)-4- (1 methylethyl), (4,alpha., 4a.alpha., 8a.alpha.)- (3.90%); Cyclohexane,1-ethenyl-1-methyl-2,4-bis(1 methylethenyl)-, [1S-(1.alpha., 2.beta., 4.beta.)]- (3.90%); 1,6-Cyclodecadiene, 1-methyl-5-methylene-8- (1-methylethyl)-, [S-(E,E)]- (3.60%); 1HCyclopenta [1,3]cyclopropa [1,2] benzene,octahydro-7-methyl-3-methylene-4-(1-methylethyl)-,[3aS-(3a.al)] (3.60%); Caryophyllene oxide (3.23%); Cis-muurola-3,5-diene (2.71%); .alpha,-Cubebene (2.71%); 4-epi-cubedol (2.76%); Cubedol (2.76%); Cis-muurola-3,5-diene (2.76%); L-alpha.-Terpineol (2.06%); .alpha.-Terpineol (2.06%); Humulene (1.79%); 1,4,7, cycloundecatriene,1,5,9,-tetramrthyl-Z,Z,Z- (1.79%); .alpha.-cubebene (1.62%); .alpha.-copaene (1.62%); Copaene (1.62%); 1,3-Cyclooctadiene,(z,z) (1.49%); 1-octen-3-yne (1.49%); Furan,2- (2-propenyl) (1.49%); Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4- (1-methylethyl)- (1.49%); 1Naphthalenol, 1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-, [1S-(1.alpha., 4.alpha., 4a.beta.,)] (1.49%) and Di-epi-.alpha.-cedrene-(I) (1.49%) were also reported from essential oil leaves of *C.citratus*. The bioactive compounds with their mass spectrums are presented in table 2.

Table 2
GC-MS analysis of bioactive compounds and mass spectrum of essential oil of *Cymbopogon citratus* leaves

S.N.	Name of the compound	Mass Spectrum
1	D-Limonene	
2	Limonene	
3	1,7,7-Trimethylbicyclo[2.2.1]heptan-2-ol	
4	Endo-borneol	
5	Bicyclo[2.2.1]heptan-2-ol.1.7-trimethyl-(1S-endo)	
6	1,3-Cyclooctadiene,(z,z)	
7	1-octen-3-yne	
8	Furan,2-(2-propenyl)	
9	L-alpha.-Terpineol	
10	.alpha.-Terpineol	

11	8-Isopropenyl-1,5-dimethyl-cyclodeca-1,5-diene	
12	Naphthalene,decahydro-1,6-bis(methylene)-4-(1-methylethyl)-,(4,alpha.,4a.alpha.,8a.alpha.)-	
13	Cyclohexane,1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-,[1S-(1.alpha.,2.beta.,4.beta.)]-	
14	Caryophyllene	
15	Bicyclo[7.2.0]undec-4-ene,4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]-	
16	Humulene	
17	1,4,7,-cycloundecatriene,1,5,9,-tetramrthyl-Z,Z,Z-	
18	1,6-Cyclodecadiene,1-methyl-5-methylene-8-(1-methylethyl)-,[S-(E,E)]-	
19	1H Cyclopenta [1,3] cyclopropa [1,2] benzene,octahydro-7-methyl-3-methylene-4-(1-methylethyl)-,[3aS-(3a.al)]	
20	Cis-muurola-3,5-diene	
21	.alpha,-Cubebene	
22	4-epi-cubedol	

23	Cubedol	
24	Cis-muurola-3,5-diene	
25	Naphthalene,1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl),(1S-cis)-	
26	Benzene,1,2,3-trimethoxy-5-(2-propenyl)-	
27	Caryophyllene oxide	
28	Naphthalene,1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)-	
29	1-Naphthalenol,1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-,[1S-(1.alpha.,4.alpha.,4a.beta.,)]	
30	Di-epi-.alpha.-cedrene-(I)	
31	.alpha.-cubebene	
32	.alpha.-copaene	
33	Copaene	

The first compounds identified with less retention (2.370min.) were D-Limonene and Limonene whereas .alpha.-cubebene, .alpha.-copaene and copaene were the last compounds which took longest retention time (8.583 min.) to identify. At (7.609 min.) retention time, benzene,1,2,3-trimethoxy-5-(2-propenyl)- compound were found to be very high (48%). The identified bioactive compounds from the essential oil of *C.citratus* have many biological uses (Table 3).

