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The Essential Oil of *Citrus aurantifolia* Metabolic Profiling by GC/MS Analysis

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Abstract: Essential oil obtained from *Citrus aurantifolia* has been shown to have various biological activities. Hence, it has been traditionally used in the management of numerous diseases and has the prospects of being developed into valuable drugs. A total of forty-eight volatile compounds of biological interests were characterized qualitatively and quantitatively using GC/MS technique. These compounds comprise two main groups, monoterpenes (67.39%) and sesquiterpenes (25.08%). The more abundant components of *C. aurantifolia* essential oil were *α*-terpineol (9.78%), *p*-cymene (9.32%), *β*-pinene (7.68%), D-limonene (6.64%), 1-terpinen-4-ol (5.91%), (+)-*α*-himachalene (5.87%), citronellol (5.81%), linalool (5.57%), geraniol (4.40%), *α*-citral (3.92%) and *α*-bergamotene (3.15%).

keywords: Volatile oil, *Citrus aurantifolia*, essential oil, GC/MS analysis, metabolic profiling.

1.Introduction

Essential oils (EOs), consisting of volatile components, display a range of biological activities, including antioxidant, antimicrobial, anti-inflammatory, and immunomodulatory properties **[1]**. They are regarded as a part of traditional medicines. They were most likely in use in ancient Egypt as early as 5000 BCE **[2]**. Essential oils are identified as safe substances by the United States Food and Drug Administration and are regarded as a proper alternative to food preservation methods, such as natural antimicrobial agents **[3]**.

Citrus aurantifolia, (Christm.) Swingle, commonly known as lime or key lime, belongs to the family Rutaceae, a well-known evergreen spiny tree, to 7 m; leaves 5 -7.5 x 3.5 cm, elliptic, with characteristic winged petiole, acuminate, with spiny stipules; flowers axillary, in groups, white, c. 1.3 cm; fruit globose to ovoid, with appendages, greenish yellow, 2.5 - 3.5 cm in diameter, which distributes in tropical and subtropical region **[4,5]**.

The phytochemical screening revealed that *C. aurantifolia* essential oil contains many different secondary metabolites including *β*-pinene, D-limonene, neral, linalool, *α*-terpineol, *p*-cymene **[6,7]**, *γ*-terpinolene **[8]**, citral **[9]**, bornane and germacrene isomers **[10]**, as the main compounds of this oil. Other substances found in *C. aurantifolia* essential oil include citronellol, neryl acetate, fenchone, farnesene, geraniol, felandrene, sesquiphellandrene, and linalyl acetate **[11,12]**.

The essential oil of *C. aurantifolia* peel contains 75% terpenes, 12% oxygenated substances, and 3% sesquiterpenes. Among the volatile components are monoterpenes (include d-limonene and *γ*-terpinene), sesquiterpenes, hydrocarbons (and their oxygenated derivatives for instance linalool, geranial, and nonanal), As well as aldehydes, ketones, alcohols, acids, and esters. Volatile compounds are further classified as alcohols, aldehydes, ketones, ethers, esters, amines, amides, heterocyclics, phenols, and specially terpene **[13]**. whereas, non-volatile components involve fatty acids, long chain hydrocarbons, sterols, limonoids, and waxes **[14]**.

Lime (*C. aurantifolia*) represents a promising medicinal plant as their essential oil has various biological activity such as antioxidant, antimicrobial, and insecticidal activity **[15]**. Besides, antiulcer, Anti-obesity activity, antityphoid, hypolipidemic, and

hepatoprotective properties **[11]**. Furthermore, it has exhibited a significant anticancer effect **[16]** and useful in treating Alzheimer's disease **[17]**. Recently, Citrus essential oils have been used to treat severe respiratory syndrome caused by coronavirus **[18]**.

Traditionally, lime essential oil has been used to relieve common cold, flu, asthma, arthritis, and bronchitis **[19]**. Moreover, they are utilized by the food industry to give flavoring to foods and drinks. Additionally, they have many applications in the pharmaceutical industry for the preparation of drugs, soaps, fragrances, hair creams, body oils and other kinds of cosmetics as well as for home cleaning products **[20]**.

Ultimately, different *Citrus* essential oils have distinctive pleasant fragrances, which makes them important in aromatherapy, especially for treating emotional, psychological, and memory issues like pain, depression, and anxiety **[21]**.

Herein, this study was directed to identify the bioactive phytochemicals produced from the less polar extract, chloroform, of *Citrus aurantifolia* peels using GC/MS technique.

2. Materials and methods

2.1. General

GC/MS analysis of the volatile fractions was carried out on a Varian GC / Finnegan SSQ 7000 Mass, its description and specification as described previously **[22]**.

2.2. Chemicals

Anhydrous sodium sulphate was purchased from ADWIC Company, Egypt.

2.3. plant material

C. aurantifolia peels was collected from Faculty

of Agriculture Garden, Mansoura University, Egypt in September 2021.

