RESEARCH PAPER

Chemical profiling and antimicrobial activity of essential oils of *Curcuma caesia* and *Curcuma longa*

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ABSTRACT
Curcuma caesia also known as black turmeric belongs to the family Zingiberaceae. It is a rare medicinal plant which is currently listed as an endangered species. The rhizomes and leaves of this plant are widely utilized in ayurveda medicine for the treatment of a wide range of diseases. The plant shows a variety of bioactive compounds that makes it a potential source for pharmaceutical industries. Moreover, the plant is abundant in essential oils. The presence of camphor and eucalyptol as key constituents was shown by Gas Chromatography-Mass Spectroscopy study of rhizome essential oil. The rhizome EOs area percentage showed epicurzerenone (25.01) as the predominate fractions followed by (+)-2-bornanone (13.50) in black turmeric whereas tumerone (40.68) followed by curlone (12.07) were the major constituents in the rhizome EO of curcuma longa, The current study aimed at predicting the active phytoconstituents present in two different varieties of curcuma species grown in distinct geographic areas thus exhibiting a wide range in the composition and quantity of the elements.
Keywords: Essential oils; curcuma caesia; GC-MS; phytochemistry; antioxidant
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INTRODUCTION

Essential oil which come from a variety of plant sources, have attracted a lot of interest lately because of their wide range of pharmacological characteristics and possible use in medicine. Of all the plant species that are used in traditional medicine and cooking, the genus Curcuma is the most widely used for its essential oils. Curcuma, is a genus of plants that includes multiple species that are well-known for their abundance of bioactive chemicals and unique aromatic characteristics. Due to their medicinal properties and industrial uses, two well-known species in this genus, *Curcuma longa* (turmeric) and *Curcuma caesia* (black turmeric), have been the focus of much research. Comparatively speaking, *Curcuma longa* is a more well-known species than *Curcuma caesia*, sometimes known as Black Turmeric. Native to the Indian subcontinent, *Curcuma caesia* is most common in the northeast region of the country. It has long been used in traditional medicine for its supposed therapeutic qualities (Ibrahim NNA et al., 2023)1. On the other hand, Curcuma longa, better known by its common name, turmeric, is a widely used spice and medicinal herb in many different cultures and medical traditions worldwide. These two species are closely related in terms of geography and flora; however, they differ in terms of morphology, phytochemistry, and medicinal use (Jyotirmayee & Mahalik, 2022)2.

Curcuma longa and *Curcuma caesia* essential oils are sources of bioactive chemicals that support their various pharmacological actions and medicinal benefits. The main constituents of these essential oils are volatile chemical molecules, such as phenolics, terpenoids, and other secondary metabolites, which give many plant species their distinctive perfume and medicinal qualities. *Curcuma longa* and *Curcuma caesia* may differ greatly in their bioactive element's abundance and composition, which could have an impact on the pharmacological actions and possible uses of each plant.

The essential oils of *Curcuma longa* and *Curcuma caesia* include a variety of bioactive components, including phenolic compounds, sesquiterpenes, monoterpenes, and curcuminoids according to phytochemical investigations. The polyphenolic chemical curcumin, which is mostly present in *Curcuma longa*, has attracted significant attention because of its anti-inflammatory, antioxidant, and anticancer characteristics. On the other hand, new substances found in *Curcuma caesia*, such as xanthorrhizol and curcumin analogues, have a variety of pharmacological properties, such as antibacterial, anti-inflammatory and hepatoprotective actions (Paw M & Gogoi R et al., 2020)3

The comparative analysis of major constituents in the essential oils of *Curcuma caesia* and *Curcuma longa* provides valuable insights into their chemical composition, therapeutic potential and industrial applications. Understanding the differences in the phyto-chemical profiles of these two species is crucial for harnessing their therapeutic benefits effectively and exploring their potential synergistic effects in combination therapies. Moreover, elucidating the

underlying mechanisms of action of key constituents in these essential oils can facilitate the development of novel therapeutic agents with enhanced efficacy and safety profiles.

MATERIALS AND METHODS

2.1 Plant Sample Collection:

The Plant rhizomes of *Curcuma caesia* and *Curcuma longa* were harvested in the month of february from village Seri Tanda of district Reasi of Jammu and Kashmir (33° 4' 58.1016" N). The authentication of the samples was done by Krishi Vigyan Kendra, Farm Science Centre, Seri Tanda Reasi. The rhizomes of *Curcuma caesia* (Kali haldi) and *Curcuma longa* (yellow turmeric) were separated, cleaned and then weighed. An herbarium specimen of *Curcuma caesia* was submitted to Janaki Ammal herbarium, Indian Institute of Integrative medicine Jammu.

