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Studies on key bioactive compounds in volatile and fixed oil of cardamom (*Elettaria cardamomum* L.)

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ABSTRACT

Experiment was conducted in Cardamom (*Elettaria cardamomum* L.) with extraction of the volatile and fixed oil to analysing the major bioactive compounds and fatty acids detection. The major whole dry green pod like structures called as capsule and is used as flavouring in Tea and many foods preparation and pan masala too. It is also known as “Elaichi”. By using the rotary evaporator apparatus 2% oils were extracted. These oils were utilized after the making FAME and injected in autosampler of GC MS for detection of compounds with untargeted approaches and compared with RT and score of NIST library. The experimental results shown the 54 compounds identified in cardamom oils out of them 51 were unique. More than 60% area were detected in the analysis of volatile compounds of Cardamom viz., Eucalyptol (25.79%), 3-Cyclohexene-1-methanol, α ,4-trimethyl-, acetate (37.05%). Thirteen compounds were in the range of 1 to 5% and 39 compounds were detected in the range of 0.02 to 0.92% in volatile oils of cardamom. In Fatty acids profiling showed 18 fatty acids including SFA (Saturated Fatty acids) 7.17%, MUFA (Monounsaturated Fatty acids) 69.71%, PUFA (Poly Unsaturated Fatty acids) 23.12%, MUFA/PUFA ratio showed 3.015% and UnsFA/SFA (Unsaturated Fatty acids/SFA) ratio indicated 12.95% area in Cardamom

Keywords : Cardamom, GC MS, fixed oil, volatile oil

INTRODUCTION

Elettaria cardamomum (L.) Maton, also known as Indian cardamom, green cardamom botanically is a herbaceous perennial plant belonging to *Zingiberaceae* family also reported as “Queen of spices”. The essential oil of cardamom capsules is a high-value ingredient in foods, beverages, perfumery and traditional medicines. It is responsible for the characteristic aroma of cardamom and variability in volatile contents of this capsule (Ashokkumar *et al.* 2021) As the scientist already know that phytochemicals and bioactive compounds in medicinal plants significantly benefit human health as Cardamom essential oil exhibits potential as a broad-spectrum antimicrobial and anticancer agent and proven test with cardamom essential oils and identify the inhibition zone. *Staphylococcus aureus* (ATCC 6538) and *Bacillus cereus* (ATCC6629) are two examples of Gram-positive bacteria against which the essential oil such as *Pseudomonas aeruginosa* (ATCC 27853), *Escherichia coli* (ATCC25922), and yeast *Candida albicans* were also evaluated for antimicrobial activity. (Tahani *et al.* 2024). Despites of

these facts, the literature cited is vary scares, In recent era of Artificial intelligence and the advancement of scientific instruments. It must be redefining the value of bioactive compounds. Uses are numerous in food flavour, though it is a very popular ingredients for Arab and Asian countries for pan masala from centuries ago (Teresa-Martinez *et al.* 2025). Some had a belief of aphrosaidic in nature and causing internal heat. Therefore, it is used as “first night” milk or juice or pan masala ingredients in many Indians family's tradition too.

Real *et al.* (2015) determine the presence of hormone-like activities dependent on the activation of human estrogen receptor alpha (hER) and/or androgen receptor (hAR) in methanol extracts prepared and the analysis of the nutritional and therapeutic properties of fatty acids derived from *Elettaria cardamomum* reveals significant potential for both health benefits and culinary applications. Research indicates that extracts from cardamom seeds exhibit estrogenic and androgenic activities, suggesting their capability to influence hormonal function, which could be particularly relevant in addressing hormone-related health concerns. It has many roles in Hinduism pujasthal and