Antimicrobial activity: In the present study, antimicrobial activities of leaves essential oil of *C.citratus* against selected human pathogenic microorganisms such as gram positive, gram negative bacteria and fungi were comparable to the standard antibiotic ampicillin (10 mcg) by disk diffusion method. Among these different concentration (50µg/ml, 100µg/ml and 150µg/ml) of the essential oil of *C.citratus* antimicrobial activity exhibited against all the selected microorganisms.

Among these three concentrations (50µg/ml, 100µg/ml and 150µg/ml) of the essential oil of *C.citratus*, higher concentration (150µg/ml) showed higher inhibitory activity against all the tested microorganisms.

Table 3
Biological uses of bioactive compounds identified from essential oil of *Cymbopogon citratus* leaves

S.N.	Name of the compound	Biological uses
1	D-Limonene	Weight loss and treat or prevent certain diseases, Anticancer, Antidiabetic, Antimicrobial and Gastroprotective effects
2	Limonene	Anti-inflammatory, Antioxidant, Antinociceptive, Anticancer, Antidiabetic, Antihyperalgesic, Antiviral and Gastroprotective effects
3	1,7,7-Trimethylbicyclo [2.2.1] heptan-2-ol	Antiulcerogenic, Anti-inflammatory, Antipyretic, Antioxidant, Cytotoxic, Antibacterial, Hypoglycemic and immunosuppressive.
4	Endo-borneol	Antinociceptive and Anti-inflammatory.
5	Bicyclo[2.2.1]heptan-2-ol.1.7-trimethyl-(1S-endo)	Antibacterial, Antioxidant and Antitumor activities.
6	1,3-Cyclooctadiene,(z,z)	Antioxidant, Antitumor, Anti-inflammatory and Antiviral.
7	1-octen-3-yne	Inflammatory pain, Headaches, Congestion, Liver disorders, ulcer, Fever, Renal pain, Dyspepsia and remedy for stomach disorders.
8	Furan,2-(2-propenyl)	Antimicrobial, Antioxidant, Cytotoxic and Wound healing activities.
9	L-alpha.-Terpineol	Antifungal, Antibacterial and Antioxidant.
10	.alpha.-Terpineol	Antibacterial, Antiviral and Anti-inflammatory and insecticidal properties
11	8-Isopropenyl-1,5-dimethyl-cyclodeca-1,5-diene	Nausea, vomiting, diarrhea, dyspepsia, rheumatism and colds
12	Naphthalene,decahydro-1,6-bis(methylene)-4-(1-methylethyl)-, (4,alpha.,4a.alpha.,8a.alpha.)-	Anti-oxidative, Anti-tumor and Anti-viral activities.
13	Cyclohexane,1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-,[1S-(1.alpha.,2.beta.,4.beta.)]-	Diabetes, Cystitis, Malaria, Kidney disorders, leucorrhoea and Laryngitis.
14	Caryophyllene	Anti-angiogenic activity, Anticancer and Antimicrobial activity.
15	Bicyclo[7.2.0]undec-4-ene,4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]-	Improve myocardial function and antioxidant properties
16	Humulene	Treatment of chronic diarrhea, dysentery and peptic ulcers
17	1,4,7,-cycloundecatriene, 1,5,9,-tetramrthyl-Z,Z,Z-	Anti-aging, antihyperlipidemia and antimicrobial activities.
18	1,6-Cyclodecadiene,1-methyl-5-methylene-8-(1-methylethyl)-,[S-(E,E)]-	Carminative, diuretic, spasmolytic, hypoglycaemic and stomach disorders
19	1H-Cyclopenta [1,3] cyclopropa [1,2] benzene, octahydro-7-methyl-3-methylene-4-(1-methylethyl)-,[3aS-(3a.al)]	Treatment of headaches, coughs, diarrhoea, constipation, warts, worms and kidney malfunctions.
20	Cis-muurola-3,5-diene	Antibacterial and Antifungal.
21	.alpha,-Cubebene	Antibacterial and Antifungal.
22	4-epi-cubedol	In traditional medicine against ulcers, snake bite, as well as headache and diseases
23	Cubedol	In treating many diseases like mouth ulcer, sour throat, jaundice and ulcers
24	Cis-muurola-3,5-diene	Antimicrobial and antitumor activities
25	Naphthalene,1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl),(1S-cis)-	Bio-energy, bio-medicine, cosmetics, skin care products and spices
26	Benzene,1,2,3-trimethoxy-5-(2-propenyl)-	Headache, toothache, snuffling and rheumatism