2.2 Soil Analysis:

Soil samples were collected from diverse locations, ensuring comprehensive representation of the block in which the trial was planted. The lower layer of soil i.e 2mm underneath the top layer was selected for soil analysis (Revati P. Potdar et al., 2021)4. After collection, the samples were sieved to eliminate extraneous particles. Soil pH, total organic content, nitrogen and phosphorus were some of the parameters analysed.

2.3 Extraction of essential oil:

The cleaned rhizomes weighed around 500gm were sliced and hydro distillated and extracted with water for 4h. The essential oil was collected, dried and stored at 4°C for chemical and bioassay analyses. The quantity of oil extracted was measured relative to the fresh weight of the rhizomes (expressed as mL per 100 grams of fresh weight (Ibanez MD & Blazquez MA., 2020)5. Yield percentage was calculated using fresh weight basis % yield (v/w) = Volume of Essential oil/ weight of fresh rhizomes X 100.

2.4 Chemical Profiling of Essential Oil:

The identification of the active compounds present in essential oils of both the species was done by Gas Chromatography-Mass spectroscopy (GC-MS) of samples. Helium was utilized as the carrier gas for gas chromatography- mass spectroscopy, with a sample volume of 0.50 µl and an injector temperature of 230°C. With a CP SIL Varian 8 CB column 1µm film thickness, a GC-MS 4000 (VARIAN, USA) system was used. The oven temperature program was set to 60°C for 5 mins of holding, 250°C for 30°C each minute of heating and 250°C for 10 mins of constant temperature. A mass range of 40-500 m/z and an electron impact ionization voltage of 70 eV were incorporated in the MS scan settings (Fahmy NM et al., 2023)6. By comparing the mass spectra peaks, retention time of the essential oils with those in the NISTO5 (version 2.0) library, the components of the oils were identified.

2.5 Antibacterial Activity of Essential Oil:

Antibacterial property of *Curcuma caesia* essential oil was determined by the agar well diffusion method. A 100 µl volume of each of the following bacterial suspensions: *Bacillus subtilis, Micrococcus luteus, Staphylococcus aureus* and *Pseudomonas aeruginosa* were spread on agar plates (Hussain Y et al., 2022)7. A borer was used to create the wells in the pre-seeded plates. Sample extract was added onto each well. The plates were incubated at 37ºC for 24h. A positive reference of chloramphenicol 10g/ml was employed. The zone of inhibition was measured to determine the growth of micro-organisms.

2.6 Anti-Fungal Activity of Essential Oil:

Antifungal property of *Curcuma caesia* essential oil was determined by the plate diffusion assay. Distinct plant pathogenic fungus, namely *Alternaria alternata* and *Curvularia lunata* were selected for the assay.As mentioned above, plates were prepared using fungus and incubated at 26°C in the dark (Schroder et al., 2017)8. The diameter of the hyper growth extension was measured every 24 hours until the fungus on the plate grew to the edge without the test component (control). To calculate the percentage of growth inhibition, the fungal growth diameter in each plate with varying test component concentrations was measured. The antifungal indices were analysed by using the formula: Antifungal index (%) = (1-Da/Db) x 100.

2.7 Antioxidant Activity of Essential oil:

Antioxidant analysis of essential oils was done using DPPH Radical Scavenging Assay - The DPPH radical scavenging ability of Curcuma essential oils was monitored at 517 nm by the method of Bozin. A mixture containing 1mL of DPPH (90M, in methanol) was mixed with both the essential oil samples and volume was made up to 4mL by adding methanol. The mixture was then kept at 25°C in the dark for 60mins. After an hour, absorption was measured at 517nm wavelength. Following, the capacity to capture DPPH radicals i.e., scavenging effect was calculated by using underlying formula:

DPPH radical scavenging effect (%) =AC-AT/ AcX100

Chelation power on ferrous (Fe2+) ions- The essential oils of both species were used to test the chelating power on ferrous ions by using Dinis method with minor alterations.