2.4. Extraction process

C. aurantifolia fresh peels (690 g) were extracted by hot water (8×15L) for 15 mins then filtrated, the water extract was exposed to hydro-distillation using a Clevenger-type apparatus for 8 hours. The obtained oil was dried over anhydrous sodium sulfate (0.731g, 0.11% from fresh peels).

3. Results and Discussion

The essential oil of *C. aurantifolia* peels was isolated by hydro-distillation using a Clevenger-type apparatus. The essential oil metabolic profiling was investigated using chromatographic retention data (GC), mass spectra acquired by GC/MS. Sample components are identified by comparing their mass spectra to those of known compounds found in mass spectral libraries NIST and Wiley. GC/MS analyses of *C. aurantifolia* essential oils (Table 1) qualified and quantified the presence of different secondary metabolites belonging to several classes, oxygenated monoterpenes (42.46%) are the highest in concentration followed by monoterpenes hydrocarbon (24.93%), sesquiterpenes hydrocarbon (17.63%) and oxygenated sesquiterpenes (7.45%).

Forty-eight compounds were efficiently matched and recognized in *C. aurantifolia* essential oil, and the most abundant compounds were *α*-terpineol (9.78%), *p*-cymene (9.32%), *β*-pinene (7.68%), D-limonene (6.64%), 1-terpinen-4-ol (5.91%), (+)-*α*-himachalene (5.87%), citronellol (5.81%), linalool (5.57%), geraniol (4.40%), *α*-citral (3.92%) and *α*-bergamotene (3.15%). A further characterization for each identified metabolite was performed by matching their mass fragmentation peaks with their own mass spectra obtained from GC/MS (table 1).

Table 1. Identified volatile constituents of essential oil of *C. aurantifolia* peels using GC/MS technique.

No.	Compound name	R_t	Area %	MF	M. Wt.	m/z (ret. Int. %)
Monoterpenes Hydrocarbons						
1	*β*-Pinene	4.29	7.68	$C_{10}H_{16}$	136	136 (12) $[M]^+$, 121(18) $[C_9H_{13}]^+$, 93 (100) $[C_7H_9]^+$, 53 (10) $[C_4H_5]^+$, 94 (16) $[C_7H_{10}]^+$, 55 (20) $[C_4H_7]^+$, 106 (6) $[C_8H_{10}]^+$, 107 (5) $[C_8H_{11}]^+$, 70 (25) $[C_5H_{10}]^+$, 83 (14) $[C_6H_{11}]^+$, 80 (15) $[C_6H_8]^+$, 79 (38) $[C_6H_7]^+$,