“shreelaxmi- poojan” (Worshipping goddess of money) too. To knowing these facts and rumour researcher has keen interest in chemotypes or chemical profiling of Elachi or cardamom seeds inside the capsules. Though the black or brown seeds inside have variability in size and structure. The experiment was laid out with the phytochemical evaluation through GC MS extracts in both volatile and fixed oils through study of fatty acids profiling in *Elettaria cardamomum* (L.) Maton, It has more uses especially relevance due to their implications in both culinary and medicinal contexts. Cardamom, a spice cherished for its aromatic properties, possesses a distinct biochemical composition that contributes not only to its flavor but also to its health-promoting attributes (Masoumi-Ardakaniet *al.*, 2016; Alam *et al.*, 2019, Bhutia *et al.*, 2022; Vijayan *et al.*, 2017; Ashokkumar *et al.*, 2021; Noumi *et al.*, 2018 and Tan *et al.*, 2023). Understanding the fatty acid profile of this plant can elucidate mechanisms responsible for various health benefits, such as anti-inflammatory and antioxidant effects. Furthermore, the identification and quantification of different fatty acids can aid in the assessment of cardamoms nutritional value and potential applications in food science and pharmacology. By examining the lipid composition of *Elettaria cardamomum*, this research aims to bridge the gap between traditional usage and contemporary scientific insights, thereby enriching the existing body of knowledge surrounding this valuable crop and fostering greater appreciation for its multifaceted roles.

MATERIAL AND METHODS

Extraction: Methanolic extracts of powdered form of *Elettaria cardamomum* seeds were used. The Soxhlet oil extracted 2 % oils in dry weight basis. It was used for the FAME making and same was injected in autosampler. Protocol developed at FTL (Food testing laboratory JAU) Junagadh. The fatty acids were analysed by Rathod *et al.* (2025).

Instruments programme and conditions: The GC–MS system consisted of a Shimadzu QP2010S mass spectrometer with an autosampler (Shimadzu, Kyoto, Japan). The column temperature was programmed as follows: 60 °C, hold for 0 min, ramp at 150 °C/2min to 240 °C, hold for 5 min. Column Oven Temp. :60.0 °C, Injection Temp.: 250.00 °C, Injection Mode: Split, Flow Control Mode: Pressure, Pressure: 57.4 kPa, Total Flow: 54.0 mL/min, Column Flow: 1.00 mL/min, Linear Velocity: 36.5 cm/sec. Purge Flow: 3.0 mL/min, Split Ratio: 50.0; High Pressure Injection, Carrier Gas Saver, Splitter Hold: OFF for GCMS-QP2010 Plus:, Ion Source Temp: 230.00 °C, Interface Temp.: 240.00 °C, Solvent Cut Time: 2.00 min,

Detector Gain Mode: Relative, Detector Gain: +0.00 kV, Threshold: 1000 for MS table; Start Time: 2.30 min End Time: 31.50 min, ACQ Mode: Scan, Event Time: 0.50 sec, Scan Speed: 2000, Start m/z: 50.00, End m/z: 1000.00.