A 20 µl of both the essential oil extracts (diluted 10 times with DMSO) were taken separately for each sample and was brought to a final volume of 3ml with methanol. Then, 60 µl of 2 mM FeCl2was added. To initiate the reaction 120 µl of 5 mM ferrozine was mixed with it and was allowed to stand at room temperature for 2mins, then measuring its absorbance at 562nm wavelength. The inhibition ratio of ferrozine-Fe2+complex formation was determined by using:

% inhibition = ([absorbance of control –absorbance of test sample]/absorbance of control) ×100.

RESULTS AND DISCUSSION:

3.1 Soil analysis: On analysis of the soil from the site, followed data was obtained (Table 1). The soil was found to be abundant in nitrogen and potassium which are known micronutrients for plant nourishment. Soil profiling was done to check the fertility of the land and

to check for the need of any additional nutrients supply (Havlin, J.L., & Heiniger, R.W., 2020)9. Effective nutrient management requires quantifying crop nutrient requirement and the nutrient supplying capacity of the soil through soil testing.

Table 1: Soil analysis of the sample field

Element total content	**Quantity present (in %age)**
Nitrogen	562.95
Phosphorus	29.68
Potassium	325.52
Organic carbon	0.81
Electric conductivity	0.77
pH	7.02

3.2 Essential Oil Yield:

Out of the myriad of plants the importance of *Curcuma longa* essential oil has been known for many years whereas the study on essential oil of *Curcuma caesia* has still a long way to go. There are many techniques using steam distillation, hydro distillation and pressurized water extraction as mentioned by several researchers to extract oil from turmeric (Mc Gaw & Skeene et al., 2021)10. whereas we have extracted oil from the unpeeled fresh rhizomes of both the species separately by the technique of hydro-distillation. Hydro-distillation is the commonly used organic solvent-free extraction method for essential oils due to its simplicity, repeatability and cost- effectiveness. Using Clevenger type hydro distillation is a widely used extraction method in academic research labs. Hydro distillation was performed based on the availability of the apparatus. Essential oil extracted from *Curcuma caesia* was found to be 0.75ml and 1.5ml from *Curcuma longa*. The percentage yield of both *Curcuma longa* and *curcuma caesia* essential oil are tabulated and graphed below (Table 2, Figure 1).

Table 2. Percentage yield of Essential oil extracted by hydro distillation technique

S.No.	**Plant rhizome Species**	**Essential oil Yield**
		Percentage (%)
1.	*Curcuma longa*	0.60
2.	*Curcuma caesia*	0.15

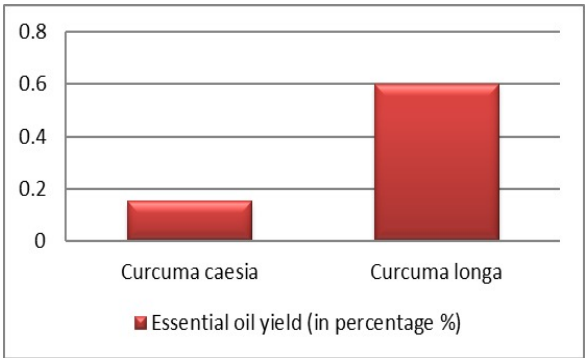

Figure 1: Yield percentage of Curcuma essential oils

3.3 Chemical profile of Curcuma essential oils by GC-MS method:

Curcuma rhizomes, renowned for their aromatic and remedial properties, have been valued for centuries in traditional medicine and gastronomy. Since ancient times, oil extracts have been valued for their extensive cultural, therapeutic and culinary uses These rhizomatous plants, which are both members of the Zingiberaceae family and the widest genus Curcuma, have different essential oil compositions and characteristics (Dosoky NS & Setzer WN.,2018)11.