						67 (22) $[C_5H_7]^+$, 69 (25) $[C_5H_9]^+$.
2	*p*-Cymene	5.15	9.32	$C_{10}H_{14}$	134	134 (30) $[M]^+$, 119 (100) $[C_9H_{11}]^+$, 91 (35) $[C_7H_7]^+$, 77 (7) $[C_6H_5]^+$, 104 (5) $[C_8H_8]^+$.
3	D-Limonene	5.32	6.64	$C_{10}H_{16}$	136	136 (15) $[M]^+$, 107 (29) $[C_8H_{11}]^+$, 121 (32) $[C_9H_{13}]^+$, 67 (100) $[C_5H_7]^+$, 68 (78) $[C_5H_8]^+$, 53 (18) $[C_4H_5]^+$, 107 (29) $[C_8H_{11}]^+$, 54 (5) $[C_4H_6]^+$, 94 (52) $[C_7H_{10}]^+$, 81 (13) $[C_6H_9]^+$.
4	γ-Terpinene	5.89	0.88	$C_{10}H_{16}$	136	136 (39) $[M]^+$, 121 (34) $[C_9H_{13}]^+$, 93 (100) $[C_7H_9]^+$, 79 (28) $[C_6H_7]^+$, 93 (100) $[C_7H_9]^+$, 91 (70) $[C_7H_7]^+$, 77 (40) $[C_6H_5]^+$, 65 (10) $[C_5H_5]^+$, 106 (14) $[C_8H_{10}]^+$, 68 (8) $[C_5H_8]^+$.
5	*p*-Mentha-1,4(8)-diene	6.53	0.41	$C_{10}H_{16}$	136	136 (69) $[M]^+$, 121 (80) $[C_9H_{13}]^+$, 10 (18) $[C_8H_{11}]^+$, 93 (100) $[C_7H_9]^+$, 91 (70) $[C_7H_7]^+$, 79 (43) $[C_6H_7]^+$, 77 (36) $[C_6H_5]^+$, 65 (12) $[C_5H_5]^+$, 92 (17) $[C_7H_8]^+$.
Total			**24.93**			
Oxygenated Monoterpenes						
6	Linalool	6.74	5.57	$C_{10}H_{18}O$	154	154 (1) $[M]^+$, 71 (98) $[C_4H_7O]^+$, 69 (41) $[C_5H_9]^+$, 54 (62) $[C_4H_6]^+$, 83 (17) $[C_6H_{11}]^+$, 68 (12) $[C_5H_8]^+$, 139 (5) $[C_9H_{15}O]^+$, 70 (8) $[C_4H_6]^+$.
7	(1R)-endo- (+)-Fenchyl alcohol	6.97	0.56	$C_{10}H_{18}O$	154	154 (5) $[M]^+$, 81 (100) $[C_6H_9]^+$, 121 (22) $[C_9H_{13}]^+$, 139 (10) $[C_9H_{15}O]^+$, 53 (11) $[C_4H_5]^+$, 55(30)$[C_4H_7]^+$,67 (31) $[C_5H_7]^+$, 107 (18) $[C_8H_{11}]^+$, 77 (12) $[C_6H_5]^+$, 106 (5) $[C_8H_{10}]^+$.
8	*cis*-Limonene oxide	7.36	0.74	$C_{10}H_{16}O$	152	152 (5) $[M]^+$, 67 (100) $[C_5H_7]^+$, 109 (58) $[C_8H_{13}]^+$, 137 (52) $[C_9H_{13}O]^+$, 81 (42) $[C_6H_9]^+$, 82 (26) $[C_6H_{10}]^+$, 122 (14) $[C_8H_{10}O]^+$, 96 (8) $[C_6H_8O]^+$, 83 (19) $[C_5H_7O]^+$, 54 (7) $[C_4H_6]^+$, 95 (35) $[C_7H_{11}]^+$.
9	*p*-Mentha-1,8-dien-7-ol	7.64	0.45	$C_{10}H_{16}O$	152	152 (5) $[M]^+$, 122 (24) $[C_9H_{14}]^+$, 93 (63) $[C_7H_9]^+$, 79 (100) $[C_6H_7]^+$, 67 (49) $[C_5H_7]^+$, 94 (33)$[C_7H_{10}]^+$,109 (32) $[C_7H_9O]^+$, 137 (10) $[C_9H_{13}O]^+$, 111 (14) $[C_7H_{11}O]^+$, 80 (28) $[C_6H_8]^+$, 53 (15) $[C_4H_5]^+$, 78 (9) $[C_6H_6]^+$, 92 (21) $[C_7H_8]^+$, 81 (29) $[C_6H_9]^+$, 65 (13) $[C_6H_5]^+$.
10	Isoborneol	8.12	0.84	$C_{10}H_{18}O$	154	154 (3) $[M]^+$, 136 (5) $[C_{10}H_6]^+$, 139 (4) $[C_9H_{15}O]^+$, 110 (16) $[C_7H_{10}O]^+$, 95 (100) $[C_7H_{11}]^+$, 94 (13) $[C_7H_{10}]^+$, 67 (18) $[C_5H_7]^+$, 69 (17) $[C_5H_9]^+$, 55 (19) $[C_4H_7]^+$, 122 (8) $[C_6H_{14}]^+$, 109 (5) $[C_8H_{13}]^+$, 79 (9) $[C_6H_7]^+$, 65 (4) $[C_5H_5]^+$.
11	1-Terpinen-4-ol	8.47	5.91	$C_{10}H_{18}O$	154	154 (16) $[M]^+$, 111 (59) $[C_7H_{11}O]^+$, 93 (70) $[C_7H_9]^+$, 91 (26) $[C_7H_7]^+$, 68 (14) $[C_5H_8]^+$, 55 (23) $[C_4H_7]^+$, 95 (12) $[C_7H_{10}]^+$, 53 (9) $[C_4H_5]^+$, 139 (6) $[C_9H_{15}O]^+$, 110 (10) $[C_7H_{10}O]^+$, 121 (5) $[C_9H_{13}]^+$, 79 (10)$[C_6H_7]^+$, 77 (15) [15) $[C_6H_5]^+$, 92 (16) $[C_7H_8]^+$.
12	α-terpineol	8.81	9.78	$C_{10}H_{18}O$	154	154 (1) $[M]^+$, 121 (98) $[C_9H_{13}]^+$, 93 (100) $[C_7H_9]^+$, 92 (36) $[C_7H_8]^+$, 91 (25) $[C_7H_7]^+$, 81 (56) $[C_6H_9]^+$, 80 (10) $[C_6H_8]^+$, 79 (29) $[C_6H_7]^+$, 77 (19) $[C_6H_5]^+$, 67 (32) $[C_5H_7]^+$, 59 (93) $[C_3H_7O]^+$, 95 (22) $[C_7H_{11}]^+$, 139 (12) $[C_9H_{15}O]^+$, 68 (12) $[C_5H_8]^+$, 106 (15) $[C_8H_{10}]^+$, 107 (17) $[C_8H_{11}]^+$.
13	*p*-Menth-1-en-9-al	9.16	0.24	$C_{10}H_{16}O$	152	152 (1) $[M]^+$, 109 (9) $[C_8H_{13}]^+$, 93 (28) $[C_7H_9]^+$, 91 (24) $[C_7H_7]^+$, 79 (89) $[C_6H_7]^+$, 55 (29) $[C_4H_7]^+$, 81 (23) $[C_6H_9]^+$, 77 (20) $[C_6H_5]^+$, 68 (19) $[C_5H_8]^+$, 57 (15) $[C_3H_5O]^+$, 122 (8) $[C_8H_{10}O]^+$,137 (5) $[C_9H_{13}O]^+$, 95 (28) $[C_7H_{11}]^+$, 80 (9) $[C_6H_8]^+$.
14	(*E*)-Carveol	9.21	0.21	$C_{10}H_{16}O$	152	152 (1) $[M]^+$, 109 (9) $[C_8H_{13}]^+$, 93 (28) $[C_7H_9]^+$, 91 (24) $[C_7H_7]^+$, 79 (89) $[C_6H_7]^+$, 55 (29) $[C_4H_7]^+$, 81 (23) $[C_6H_9]^+$, 77 (20) $[C_6H_5]^+$, 68 (19) $[C_5H_8]^+$, 57 (15) $[C_3H_5O]^+$, 122 (8) $[C_8H_{10}O]^+$,137 (5) $[C_9H_{13}O]^+$