27	Caryphyllene oxide	Medicine in cough, diarrhea and oral ulcers and in some swollen gums wound.
28	Naphthalene,1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)-	Many chronic diseases in human beings, including diabetes, cancer, cardiovascular diseases, alzheimer's disease, neurodegenerative disorders, atherosclerosis and inflammation [
29	1-Naphthalenol,1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-,[1S-(1.alpha.,4.alpha.,4a.beta.,)]	Enhance human immunity, analgesic and anti-inflammatory
30	Di-epi-.alpha.-cedrene-(I)	Antiinflammatory, Antimicrobial, Antiseptic, Analgesic, Antipyretic, Blood and Coagulan.
31	.alpha.-cubebene	Antinociceptive, anticancer, antiphlogistic, antiviral, antioxidant and antimicrobial activities
32	.alpha.-copaene	Treatment of gastrointestinal disturbances such as vomiting, diarrhea, inhibition of the peristaltic reflex, gastroenteritis, spasmolytic activity, dysentery, abdominal distention, flatulence and gastric pain.
33	Copaene	Antioxidant and anticarcinogenic activity

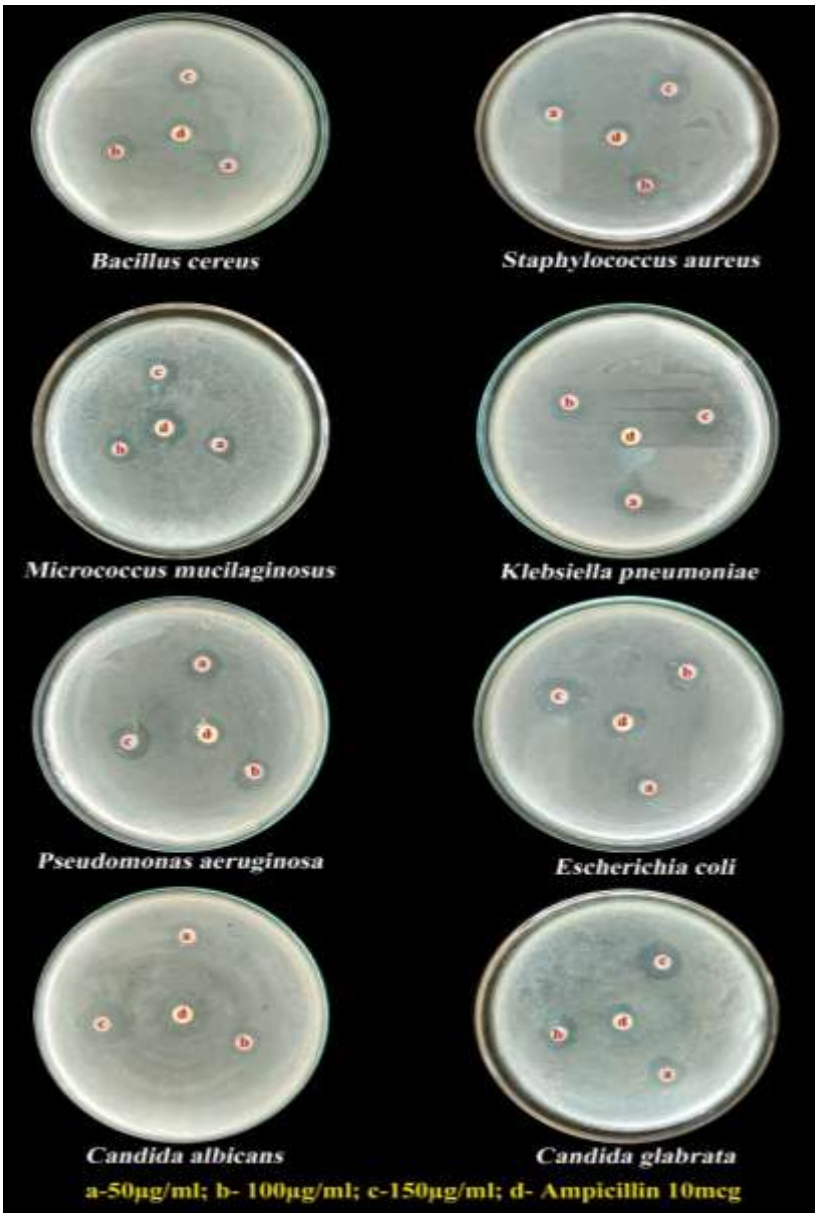


Plate 1: Antimicrobial activity of essential oil leaves of *C. citratus* against selected human pathogenic microorganisms