The chromatograph for *Curcuma caesia* essential oil along with the compounds detected through gas chromatography and mass spectroscopy are mentioned in the Table 3 and the chromatograph for *Curcuma longa* essential oils along with the detected compounds are tabulated in the table 4 below. There was a total of 83 compounds identified in *C. caesia* essential oil sample and a total of 64 compounds was identified in *C. longa* essential oil extract. The major constituents found in C. caesia were Eucalyptol, Epicurzerenone, (+)-2-Bornanone, Isoborneol, Androstan-3-one, 17-hydroxy-1,17-dimethyl-, (1.alpha.,5.alpha.,17.beta.)-, Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1.alpha.,2.beta.,4.beta.)]-, 3,7-Cyclodecadien-1-one, 3,7-dimethyl-10-(1-methylethylidene)-, (E,E)-, Benzene, 1,3-bis(1,1-dimethylethyl)- with percentage of 25.8%, 25.01%, 13.5%, 2.63%, 2.12%, 2.01%,1.87%, 1.46% respectively and other minor constituents to be identified in volume ≤ 1.The major constituents of essential oil extracted from Curcuma longa are Tumerone, Curlone,(+)-4-Carene,2-((2S.4aR)-4a,8-Dimethyl-1,2,3,4,4a,5,6,7-octahydronapthalen-2-yl)propan-2-ol,Cyclohexane,3-(1,5-dimethyl-4-hexenyl)-6-methylene-,[S-(R*,S*)]-,1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, [S-(R*,S*)]-, Eucalyptol, Citronellol, caryophyllene, (1R,4R)-1-methyl-4-(6-Methylhept-5-en-2-yl)cyclohex-2-enol, 3,5,5,9-Tetramethyl-4a,5,6,7,8,9-hexahydro-2H-benzo[7]annulene, (6R,7R)-Bisabolone, Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-, 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)- with percent area of 40.68%, 12.07%, 8.17%, 4.26%, 3.44%, 2.93%, 2.46%, 2.34%, 1.95%, 1.88%, 1.45%, 1.28%, 1.15%, 1.15% respectively. As compared to *Curcuma caesia Curcuma longa* has less amount of eucalyptol as mentioned above and has tumerone as major compound which is absent in *Curcuma caesia.*

Table 3: Chemical composition of essential oil extracted from *Curcuma caesia*

S. No.	Compound	RT (min)	Percentage (%)	Mode of Identification
1	(1R)-2,6,6-Trimethylbicyclo [3.1.1]hept-2-ene	3.940	0.34	GC-MS
2	Camphene	4.109	0.99	GC-MS
3	Bicyclo[3.1.0]hexane, 4-methylene-1-(1-methylethyl)-	4.355	0.11	GC-MS
4	Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methylene-, (1S)-	4.407	0.52	GC-MS
5	Undecane, 2,8-dimethyl-	4.677	0.14	GC-MS
6	Decane, 2,3,4-trimethyl-	4.720	0.11	GC-MS
7	Eucalyptol	4.974	25.81	GC-MS
8	1-Decene, 8-methyl-	5.433	0.13	GC-MS
9	2-Isopropyl-5-methyl-1-heptanol	5.478	0.19	GC-MS
10	(+)-2-Bornanone	6.212	13.5	GC-MS
11	Isoborneol	6.340	2.63	GC-MS
12	Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, (1S-endo)-	6.433	0.59	GC-MS
13	Dodecane, 4,6-dimethyl-	7.018	0.12	GC-MS
14	Dodecane, 4,6-dimethyl-	7.102	0.23	GC-MS
15	Oxalic acid, 2-ethylhexyl isohexyl ester	7.172	0.19	GC-MS
16	Benzene, 1,3-bis(1,1-dimethylethyl)-	7.248	1.46	GC-MS
17	2-Isopropyl-5-methyl-1-heptanol	7.702	0.6	GC-MS
18	2-Isopropyl-5-methyl-1-heptanol	7.782	0.91	GC-MS
19	2-Isopropyl-5-methyl-1-heptanol	7.864	0.6	GC-MS
20	Cyclohexene, 4-ethenyl-4-methyl-3-(1-methylethenyl)-1-(1-methylethyl)-, (3R-trans)-	8.089	0.46	GC-MS
21	1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethenyl)-, [S-(Z,E)]-	8.530	0.07	GC-MS
22	Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1.alpha.,2.beta.,4.beta.)]-	8.597	2.01	GC-MS
23	Caryophyllene	8.905	0.17	GC-MS
24	1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethylidene)-, (E,E)-	8.963	0.21	GC-MS
25	Dodecane, 4,6-dimethyl-	9.099	0.26	GC-MS
26	Dodecane, 4,6-dimethyl-	9.171	0.44	GC-MS
27	Dodecane, 4,6-dimethyl-	9.258	0.42	GC-MS
28	Eicosane, 1-iodo-	9.338	0.22	GC-MS
29	Germacrene D	9.433	0.60	GC-MS
30	Benzofuran, 6-ethenyl-4,5,6,7-tetrahydro-3,6-dimethyl-5-isopropenyl-, trans-	9.526	1.78	GC-MS
31	2,4-Di-tert-butylphenol	9.558	1.22	GC-MS
32	Pentafluoropropionic acid, heptadecyl ester	9.629	0.28	GC-MS
33	Pentadecafluorooctanoic acid, octadecyl ester	9.708	0.37	GC-MS
34	Heptacos-1-ene	9.775	0.46	GC-MS
35	1-Decanol, 2-hexyl-	9.854	0.48	GC-MS
36	Nonyl tetradecyl ether	9.943	0.23	GC-MS
37	Octadecane	10.232	0.26	GC-MS
38	(-)-Isolongifolol, acetate	10.322	0.18	GC-MS
39	2-((4aS,8R,8aR)-4a,8-Dimethyl-	10.355	0.07	GC-MS