						, 95 (28) $[C_7H_{11}]^+$, 80 (9) $[C_6H_8]^+$.
15	Citronellol	9.80	5.81	$C_{10}H_{20}O$	156	156 (1) $[M]^+$, 123 (15) $[C_9H_{15}]^+$, 109 (22) $[C_8H_{13}]^+$, 81 (42)$[C_6H_9]^+$, 82 (32) $[C_6H_{10}]^+$, 69 (100) $[C_5H_7]^+$, 67 (60) $[C_5H_7]^+$, 55 (30) $[C_4H_7]^+$, 68 (24) $[C_5H_8]^+$.
16	Geraniol	10.41	4.40	$C_{10}H_{18}O$	154	154 (1) $[M]^+$, 139 (5) $[C_9H_{15}O]^+$, 121 (12) $[C_9H_{13}]^+$, 93 (20)$[C_7H_9]^+$, 69 (100) $[C_5H_9]^+$, 68 (22) $[C_5H_8]^+$, 67 (24) $[C_5H_7]^+$, 53 (7) $[C_4H_5]^+$, 54 (8) $[C_4H_6]^+$, 81 (10) $[C_6H_9]^+$, 71 (8) $[C_4H_7O]^+$, 55 (9) $[C_4H_7]^+$, 83 (8) $[C_6H_{11}]^+$, 79 (7) $[C_6H_7]^+$.
17	α-Citral	10.56	3.92	$C_{10}H_{16}O$	152	152 (5) $[M]^+$, 137 (22) $[C_9H_{13}O]^+$, 123 (15) $[C_9H_{15}]^+$, 109 (24) $[C_8H_{13}]^+$, 69 (100) $[C_5H_9]^+$, 94 (23) $[C_7H_{10}]^+$, 83 (20) $[C_5H_7O]^+$, 81 (12) $[C_6H_9]^+$, 55 (8) $[C_4H_7]^+$, 70 (7) $[C_5H_{10}]^+$, 78 (5) $[C_6H_6]^+$.
18	α-Limonene diepoxide	10.84	0.25	$C_{10}H_{16}O_2$	168	168 (1) $[M]^+$, 139 (5) $[C_8H_{11}O_2]^+$, 109 (22) $[C_8H_{13}]^+$, 55 (19) $[C_4H_7]^+$, 95 (30) $[C_6H_7O]^+$, 69 (25) $[C_4H_5O]^+$, 67 (24) $[C_4H_3O]^+$, 80 (12) $[C_6H_8]^+$, 57 (8) $[C_3H_5O]^+$, 83 (15) $[C_5H_7O]^+$.
19	Linalool oxide	11.28	0.29	$C_{10}H_{18}O_2$	170	170 (1) $[M]^+$, 59 (100) $[C_3H_7O]^+$, 71 (60) $[C_4H_7O]^+$, 69 (28) $[C_4H_5O]^+$, 67 (31) $[C_5H_7]^+$, 58 (17) $[C_3H_6O]^+$, 54 (26) $[C_4H_6]^+$, 53 (10) $[C_4H_5]^+$, 111 (21) $[C_7H_{11}O]^+$, 81 (20) $[C_6H_9]^+$.
20	*p*-Mentha-1,8-dien-7-ol	11.33	0.32	$C_{10}H_{16}O$	152	152 (5) $[M]^+$, 137 (12) $[C_9H_{13}O]^+$, 139 (13) $[C_9H_{15}O]^+$, 109 (46) $[C_7H_9O]^+$, 93 (70) $[C_7H_9]^+$, 91 (60) $[C_7H_7]^+$, 79 (100) $[C_6H_7]^+$, 55 (50) $[C_4H_7]^+$, 53 (24) $[C_4H_5]^+$, 70 (35) $[C_4H_6O]^+$, 77 (33) $[C_6H_5]^+$, 83 (29) $[C_5H_7O]^+$, 97 (23) $[C_6H_9O]^+$.
21	5,9-Dimethyl-4,8-decadienal	12.84	0.27	$C_{12}H_{20}O$	180	180 (1) $[M]^+$, 81 (100) $[C_6H_9]^+$, 69 (78) $[C_5H_9]^+$, 95 (72) $[C_7H_{11}]^+$, 97 (62) $[C_6H_9O]^+$, 123 (45) $[C_9H_{15}]^+$, 55 (48) $[C_4H_7]^+$, 83 (36) $[C_6H_{11}]^+$, 137 (6) $[C_{10}H_{17}]^+$.