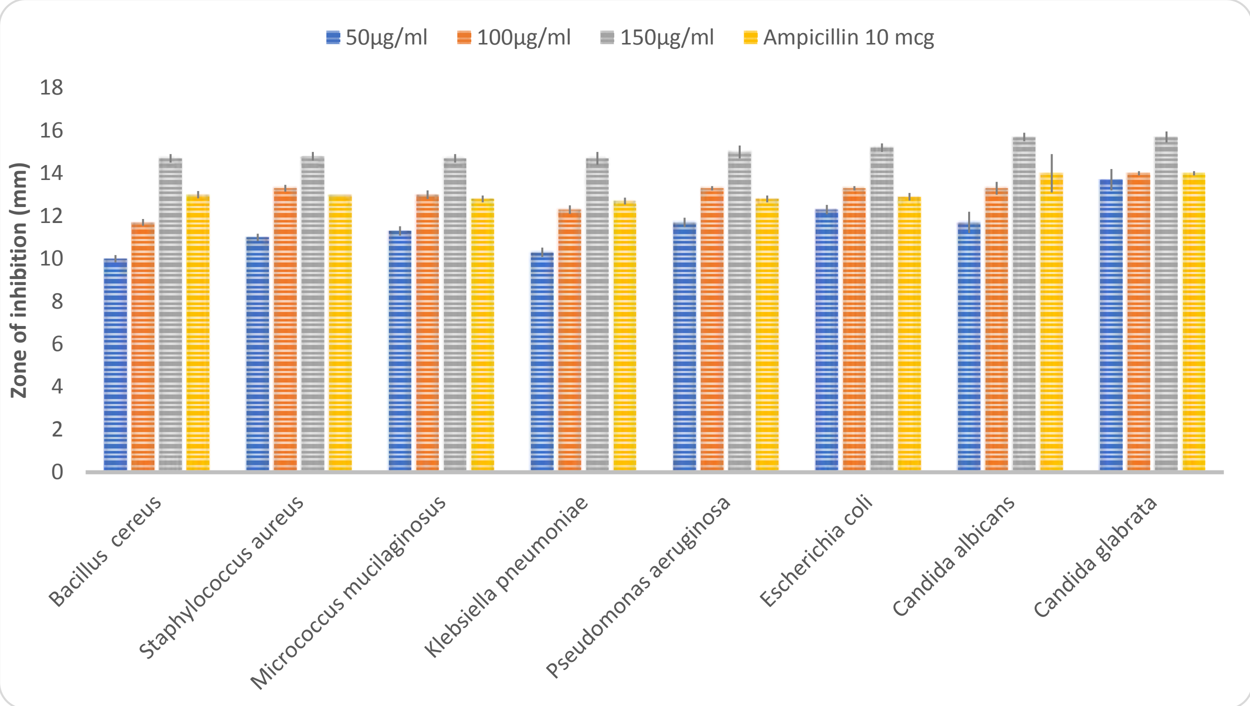


Figure 2: Antimicrobial activity of essential oil leaves of *C. citratus* against selected human pathogenic microorganisms

The essential oil of *C. citratus* (150 µg/ml) showed (Plate 1; Fig. 2) higher zone of inhibition against *Candida glabrata* followed by *Candida albicans, Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, Klebsiella pneumonia, Micrococcus mucilaginosus* and *Bacillus cereus*. In the present study, the antimicrobial activity of this essential oil of *C. citratus* could be due to the presence of several bioactive compounds known to antimicrobial activity. These major bioactive compounds of the essential oil Benzene,1,2,3-trimethoxy-5-(2-propenyl)-(48%), Caryophyllene (11.24%) and Bicyclo[7.2.0]undec-4 ene,4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]-(11.24%) have been reported to have high antimicrobial potential. Previously Josphat et al[17] reported that the antifungal activities of essential oil of *C. citratus* against mycotoxigenic species *Aspergillus flavus, A. parasiticus, A. ochraceus, A. niger and A. fumigatus.*

Conclusion

In this present study, GC-MS analysis of bioactive compounds and antimicrobial potential of the essential oil of *Cymbopogon citratus* (DC.) Stapf. and GC-MS analysis of essential oil of *Cymbopogon citratus* clearly showed the presence of 33 bioactive compounds. Antimicrobial activities of the essential oil showed a strong antimicrobial activity against all the tested microorganisms. So, it is concluded that essential oil of *C. citratus* might be utilized as natural drug for the treatment of several infectious diseases.

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