	3,4,4a,5,6,7,8,8a-octahydronaphthalen-2-yl) propan-2-ol			
40	Epicurzerenone	10.411	25.01	GC-MS
41	Curcumenol	10.631	0.77	GC-MS
42	Heptadecane, 8-methyl-	10.830	0.12	GC-MS
43	2,6,10-Trimethyltridecane	10.901	0.24	GC-MS
44	Octadecane, 1-chloro-	10.976	0.27	GC-MS
45	Eicosane	11.040	0.31	GC-MS
46	Decane, 2,8,8-trimethyl-	11.140	0.07	GC-MS
47	3,7-Cyclodecadien-1-one,3,7-dimethyl-10-(1-methylethylidene)-, (E,E)-	11.193	1.87	GC-MS
48	Nonadecyl pentafluoropropionate	11.321	0.45	GC-MS
49	1-Decanol, 2-hexyl-	11.385	0.41	GC-MS
50	Nonadecyl pentafluoropropionate	11.446	0.70	GC-MS
51	1-Decanol, 2-hexyl-	11.524	0.78	GC-MS
52	Androstan-3-one, 17-hydroxy-1,17-dimethyl-, (1.alpha.,5.alpha., 17.beta.)-	11.597	2.12	GC-MS
53	Nonadecyl pentafluoropropionate	11.678	0.38	GC-MS
54	Eicosane, 1-iodo-	11.730	0.08	GC-MS
55	Hexatriacontyl trifluoroacetate	11.764	0.25	GC-MS
56	(-)-Neoclovene-(I), dihydro-	11.855	0.61	GC-MS
57		11.919	0.54	GC-MS
58	Curcumenone	12.237	0.16	GC-MS
59	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	12.313	0.59	GC-MS
60	2,6,10-Trimethyltridecane	12.431	0.20	GC-MS
61	2,6,10-Trimethyltridecane	12.496	0.18	GC-MS
62	1,2-Benzenedicarboxylic acid, butyl 8-methylnonyl ester	12.653	0.36	GC-MS
63	Eicosane	12.815	0.09	GC-MS
64	Dotriacontyl isopropyl ether	12.886	0.35	GC-MS
65	1-Heptanol, 2,4-diethyl-	12.930	0.18	GC-MS
66	Octacosyl trifluoroacetate	13.001	0.12	GC-MS
67	Heneicosyl trifluoroacetate	13.060	0.17	GC-MS
68	Tetrapentacontane, 1,54-dibromo-	13.153	0.09	GC-MS
69	Heptacosyl heptafluorobutyrate	13.214	0.14	GC-MS
70	Pentacosyl trifluoroacetate	13.305	0.15	GC-MS
71	Octadecanoic acid	14.165	0.33	GC-MS
72	Docosyl trifluoroacetate	14.278	0.11	GC-MS
73	Hexatriacontyl trifluoroacetate	14.343	0.42	GC-MS
74	Tetrapentacontane, 1,54-dibromo-	14.390	0.24	GC-MS
75	1-Decanol, 2-hexyl-	14.495	0.15	GC-MS
76	Tetrapentacontane, 1,54-dibromo-	14.559	0.15	GC-MS
77	Tetratriacontyl heptafluorobutyrate	14.628	0.30	GC-MS
78	1-Octacosanol, 2,4,6,8-tetramethyl-, (all-R)-	14.683	0.11	GC-MS
79	Nonadecyl heptafluorobutyrate	14.842	0.14	GC-MS
80	Pentacosyl trifluoroacetate	15.821	0.20	GC-MS
81		16.745	0.36	GC-MS
82	Pentatriacontane, 13-docosenylidene-	16.860	0.19	GC-MS