22	Nerol acetate	13.06	0.84	$C_{12}H_{20}O_2$	196	196 (1) $[M]^+$, 69 (100) $[C_5H_9]^+$, 68 (44) $[C_5H_8]^+$, 67 (33) $[C_5H_7]^+$, 53 (10) $[C_4H_5]^+$, 93 (58) $[C_7H_9]^+$, 154 (4) $[C_{10}H_{18}O]^+$, 55 (8) $[C_4H_7]^+$, 137 (5) $[C_{10}H_{17}]^+$, 127 (2) $[C_7H_{11}O_2]^+$, 83 (7) $[C_6H_{11}]^+$.
23	2,6-Dimethyl-2,6-octadien-8-yl acetate	13.52	2.06	$C_{12}H_{20}O_2$	196	196 (1) $[M]^+$, 69 (100) $[C_5H_9]^+$, 68 (44) $[C_5H_8]^+$, 67 (33) $[C_5H_7]^+$, 53 (10) $[C_4H_5]^+$, 93 (58) $[C_7H_9]^+$, 154 (4) $[C_{10}H_{18}O]^+$, 55 (8) $[C_4H_7]^+$, 137 (5) $[C_{10}H_{17}]^+$, 127 (2) $[C_7H_{11}O_2]^+$, 83 (7)$[C_6H_{11}]^+$.
Total			**42.46**			
Sesquiterpenes Hydrocarbons						
24	δ-EIemene	12.72	0.30	$C_{15}H_{24}$	204	204 (1) $[M]^+$, 189 (5) $[C_{14}H_{21}]^+$, 161 (29) $[C_{12}H_{17}]^+$, 136 (45) $[C_{10}H_{16}]^+$, 93 (84) $[C_7H_9]^+$, 91 (40) $[C_7H_7]^+$, 79 (29) $[C_6H_7]^+$, 77 (24) $[C_6H_5]^+$, 67 (15) $[C_5H_7]^+$, 107 (17) $[C_8H_{11}]^+$, 92 (18) $[C_7H_8]^+$, 119 (12) $[C_9H_{11}]^+$.
25	β-Elemene	14.01	0.29	$C_{15}H_{24}$	204	204 (2) $[M]^+$, 93 (100) $[C_7H_9]^+$, 81 (82) $[C_6H_9]^+$, 67 (71) $[C_5H_7]^+$, 107 (70) $[C_8H_{11}]^+$, 121 (42) $[C_9H_{13}]^+$, 147 (45) $[C_{11}H_{15}]^+$, 161 (32) $[C_{12}H_{17}]^+$, 189 (28) $[C_{14}H_{21}]^+$, 68 (50) $[C_5H_8]^+$, 163 (5) $[C_{12}H_{19}]^+$, 95 (45) $[C_7H_{11}]^+$.
26	Caryophyllene	14.64	2.34	$C_{15}H_{24}$	204	204 (4) $[M]^+$, 53 (16) $[C_4H_5]^+$, 69 (55) $[C_5H_9]^+$, 67 (35) $[C_5H_7]^+$, 81 (33) $[C_6H_9]^+$, 91 (100) $[C_7H_7]^+$, 93 (84) $[C_7H_9]^+$, 107 (42) $[C_8H_{11}]^+$, 189 (20) $[C_{14}H_{21}]^+$.
27	α-Bergamotene	15.13	3.15	$C_{15}H_{24}$	204	204 (2) $[M]^+$, 119 (100) $[C_9H_{11}]^+$, 93 (82) $[C_7H_9]^+$, 91 (50) $[C_7H_7]^+$, 53 (7) $[C_4H_5]^+$, 55 (18) $[C_4H_7]^+$, 69 (28) $[C_5H_9]^+$,107 (32) $[C_8H_{11}]^+$, 120 (17) $[C_9H_{12}]^+$, 189 (4) $[C_{14}H_{21}]^+$, 135 (5) $[C_{10}H_{15}]^+$, 81 (9) $[C_6H_9]^+$.
28	Humulene	15.4	0.54	$C_{15}H_{24}$	204	204 (5) $[M]^+$, 93 (100) $[C_7H_9]^+$, 80 (30) $[C_6H_8]^+$, 53