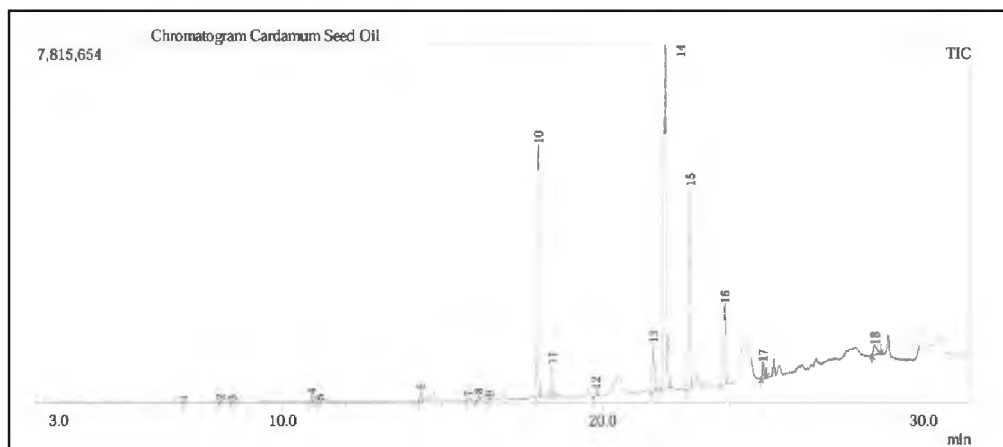
RESULTS AND DISCUSSION

Fatty acids profiling: The fatty acid profile of *Elettaria cardamomum* known as cardamom or Elachi oil was esterified and make FAME Ester used in autosampler for GCMS analysis (Table.1). The chromatogram is presented in fig.1 The diverse range of class fatty acids presence was found to be saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA). (Table.1). The Results of analysis shown 18 fatty acids in cardamom, with six number of Saturated Fatty Acids (SFA) and 10 were found as Monounsaturated Fatty Acids (MUFA) with total area of 69.71% while Two fatty acids of Polyunsaturated Fatty Acids (PUFA) with total area of 23.12%. The data shown Maximum amounts of Mono unsaturated fatty acids in *Elettaria cardamomum*, which constitutes higher amounts that was 69.71% of the total fatty acid content as compared to PUFA and SFA. In case of key Bioactive compounds in Elachi showed Hexa decanoic acid (Palmitic acid): as 23.08% fatty acid. The 8-Octadecenoic acid (oleic acids) was detected as highest area (42.48%) and the second most percent area (16.85%) was detected as 9,12-Octadecadienoic acid (Linoleic acid). The findings in line with Ramadan *et al.* (2022) studied on fixed oil, and cold pressed cardamom oil (CPCO) and they found Oleic (C18:1, 43.7%), palmitic (C16:0, 21.6%) and linoleic (C18:2, 17.6%) were the major fatty acids in CPCO. The levels of monounsaturated fatty acids (MUFA), saturated fatty acids (SFA), and polyunsaturated fatty acids (PUFA) were 47%, 32%, and 21%, respectively. Similarly, the calculation through ratio of MUFA/PUFA was suggested as 3.02 This indicated the higher presence of monounsaturated fats compared to polyunsaturated fats. There are many references said that MUFA protect the hearts of human being against cardiovascular diseases. They analysed of FAs via GC-MS revealed the presence of 8 fatty acids., The predominant fatty acids identified include oleic acid (42.75%) and palmitic acid (21.20%), polyunsaturated fatty acids (PUFAs) α -Linoleic acid (10.67%) and α -Linolenic acid (2.9%). They also determined the temperature sensitivity on fatty acids composition of Cardamom (*Elettaria cardamomum*). In case of Unsaturated Fatty Acids/SFA Ratio was found to be 12.95 which was indicated that higher unsaturated then the saturated fatty acids, this indicator also suggest the dietary healthier oils of cardamum.