83	3,7,11,15-Tetramethylhexadecane-1,2,3-triol	16.921	0.14	GC-MS

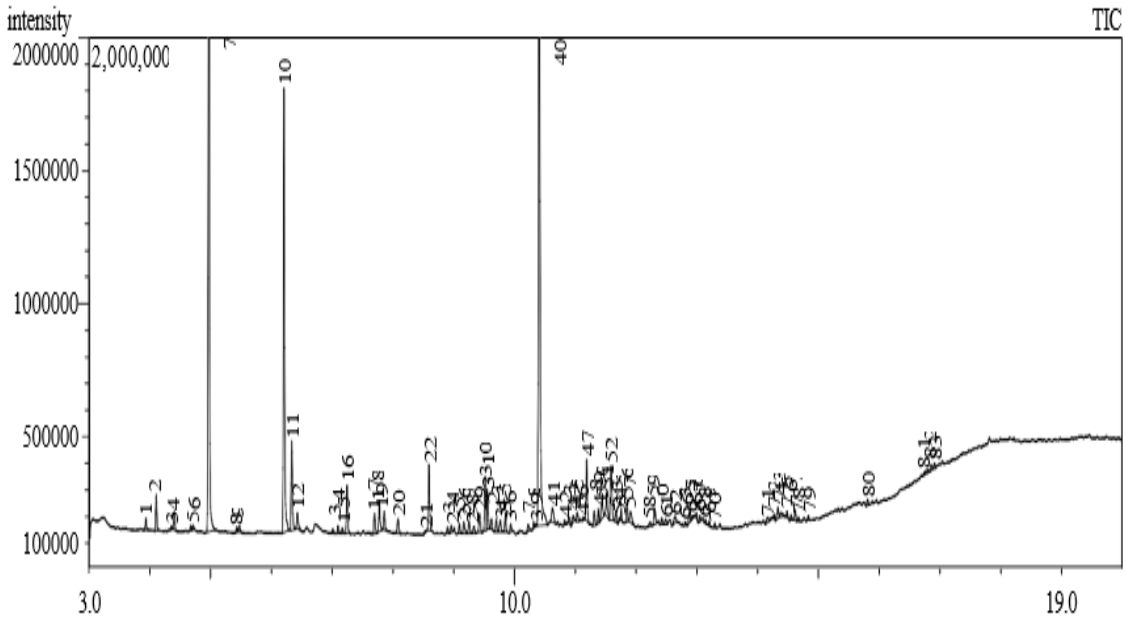

Figure 2. Chromatograph representing GC-MS results of *Curcuma caesia*

Table 4. Chemical composition of essential oil extracted from *Curcuma longa*

S. No.	Compound	RT (min)	Percentage (%)	Mode of Identification
1	(1R)-2,6,6-Trimethylbicyclo [3.1.1] hept-2-ene	3.938	0.07	GC-MS
2	Camphene	4.109	0.02	GC-MS
3	Beta -Myrcene	4.507	0.11	GC-MS
4	Alpha - Phellandrene	4.681	0.33	GC-MS
5	3-Carene	4.747	0.11	GC-MS
6	(+)-4-Carene	4.808	0.55	GC-MS
7	o-Cymene	4.900	0.13	GC-MS
8	Eucalyptol	4.973	2.46	GC-MS
9	Gamma - Terpinene	5.266	0.04	GC-MS
10	(+)-4-Carene	5.574	8.17	GC-MS
11	Linalool	5.666	0.38	GC-MS
12	(2S,4R)-4-Methyl-2-(2-methylprop-1-en-1-yl) tetrahydro-2H-pyran	5.794	0.06	GC-MS
13	(2S,4R)-4-Methyl-2-(2-methylprop-1-en-1-yl) tetrahydro-2H-pyran	5.981	0.03	GC-MS
14	p-Mentha-1,5,8-triene	6.130	0.04	GC-MS
15	(+)-2-Bornanone	6.214	0.24	GC-MS
16	Isoborneol	6.342	0.03	GC-MS
17	Cyclohexanone, 5-methyl-2-(1-methylethyl)-, (2R-cis)-	6.397	0.31	GC-MS
18	5-Isopropyl-2-methylbicyclo [3.1.0] hexan-2-ol	6.545	0.05	GC-MS
19	Benzenemethanol, alpha,4-trimethyl	6.616	0.16	GC-MS