		3				(8) $[C_4H_5]^+$, 55 (10) $[C_4H_7]^+$, 107 (19) $[C_8H_{11}]^+$, 147 (22) $[C_{11}H_{15}]^+$.
29	*cis*-*α*-Farnesene	15.59	0.24	$C_{15}H_{24}$	204	204 (4) $[M]^+$, 69 (100) $[C_5H_9]^+$, 93 (68) $[C_7H_9]^+$, 120 (32) $[C_9H_{12}]^+$, 67 (33) $[C_5H_7]^+$, 53 (17) $[C_5H_7]^+$, 55 (22) $[C_4H_7]^+$, 81 (25) $[C_6H_9]^+$, 189 (6) $[C_{14}H_{21}]^+$.
30	(+)-Epi-*β*-Santalene	15.63	0.26	$C_{15}H_{24}$	204	204 (1) $[M]^+$, 94 (100) $[C_7H_{10}]^+$, 122 (31) $[C_9H_{14}]^+$, 189 (2) $[C_{14}H_{21}]^+$, 55 (19) $[C_4H_7]^+$, 69 (12) $[C_5H_9]^+$, 67 (17) $[C_5H_7]^+$, 81 (10) $[C_6H_9]^+$.
31	4-Eudesmene	15.97	0.55	$C_{15}H_{24}$	204	204 (38) $[M]^+$, 189 (100) $[C_{14}H_{21}]^+$, 133 (80) $[C_{10}H_{13}]^+$, 147 (33) $[C_{11}H_{15}]^+$, 175 (6) $[C_{13}H_{19}]^+$, 53 (9) $[C_4H_5]^+$, 55 (18) $[C_4H_7]^+$, 67 (20) $[C_5H_7]^+$, 95 (23) $[C_7H_{11}]^+$, 109 (22) $[C_8H_{13}]^+$, 81 (33) $[C_6H_9]^+$.
32	*α*-Muurolene	16.06	0.43	$C_{15}H_{24}$	204	204 (18) $[M]^+$, 105 (100) $[C_8H_9]^+$, 91 (59) $[C_7H_7]^+$, 132 (65) $[C_{10}H_{12}]^+$, 161 (42) $[C_{12}H_{17}]^+$, 189 (12) $[C_{14}H_{21}]^+$, 67 (16) $[C_5H_7]^+$, 81 (23) $[C_6H_9]^+$.
33	*β*-Selinene	16.17	0.82	$C_{15}H_{24}$	204	204 (35) $[M]^+$, 189 (44) $[C_{14}H_{21}]^+$, 161 (58) $[C_{12}H_{17}]^+$, 147 (49) $[C_{11}H_{15}]^+$, 133 (62) $[C_{10}H_{13}]^+$, 121 (70) $[C_9H_{13}]^+$, 93 (95) $[C_7H_9]^+$, 55 (32) $[C_4H_7]^+$.
34	*α*-Selinene	16.42	0.75	$C_{15}H_{24}$	204	204 (35) $[M]^+$, 189 (100) $[C_{14}H_{21}]^+$, 175 (32) $[C_{13}H_{19}]^+$, 161 (42) $[C_{12}H_{17}]^+$, 133 (68) $[C_{10}H_{13}]^+$, 81 (48) $[C_6H_9]^+$, 67 (29) $[C_5H_7]^+$.
35	(*E*)-*α*-Bisabolene	16.64	0.48	$C_{15}H_{24}$	204	204 (18) $[M]^+$, 189 (15) $[C_{14}H_{21}]^+$, 175 (5) $[C_{13}H_{19}]^+$, 161 (20) $[C_{12}H_{17}]^+$, 93 (100) $[C_7H_9]^+$, 79 (40) $[C_6H_7]^+$, 55 (19) $[C_4H_7]^+$, 106 (39) $[C_8H_{10}]^+$.
36	(+)-*α*-himachalene	16.82	5.87	$C_{15}H_{24}$	204	204 (20) $[M]^+$, 189 (14) $[C_{14}H_{21}]^+$, 175 (5) $[C_{13}H_{19}]^+$, 161 (38) $[C_{12}H_{17}]^+$, 67 (43) $[C_5H_7]^+$, 79 (45) $[C_6H_7]^+$, 77 (15) $[C_6H_5]^+$, 91 (47) $[C_7H_7]^+$, 109 (34) $[C_8H_{13}]^+$, 107 (41) $[C_8H_{11}]^+$, 53 (12) $[C_4H_5]^+$.
37	*α*-Guaiene	17.30	0.7	$C_{15}H_{24}$	204	204 (66) $[M]^+$, 161 (100) $[C_{12}H_{17}]^+$, 79 (62) $[C_6H_7]^+$, 67 (48) $[C_5H_7]^+$, 81 (43) $[C_6H_9]^+$, 95 (49) $[C_7H_{11}]^+$, 93 (73) $[C_7H_9]^+$, 65 (20) $[C_5H_5]^+$.
38	Germacrene B	17.76	0.91	$C_{15}H_{24}$	204	204 (15) $[M]^+$, 121 (100) $[C_9H_{13}]^+$, 67 (55) $[C_5H_7]^+$, 147 (28) $[C_{11}H_{15}]^+$, 161 (45) $[C_{12}H_{17}]^+$, 189 (28) $[C_{14}H_{21}]^+$, 175 (5) $[C_{13}H_{19}]^+$, 79 (52) $[C_6H_7]^+$, 81 (43) $[C_6H_9]^+$, 133 (44) $[C_{10}H_{13}]^+$.
Total			17.63			
Oxygenated Sesquiterpenes						
39	Caryophyllene oxide	18.18	1.24	$C_{15}H_{24}O$	220	220 (1) $[M]^+$, 91 (92) $[C_7H_7]^+$, 93 (85) $[C_7H_9]^+$, 69 (54) $[C_4H_5O]^+$, 55 (39) $[C_4H_7]^+$, 53 (20) $[C_4H_5]^+$, 149 (21) $[C_{11}H_{17}]^+$, 177 (13) $[C_{13}H_{21}]^+$, 138 (12) $[C_9H_{14}O]^+$, 110 (28) $[C_8H_{14}]^+$.
40	Epiglobulol	18.48	0.26	$C_{15}H_{26}O$	222	222 (3) $[M]^+$, 161 (100) $[C_{11}H_{13}O]^+$, 81 (48) $[C_6H_9]^+$, 53 (12) $[C_4H_5]^+$, 67 (32) $[C_5H_7]^+$, 69 (28) $[C_5H_9]^+$, 205 (28) $[C_{14}H_{21}O]^+$, 207 (6) $[C_{14}H_{23}O]^+$, 65 (10) $[C_5H_5]^+$.
41	Neointermedeol	18.91	0.41	$C_{15}H_{26}O$	222	222 (4) $[M]^+$, 81 (100) $[C_6H_9]^+$, 189 (62) $[C_{14}H_{21}]^+$, 93 (90) $[C_7H_9]^+$, 67 (79) $[C_5H_7]^+$, 53 (25) $[C_4H_5]^+$, 55 (45) $[C_4H_7]^+$, 69 (62) $[C_5H_9]^+$, 69 (62) $[C_5H_9]^+$, 207 (40) $[C_{14}H_{23}O]^+$.
42	Selin-6-en-4*α*-ol	18.98	0.53	$C_{15}H_{26}O$	222	222 (2) $[M]^+$, 81 (100) $[C_6H_9]^+$, 204 (34) $[C_{15}H_{24}]^+$, 189 (28) $[C_{14}H_{21}]^+$, 135 (28) $[C_{10}H_{15}]^+$, 105 (41) $[C_8H_9]^+$, 67 (38) $[C_5H_7]^+$, 55 (36) $[C_4H_7]^+$, 53 (10) $[C_4H_5]^+$.
43	Isospathulenol	19.22	0.99	$C_{15}H_{24}O$	220	220 (4) $[M]^+$, 205 (18) $[C_{14}H_{21}O]^+$, 187 (19) $[C_{14}H_{19}]^+$, 159 (58) $[C_{11}H_{11}O]^+$, 119 (100) $[C_9H_{11}]^+$, 53 (12) $[C_4H_5]^+$, 161 (50) $[C_{12}H_{17}]^+$, 67 (25) $[C_5H_7]^+$, 81 (32) $[C_6H_9]$.