Table.1 Fatty acids profiling of *Elettaria cardamomum* (L.) Maton

Peak#	R.Time	Area%	Name	Chemical Formula	Carbon No	Class
1	6.902	0.06	Nonanoic acid	C ₉ H ₁₈ O ₂	9	SFA
2	8.056	0.1	METHYL DECANOATE	C ₁₁ H ₂₂ O ₂	14	SFA
3	8.419	0.06	4-Decenoic acid	C ₁₀ H ₁₈ O ₂	10	MUFA
4	10.904	0.4	Dodecanoic acid	C ₁₂ H ₂₄ O ₂	12	SFA
5	11.177	0.08	6-Nonenoic acid	C ₉ H ₁₆ O ₂	9	MUFA
6	14.312	0.65	Methyl tetradecanoate	C ₁₅ H ₃₀ O ₂	15	SFA
7	15.812	0.25	Decanal dimethyl acetal	C ₁₂ H ₂₄ O ₂	12	SFA
8	16.123	0.4	Pentadecanoic acid	C ₁₅ H ₃₀ O ₂	15	SFA
9	16.461	0.15	Nonanedioic acid	C ₉ H ₁₆ O ₄	9	SFA
10	17.985	23.08	Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	18	SFA
11	18.429	2.08	9-Hexadecenoic acid	C ₁₆ H ₃₀ O ₂	18	MUFA
12	19.784	0.48	Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	18	SFA
13	21.591	3.71	Octadecanoic acid	C ₁₈ H ₃₆ O ₂	18	SFA
14	21.961	42.48	8-Octadecenoic acid	C ₁₈ H ₃₄ O ₂	18	MUFA
15	22.729	16.85	9,12-Octadecadienoic acid	C ₁₈ H ₃₂ O ₂	18	PUFA
16	23.822	6.27	9,12,15-Octadecatrienoic acid	C ₁₈ H ₃₀ O ₂	18	PUFA
17	25.012	1.27	Eicosanoic acid	C ₂₀ H ₄₀ O ₂	20	SFA
18	28.482	1.63	Docosanoic acid	C ₂₂ H ₄₄ O ₂	22	SFA
Total		99.78				
Name of class				% Area	No. of Fatty acids	
SFA (Saturated Fatty acids)				7.17	6	
MUFA (Mono Unsaturated Fatty acids)				69.71	10	
PUFA(Poly Unsaturated Fatty acids)				23.12	2	
MUFA/PUFA				3.015		
UnsFA/SFA (Unsaturated Fatty acids/SFA)				12.95		

In the previous studies also reported the terpenes are the major aroma compounds responsible for the odour of black pepper samples and their essential oil products.

Figure 1 : Chromatogram of fixed oils of *Elettaria cardamomum* (L.) Maton

Phytochemicals: Analysis through phytochemical protocols in volatile Oil of *Elettaria cardamomum* through GC MS are presented in table.2 and figure 2. The volatile oil extracted from *Elettaria cardamomum* (cardamom) contains a range of classes of compounds, each contributing to its unique aroma and flavor characteristics features. The analysis through mass spectrometry revealed 50 compounds, with varying area percentages and 54 peaks. This Findings of experimental results suggested that Compounds which were more than Area > 5% was found as Eucalyptol: 25.79% and Eucalyptol, also known as 1,8-cineole, is a monoterpene oxide that contributes a fresh, minty aroma. Other compounds shown many times peak at different RT was 3-Cyclohexene-1-methanol with sum of area % was 37.05 Many scientists had proven their potential anti-inflammatory and antimicrobial properties. Same in the range or less than five % area covered include that Limonene and It was found to be 3.15% Mostly limonene is responsible for the scent in fresh herbs Therefore it is used in perfumery. This can also be recognized for aroma therapy and potential health benefits.

In case of compounds with Minimal Presence (Area % < 1%): Camphene was found as 0.02% and it is under the class of bicyclic monoterpene and shown a camphor-like aroma, therefore it is used in fragrances and as a flavouring agent. 3-Carene was found with 0.27% area also A bicyclic

monoterpene that has a sweet, pungent aroma, often found in pine and cedar. Phenol, 2-methoxy-3-(2-propenyl) with 0.27% and This compound has a clove-like aroma and is used in flavouring and fragrance applications. n-Hexadecanoic acid: 0.02% also known as saturated fatty acid that contributes a waxy, fatty note to the aroma profile. Farnesol: 0.01% recognized as A sesquiterpene alcohol with a floral scent, commonly used in perfumes and cosmetics. The flavour compounds identified in the volatile oil of *Elettaria cardamomum* classified based on their chemical structure and aroma characteristics. The data shown Monoterpenes with an example of Limonene, Eucalyptol, Camphene with characteristics flavour of fresh, citrusy, or herbal aroma. In Sesquiterpenes class with examples of Farnesol, Germacrene D and it was contributed to deeper, earthy, or woody notes many alcohol derivatives especially 3-Cyclohexene-1-methanol, Terpeneol Similarly in Aldehydes provides sweet, floral, or fruity aromas 2,6-Octadienal many ester compounds like Methyl cinnamate which was characterized as fruity and sweet in aroma. Overall compounds were detected through cardamom volatile oils suggested 54 compounds and similar results also compared with bioactivity founds in literatures cited here with references in table.5 it suggested antifungal, antimicrobial, insecticidal, flavouring compounds in food as well as the

Table.4 Volatile /Essential oils from different seeds and plant parts.