20	L- alpha - Terpineol	6.666	0.19	GC-MS
21	Citronellol	6.947	2.34	GC-MS
22	Geraniol	7.245	0.55	GC-MS
23	6-Octen-1-ol, 3,7-dimethyl-, formate	7.414	0.50	GC-MS
24	Ascaridole	7.700	0.10	GC-MS
25	Pentadecafluoro octanoic acid, tridecyl ester	7.778	0.04	GC-MS
26	2-Isopropyl-5-methyl-1-heptanol	7.859	0.03	GC-MS
27	Copaene	8.476	0.05	GC-MS
28	Octadecane, 1-chloro-	8.537	0.03	GC-MS
29	Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1.alpha.,2.beta., 4.beta.)]-	8.594	0.06	GC-MS
30	(1S,5S)-2-Methyl-5-((R)-6-methylhept-5-en-2-yl) bicyclo[3.1.0]hex-2-ene	8.664	0.05	GC-MS
31	(3R,4aS,8aS)-8a-Methyl-5-methylene-3-(prop-1-en-2-yl)-1,2,3,4,4a,5,6,8a-octahydronaphthale	8.735	0.02	GC-MS
32	Caryophyllene	8.901	1.95	GC-MS
33	(E)-.beta.-Famesene	9.076	0.21	GC-MS
34	Alloaromadendrene	9.132	0.06	GC-MS
35	1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-	9.201	0.42	GC-MS
36	Alloaromadendrene	9.267	0.09	GC-MS
37	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	9.350	1.15	GC-MS
38	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, [S-(R*,S*)]-	9.450	2.93	GC-MS
39	.beta.-Bisabolene	9.568	0.82	GC-MS
40	Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)-6-methylene-, [S-(R*,S*)]-	9.706	3.44	GC-MS
41	1H-Cyclopropa[a]naphthalene, decahydro-1,1,3a-trimethyl-7-methylene-, [1aS-(1a.alpha.,3a.alp	9.878	0.08	GC-MS
42	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	9.968	1.15	GC-MS
43	2-Methyl-6-(p-tolyl)hept-2-en-4-ol	10.165	0.92	GC-MS
44	trans-Sesquisabinene hydrate	10.258	0.99	GC-MS
45	(E)-.gamma.-Atlantone	10.307	0.62	GC-MS
46	3,5,5,9-Tetramethyl-4a,5,6,7,8,9-hexahydro-2H-benzo[7]annulene	10.375	1.45	GC-MS
47	(1R,4R)-1-methyl-4-(6-Methylhept-5-en-2-yl)cyclohex-2-enol	10.440	1.88	GC-MS
48	2-((2S,4aR)-4a,8-Dimethyl-1,2,3,4,4a,5,6,7-octahydronaphthalen-2-yl)propan-2-ol	10.605	4.20	GC-MS
49	Longifolene-I2	10.658	0.50	GC-MS
50	(E)-.gamma.-Atlantone	10.756	0.70	GC-MS

51	Tumerone	10.897	40.68	GC-MS
52	Geranyl tiglate	11.046	1.08	GC-MS
53	Curlone	11.145	12.07	GC-MS
54	5-Methyl-2-(6-methylhept-5-en-2-yl)phenol	11.214	0.31	GC-MS
55	Bicyclo[4.4.0]dec-5-ene, 1,5-dimethyl-3-hydroxy-8-(1-methylene-2-hydroxyethyl-1)-	11.370	0.04	GC-MS
56	(6R,7R)-Bisabolone	11.476	1.28	GC-MS
57	3,5,9-Trimethyl-deca-2,4,8-trien-1-ol	11.533	0.08	GC-MS
58	Tumerone	11.579	0.72	GC-MS
59	3-Methyl-2-butenoic acid, tridec-2-ynyl ester	11.631	1.08	GC-MS
60	(E)-Atlantone	11.678	0.79	GC-MS
61	Pinocamphyl tiglate, iso-	11.849	0.24	GC-MS
62	(E)-.gamma.-Atlantone	11.979	0.77	GC-MS
63	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	12.305	0.03	GC-MS
64	l-(+)-Ascorbic acid 2,6-dihexadecanoate	12.882	0.03	GC-MS