44	γ-Eudesmol	19.34	0.26	$C_{15}H_{26}O$	222	222 (4) $[M]^+$, 189 (100) $[C_{14}H_{21}]^+$, 175 (12) $[C_{13}H_{19}]^+$, 147 (21) $[C_{11}H_{15}]^+$, 133 (54) $[C_{10}H_{13}]^+$, 93 (36) $[C_7H_9]^+$, 59 (24) $[C_3H_7O]^+$, 53 (8) $[C_4H_5]^+$, 163 (12) $[C_{12}H_{19}]^+$, 65 (8) $[C_5H_5]^+$.
45	Neointermedeol	19.74	1.73	$C_{15}H_{26}O$	222	222 (5) $[M]^+$, 81 (100) $[C_6H_9]^+$, 205 (62) $[C_{15}H_{25}]^+$, 189 (65) $[C_{14}H_{21}]^+$, 147 (36) $[C_{11}H_{15}]^+$, 133 (38) $[C_{10}H_{13}]^+$, 109 (58) $[C_8H_{13}]^+$, 67 (58) $[C_5H_7]^+$, 55 (39) $[C_4H_7]^+$, 53 (17) $[C_4H_5]^+$.
46	α-Bisabolol	20.57	1.43	$C_{15}H_{26}O$	222	222 (1) $[M]^+$, 119 (100) $[C_9H_{11}]^+$, 204 (19) $[C_{15}H_{24}]^+$, 189 (8) $[C_{14}H_{21}]^+$, 175 (4) $[C_{13}H_{19}]^+$, 81 (20) $[C_6H_9]^+$, 69 (70) $[C_5H_9]^+$, 55 (21) $[C_4H_7]^+$, 105 (20) $[C_8H_9]^+$, 91 (16) $[C_7H_7]^+$.
47	Iso aromadendrene epoxide	20.82	0.22	$C_{15}H_{24}O$	220	220 (6) $[M]^+$, 67 (100) $[C_4H_3O]^+$, 69 (55) $[C_5H_9]^+$, 53 (25) $[C_4H_5]^+$, 55 (62) $[C_3H_3O]^+$, 79 (53) $[C_6H_7]^+$, 81 (50) $[C_5H_5O]^+$, 83 (36) $[C_6H_{11}]^+$, 121 (46) $[C_8H_9O]^+$, 205 (15) $[C_{14}H_{21}O]^+$.
48	Aromadendrane -4,10-diol	21.10	0.38	$C_{15}H_{26}O_2$	238	238 (1) $[M]^+$, 119 (100) $[C_9H_{11}]^+$, 91 (90) $[C_7H_7]^+$, 93 (65) $[C_7H_9]^+$, 81 (55) $[C_6H_9]^+$, 67 (59) $[C_5H_7]^+$, 55 (41) $[C_4H_7]^+$, 147 (65) $[C_{11}H_{15}]^+$, 159 (42) $[C_{12}H_{15}]^+$.
Total			**7.45**			