Peak No.	RT (min)	Area (%)	Compound Identified
1	7.37	1.15	(1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene
2	8.254	0.02	Camphene
3	9.349	3.41	Bicyclo[3.1.0]hexane, 4-methylene-1-(1-methylethyl)-
4	9.82	1.63	β.-Myrcene
5	10.356	0.27	3-Carene
6	10.786	0.41	Bicyclo[4.1.0]hept-2-ene, 3,7,7-trimethyl-
7	11.294	3.15	Limonene
8	12.199	25.79	Eucalyptol
9	12.468	0.81	1,4-Cyclohexadiene, 1-methyl-4-(1-methylethyl)-
10	13.078	0.73	Terpineol, cis-.β.-
11	13.279	0.83	Cyclohexene, 1-methyl-4-(1-methylethylidene)-
12	13.645	0.62	Cyclohexane, 2-ethenyl-1,1-dimethyl-3-methylene-
13	13.946	1.23	1,6-Octadien-3-ol, 3,7-dimethyl-
14	14.251	1.3	cis-.β.-Terpineol
15	14.852	0.81	2-Cyclohexen-1-ol, 1-methyl-4-(1-methylethyl)-, trans-
16	15.624	0.92	2-Cyclohexen-1-ol, 1-methyl-4-(1-methylethyl)-, cis-
17	16.386	0.59	2-Octenoic acid, methyl ester, (E)-
18	16.752	3.07	3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-
19	17.402	2.45	(+)-.α.-Terpineol (p-menth-1-en-8-ol)

Peak No.	RT (min)	Area (%)	Compound Identified
20	17.905	1.63	1,6-Octadien-3-ol, 3,7-dimethyl-, 2-aminobenzoate
21	18.999	2.49	1,6-Octadien-3-ol
22	19.332	0.75	Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, acetate, (1S-endo)-
23	19.801	1.11	2,6-Octadienal
24	21.439	37.05	3-Cyclohexene-1-methanol
25	21.674	0.25	cis-Dodec-5-enal
26	21.821	1.12	2,6-Octadien-1-ol, 3,7-dimethyl-, acetate
27	21.996	0.48	.gamma.-Elemene
28	22.459	0.51	LONGIPINENE <B-> DB5-1393
29	22.727	0.5	3-Cyclohexene-1-methanol, α .,4-trimethyl-, propanoate
30	22.866	0.27	Phenol, 2-methoxy-3-(2-propenyl)-
31	23.383	0.54	Germacrene D
32	23.554	1.27	Eudesma-4(14),11-diene
33	23.938	0.46	METHYL CINNIMATE <(E)-> DB5-1342
34	24.232	0.37	Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-, (1. α .,4a. β .,8a. α .)-
35	24.815	0.27	3,7,11-Tridecatrienitrile, 4,8,12-trimethyl-
36	25.126	0.84	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-
37	25.485	0.3	GERMACRENE B
38	26.023	0.14	cis,cis,cis-7,10,13-Hexadecatrienal
39	26.345	0.14	1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-, [1aR-(1a. α .,4a. α .,7. α .,7a. β .,7b. α .)]-
40	27.286	0.1	GERMACRENE D-4-OL
41	27.749	0.02	Acetic acid, 1-methyl-1-(4-methyl-5-oxo-cyclohex-3-enyl)ethyl ester
42	28.467	0	SELIN-11-EN-4 A-OL
43	29.17	0.04	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-, (Z,E)-
44	29.76	0.02	2,6,10-Dodecatrienal, 3,7,11-trimethyl-, (E,E)-
45	30.975	0.02	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-, acetate, (E,E)-
46	31.877	0.01	Acetic acid, 1-[2-(2,2,6-trimethyl-bicyclo[4.1.0]hept-1-yl)-ethyl]-vinyl ester
47	32.389	0.02	n-Hexadecanoic acid
48	34.179	0.01	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester
49	35.13	0.03	1,2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester
50	35.457	0.01	Tetradecane
51	37.04	0.02	Retinal, 9-cis-
52	38.37	0.01	Tetratetracontane
53	39.985	0.01	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-, (Z,E)-
54	41.441	0.01	FARNESOL