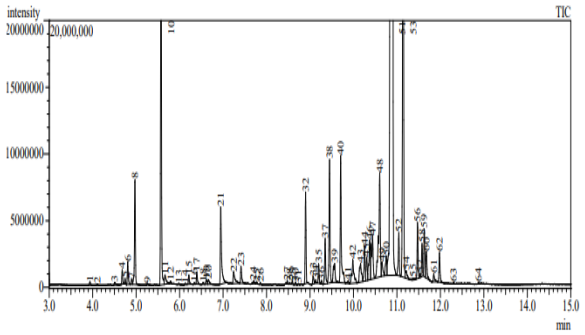

Figure3 Chromatograph representing GC-MS results of *Curcuma longa*

Table 5 represents the Antibacterial Activity; Table 6 represents the antifungal activity and Table 7 depicts the antioxidant activity of the sample extracts.

Table 5. Antibacterial activity of essential oil of *Curcuma caesia*

Micro-organism	Zone of inhibition (mm)		MIC (µg/ml)
	Essential oil	CF	Fresh essential oil
B.subtilis MTCC2389	23.3 ± 2.88	18 ± 0.57	550
M.luteus MTCC4821	20.1 ± 1.97	19 ± 1.02	> 1000
S.aureus MTCC7443	20.0 ± 0.00	20 ± 0.89	> 1000
P.aeruginosa MTCC2624	19.6 ± 0.57	17 ± 0.78	> 1000

Data presented is mean ± s.d of three replicates

Table 6. Percent antifungal index and IC50 values of the essential oil from fresh and dried Rhizome of *Curcuma caesia* and *Curcuma longa*

Pathogen[a]	**% Antifungal**		**Antifungal activity**	
	EOCC	**EOCL**	**EOCC**	**EOCL**
Alternaria	25±1.15	28.42±1.2	2932±72.27	2403.7±19.0
Curvularia lunata	29.49±1.5	34.86±1.5	2417.3±23.0	2117.7±19.80

Data presented is mean ± s.d of three replicates

Table 7. Antioxidant activity of EO obtained from *C. caesia* and *C. longa*

S. No.	Component	DPPH Radical scavenging radical activity IC_{50}(mg/mL)	% Chelating effect at 4.95 mg/mL	Reducing power IC_{50} (mg/mL)
1	*Curcuma caesia* Essential oil	1.7±0.1	88.2 ±1.2	2.80±0.100
2	*Curcuma longa* Essential oil	1.6±0.1	85.0 ±1.4	2.75±0.098

The comparative analysis of major constituents in the essential oils of *Curcuma caesia* and *Curcuma longa* underscores the intricate interplay between phytochemical diversity and pharmacological activities within the genus Curcuma. While both species share certain bioactive compounds, such as curcuminoids and terpenoids, their distinct chemical profiles give rise to unique therapeutic properties and potential applications.

One of the key findings from the comparative analysis is the differential abundance of curcuminoids, particularly curcumin, between *Curcuma caesia* and *Curcuma longa*. Curcumin, prominently found in *Curcuma longa,* has been extensively studied for its antioxidant, anti-inflammatory, and anticancer effects. Its absence or lower concentration in *Curcuma caesia* suggests that the latter species may exhibit distinct pharmacological activities mediated by alternative bioactive compounds. This highlights the importance of exploring the therapeutic potential of other constituents present in *Curcuma caesia*, such as xanthorrhizol and novel curcumin analogs.

Furthermore, the presence of unique compounds in *Curcuma caesia,* such as xanthorrhizol, warrants attention due to their diverse pharmacological activities. Xanthorrhizol, a sesquiterpenoid isolated from Curcuma xanthorrhiza, a closely related species, has demonstrated promising antimicrobial, anti-inflammatory, and hepatoprotective properties in preclinical studies. Its presence in *Curcuma caesia* suggests that this species may possess similar therapeutic benefits, which merit further investigation.

CONCLUSION

In conclusion, the comparative analysis of major constituents in the essential oils of *Curcuma caesia* and *Curcuma longa* provides valuable insights into their phytochemical diversity, pharmacological activities, and potential synergistic effects. Further research endeavors aimed at elucidating the underlying mechanisms of action and exploring their therapeutic applications are warranted for harnessing the full therapeutic potential of these botanical resources.

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