The major constituents investigated from *C. aurantifolia* essential oils were found to have various biological activities as shown below in

table (2). The wide range activities derived from these diverse volatile constituents opens new horizons of advancement of essential oils into therapeutic medicines

Table 2. Reported biological activities of *C. aurantifolia* essential oils major phyto-constituents.

Predominant component	Biological activity
Monoterpenes Hydrocarbons	
p-Cymene **(2)**	Antimicrobial **[23,24]**, antioxidant **[25,26]**, anti-inflammatory **[27]**, antiparasitic **[28,29]**, antidiabetic **[30]**, antiviral **[31]**, antitumor activities **[32,33]**, Cytotoxic and antioxidant effects on human colorectal (HCT116) and hepatocelluler carcinoma (HepG2) cell lines **[34]**. Anti-Biofilm Activity **[35]**.
β-Pinene **(1)**	Antimicrobial **[36]**, Anti-biofilm capabilities against various Candida spp. strains, antifungal activities against Candida spp. strains, and anticancer, anti-inflammatory, and antiallergenic factors **[37]**.
D-Limonene **(3)**	Antiviral effects **[38]**, antimicrobial activity **[39]**. Free radical scavenging properties **[40]**.
Oxygenated Monoterpenes	
α-terpineol **(12)**	showed potent DPPH radical scavenging activities **[41]**. Antioxidant **[42,43]**, A compound with anticancer, anticonvulsant, antiulcer, antihypertensive, anti-nociceptive properties. Additionally, it improves skin penetration and has insecticidal effects **[42]**. Antiproliferative activity against non-small cell lung carcinoma **[44]**.
1-Terpinen-4-ol **(11)**	insecticidal activity against *Sitophilus zeamais* and *S. oryzae* **[45]**.
Citronellol **(15)**	antidiabetic and antinociceptive effects **[46,47]**. antimicrobial activity against *Escherichia coli* strains **[48,49]**. cardiovascular, antidiabetic **[50]**.
Linalool **(6)**	anti-cholesterol, antibacterial, sedative, anxiolytic, anticonvulsant, anesthetic, analgesic, anti-inflammatory, antioxidant, antimicrobial **[51]**, antinociceptive, antihyperalgesic, and anti-inflammatory effects **[52]**.
Geraniol **(16)**	antibacterial activity **[53,54]**, anti-inflammatory **[54]**, and anticancer activity **[55]**.
α-citral **(17)**	antimicrobial activity **[53]**, antinociceptive effect **[56]**, antitumor **[57]**, and antispasmodic **[58]**.
Sesquiterpenes Hydrocarbons	
(+)-*α*-himachalene **(36)**	Antibacterial activity **[59]** and antimicrobial activity **[60]**.
α-Bergamotene **(27)**	Antimicrobial activity **[61]**, antibacterial and antifungal activities **[62]**.

4. Conclusion

C. aurantifolia essential oils are attributed to a multitude of valuable bioactive compounds. As regards their efficacy, it can be used in various traditional healing systems and

numerous aromatherapeutic as well as medicinal applications. These readily accessible essential oils will undoubtedly continue to play significant roles in food and beverage industries, as well as for medicinal, cosmetic, and "green" pest-control uses.

Forty-eight volatile phytochemicals were effectively matched and recognized in *C.*

aurantifolia essential oils using GC/MS technique. The identified volatile constituents are belonging to different classes, such as monoterpenes hydrocarbon, oxygenated monoterpenes, sesquiterpenes hydrocarbon and oxygenated sesquiterpenes.

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