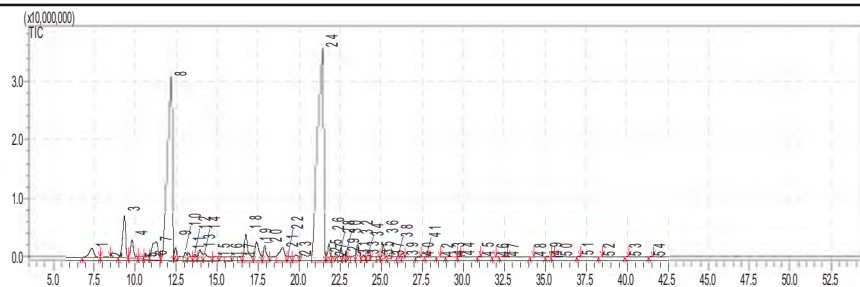


Figure 2 : Chromatogram of Volatile oils of Eleutheria cardamomum (L.) Maton

Table.3 : Application and bioactivity reported compounds Volatile and fixed oil of cardamom

No.	Compound	Reported activity or properties	Reference
1	(1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene	Antimicrobial	Alam <i>et al.</i> , 2019 Bhutia <i>et al.</i> , 2022; Noumi <i>et al.</i> , 2018 Alam <i>et al.</i> , 2019; Singh <i>et al.</i> , 2008
2	Camphene	Antifungal	Bhutia <i>et al.</i> , 2022; Noumi <i>et al.</i> , 2018
3	Bicyclo[3.1.0]hexane, 4-methylene-1-(1-methylethyl)	Insect-repellent/insecticidal potential	Hosseinpour <i>et al.</i> , 2011 Bhutia <i>et al.</i> , 2022; Vijayan <i>et al.</i> , 2017 Masoumi-Ardakani <i>et al.</i> , 2016 Bhutia <i>et al.</i> , 2022; Ashokkumar <i>et al.</i> , 2021; Tan <i>et al.</i> , 2023
4	β -Myrcene	Analgesic	Masoumi-Ardakani <i>et al.</i> , 2016
5	3-Carene	Anti-inflammatory	Bhutia <i>et al.</i> , 2022; Noumi <i>et al.</i> , 2018 Singh <i>et al.</i> , 2008
6	Bicyclo[4.1.0]hept-2-ene,	Antioxidant	Bhutia <i>et al.</i> , 2022; Noumi <i>et al.</i> , 2018 Ahamad, 2024; Alam <i>et al.</i> , 2019 Bhutia <i>et al.</i> , 2022; Ashokkumar <i>et al.</i> , 2021; Tan <i>et al.</i> , 2023
7	Limonene	Anticancer	Masoumi-Ardakani <i>et al.</i> , 2016; Alam <i>et al.</i> , 2019; Bhutia <i>et al.</i> , 2022; Vijayan <i>et al.</i> , 2017; Ashokkumar <i>et al.</i> , 2021; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
8	Eucalyptol (1,8-Cineole)	Respiratory stimulant / respiratory	Tan <i>et al.</i> , 2023
9	1,4-Cyclohexadiene	Cytotoxic activity	Noumi <i>et al.</i> , 2018 Masoumi-Ardakani <i>et al.</i> , 2016
10	cis- β -Terpineol	Sedative effects	Ashokkumar <i>et al.</i> , 2021; Tan <i>et al.</i> , 2023
11	Cyclohexene	Solvent properties	Tan <i>et al.</i> , 2023
12	Cyclohexane	Industrial solvent	Tan <i>et al.</i> , 2023 Singh <i>et al.</i> , 2008; Alam <i>et al.</i> , 2019 Bhutia <i>et al.</i> , 2022; Ashok kumar <i>et al.</i> , 2021; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
13	1,6-Octadien-3-ol (Linalool)	Antimicrobial	Singh <i>et al.</i> , 2008; Masoumi-Ardakani <i>et al.</i> , 2016; Ashokkumar <i>et al.</i> , 2021; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
14	cis- β -Terpineol	Antioxidant	Tan <i>et al.</i> , 2023
15	2-Cyclohexen-1-ol	Flavoring	Tan <i>et al.</i> , 2023
16	cis-2-Cyclohexen-1-ol	Fragrance	Tan <i>et al.</i> , 2023
17	2-Octenoic acid	Antimicrobial	Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
18	3-Cyclohexen-1-ol	Flavor enhancer	Tan <i>et al.</i> , 2023 Masoumi-Ardakani <i>et al.</i> , 2016; Singh <i>et al.</i> , 2008; Bhutia <i>et al.</i> , 2022; Vijayan <i>et al.</i> , 2017; Ashokkumar <i>et al.</i> , 2021; Tan <i>et al.</i> , 2023
19	(+)- α -Terpineol	Relaxant effects	Tan <i>et al.</i> , 2023; Noumi <i>et al.</i> , 2018 Singh <i>et al.</i> , 2008; Ashokkumar <i>et al.</i> , 2021; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
20	1,6-Octadien-3-ol	Potential neuroprotective	Bhutia <i>et al.</i> , 2022; Vijayan <i>et al.</i> , 2017 Tan <i>et al.</i> , 2023
21	1,6-Octadien-3-ol (Linalool)	Antioxidant	
22	Bicyclo[2.2.1]heptan-2-ol	Insect pheromone mimic	Bhutia <i>et al.</i> , 2022; Vijayan <i>et al.</i> , 2017
23	2,6-Octadienal	Flavoring agent	Tan <i>et al.</i> , 2023

No.	Compound	Reported activity or properties	Reference
24	3-Cyclohexene-1-methanol	Fragrance	Tan <i>et al.</i> , 2023
25	cis-Dodec-5-enal	Antimicrobial	Noumi <i>et al.</i> , 2018 Alam <i>et al.</i> , 2019; Singh <i>et al.</i> , 2008
26	2,6-Octadien-1-ol	Antimicrobial	Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
27	γ -Elemene	Antitumor	Noumi <i>et al.</i> , 2018 Hosseinpour <i>et al.</i> , 2011; Bhutia <i>et al.</i> , 2022;
28	Longipinene	Insecticidal	Noumi <i>et al.</i> , 2018
29	3-Cyclohexene-1-methanol, $\alpha,\alpha,4$ -trimethyl-, propanoate	Antioxidant	Singh <i>et al.</i> , 2008; Noumlet <i>al.</i> , 2018; Tan <i>et al.</i> , 2023
30	Phenol, 2-methoxy-3-(2-propenyl)-	Antifungal	Singh <i>et al.</i> , 2008
31	Germacrene D	Antimicrobial	Noumi <i>et al.</i> , 2018 Alam <i>et al.</i> , 2019; Noumi <i>et al.</i> , 2018 Masoumi-Ardakani <i>et al.</i> , 2016
32	Eudesma-4(14),11-diene	Anti-inflammatory	Noumi <i>et al.</i> , 2018
33	Methyl cinnamate	Analgesic	Tan <i>et al.</i> , 2023
34	Naphthalene derivative (1H-Cycloprop[e]azulene)	Antimicrobial	Alam <i>et al.</i> , 2019; Singh <i>et al.</i> , 2008 Noumlet <i>al.</i> , 2018
35	3,7,11-Tridecatrienitrile, 4,8,12-trimethyl-	Insect repellent	Hosseinpour <i>et al.</i> , 2011; Bhutia <i>et al.</i> , 2022; Noumi <i>et al.</i> , 2018
36	1,6,10-Dodecatrien-3-ol	Antioxidant	Noumi <i>et al.</i> , 2018
37	Germacrene	Antimicrobial	Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018 Alam <i>et al.</i> , 2019; Noumi <i>et al.</i> , 2018
38	cis,cis,cis-7,10,13-Hexadecatrienal	Insect pheromone	Noumlet <i>al.</i> , 2018;
39	1H-Cycloprop[e]azulene	Cytotoxic effects	Majeed <i>et al.</i> , 2023; Noumi <i>et al.</i> , 2018
40	Germacrene D-4-ol	Antimicrobial	Alam <i>et al.</i> , 2019; Noumi <i>et al.</i> , 2018 Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
41	Acetic acid	Antimicrobial properties	Alam <i>et al.</i> , 2019; Noumi <i>et al.</i> , 2018 Masoumi-Ardakani <i>et al.</i> , 2016; Noumi <i>et al.</i> , 2018
42	Selin-11-en-4 α -ol	Anti-inflammatory	2018
43	2,6,10-Dodecatrien-1-ol	Antioxidant	Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018
44	2,6,10-Dodecatrienal	Antimicrobial	Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018
45	2,6,10-Dodecatrien-1-ol	Antimicrobial	Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018
46	Acetic acid	—	Singh <i>et al.</i> , 2008; Tan <i>et al.</i> , 2023 Singh <i>et al.</i> , 2008, Tan <i>et al.</i> , 2023; Noumlet <i>al.</i> , 2018
47	n-Hexadecanoic acid (Palmitic acid)	Antimicrobial properties	Alam <i>et al.</i> , 2019; Noumi <i>et al.</i> , 2018 Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
48	1,2-Benzenedicarboxylic acid (Phthalic acid)	Plasticizer	Alam <i>et al.</i> , 2019; Noumi <i>et al.</i> , 2018 Tan <i>et al.</i> , 2023
49	1,2-Benzenedicarboxylic acid	Plasticizer	Tan <i>et al.</i> , 2023
50	Tetradecane	Biocompatibility	Tan <i>et al.</i> , 2023
51	Retinal	Vision-related function	Tan <i>et al.</i> , 2023
52	Tetratetracontane	Hydrophobic property	Tan <i>et al.</i> , 2023
53	2,6,10-Dodecatrien-1-ol	—	Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018 Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023
54	Farnesol	Antifungal properties	Alam <i>et al.</i> , 2019; Noumi <i>et al.</i> , 2018 Singh <i>et al.</i> , 2008; Noumi <i>et al.</i> , 2018; Tan <i>et al.</i> , 2023

CONCLUSION

Studies on key bioactive compounds in Volatile of cardamom through analytical instruments of GCMS showed α -Terpinyl acetate (37.05%), Eucalyptol (25.79%) and Sabinene (3.41%). The volatile oil of *Elettaria cardamomum* composed of more than 50 compounds with Eucalyptol and 3-Cyclohexene-1-methanol were found to be maximum including the presence of various monoterpenes, sesquiterpenes, and alcohols these were pertaining to flavor and aroma contribution in cardamom, thus it is being used as ingredient in culinary and aromatic in food application. The compounds detection through literatures indicated many bioactivities were reported and has potential health benefits with uses in traditional and modern era.

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